The Importance of Teaching About the Nature of Science in the Primary Classroom

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DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Clíona Murphy

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Nature-of-science (NoS): The phrase nature-of-science (NoS) will be used throughout this thesis regarding issues relating to what science is, how it works, how scientists work as a social group and how science influences and is influenced by society. The term describes science as a way of knowing, including the values and beliefs that are deep-rooted in the development of scientific knowledge. In this thesis NoS will also refer to knowledge regarding the history and philosophy of science. In a similar manner to Abd-El-Khalick and Lederman (2000a), 'NoS' rather than the more technically appropriate 'the' NoS will be utilised throughout. This signifies the author's lack of belief in a single universally accepted definition of what the phrase ' NoS' entails.

Contemporary/ Modern NoS Conceptions: Contemporary NoS conceptions in this thesis will refer to an understanding of science as a reliable body of knowledge that is testable and developmental and therefore subject to change. Such conceptions accept scientific knowledge as a reliable body of knowledge that is however tentative and developmental and therefore subject to change. Contemporary conceptions assert that there is not one 'scientific method' that comprises a fixed set of steps and procedures that all scientists follow when addressing all scientific questions but rather there are numerous accepted processes that are utilised throughout the scientific community. That science is a human endeavour involving subjectivity, creativity and imagination in determining scientific knowledge is central to contemporary conceptions, as is knowledge regarding the figures and landmarks in the history of science. Those holding contemporary conceptions of NoS have knowledge about how society and culture have affected scientific development in the past and how science and society are influenced and affected by one another in contemporary society.

Simplistic NoS Conceptions: In contrast 'simplistic' or 'traditional' NoS conceptions throughout this thesis will refer to views that have a more one-dimensional view of science and often consider scientific knowledge as absolute, static and derived from a common 'scientific method'. The 'scientific method' is a belief that there is a fixed set of steps and procedures that all scientists follow when addressing all scientific questions. Those who hold simplisitic conceptions of NoS often do not take into account that scientists make subjective decisions during scientific inquiry.

Explicit Approaches: Explicit approaches to teaching about NoS refer to approaches that do not assume that NoS conceptions can be 'caught' by merely participating in science class, but rather need to be explicitly addressed. Explicitly teaching about NoS does not mean lecturing about it or enforcing particular positions about NoS in a didactic manner, rather it does mean intentionally designing lessons that address particular NoS issues. Providing students with opportunities to discuss, debate and reflect on various NoS issues is considered equally important and the importance of teachers' roles in facilitating discussions and debates to ensure that contemporary views of NoS are being developed rather than 'traditional' views being reinforced is highlighted

Implicit Approaches: Throughout the thesis implicit approaches to NoS refer to approaches to teaching science where it is assumed that students will develop modern NoS conceptions solely by applying the process skills and 'doing science' and that direct instruction or discussions relating to different aspects of NoS are not necessary. Those who employ implicit approaches assume pupils will assimilate NoS ideas through conducting scientific inquiry.

ABSTRACT

One of the aims of this research was to explore NoS conceptions amongst pre-service and novice teachers and to establish the extent to which their pupils developed more contemporary Nose conceptions, when taught about NoS through explicit means. The study also considered the effects of explicitly teaching NoS on beginning teachers' approaches to and perceptions of teaching science and on their pupil's reflections of school science. A mixture of qualitative and quantitative methodologies, which included questionnaires, group interviews and written reflections, was utilised to explore the research questions.

There were four phases in the research. Phase one aimed at developing nineteen pre-service primary teachers' NoS conceptions. The extent to which these nineteen pre-service teachers planned and explicitly taught aspects of NoS over the course of their final teaching practice was addressed in the second phase. The third phase compared the extent to which four beginning teachers planned for and explicitly addressed NoS in their initial teaching year. Two of these teachers had taken the NoS elective course (test) the previous year and two had not (control). The third phase also explored the effect that explicitly teaching NoS had on these beginning teachers' approaches to and perceptions of teaching science. The development of NoS conceptions of the pupils of these four beginning teachers (9-11 years) was also explored in the third phase. The extent to which explicitly teaching NoS affected these primary children's reflections on school science was also established in this phase. A preliminary content analysis of seven international curriculum documents and two international assessment tools was conducted in the fourth phase to ascertain the extent to which these documents explicitly assessed NoS.

The findings of this study corroborated international research in that it indicated that explicit methods of teaching about NoS resulted in the development of more elaborate conceptions of NoS amongst pre-service primary teachers. However, the findings also revealed that beginning primary teachers' contemporary NoS conceptions could be transferred to their pupils utilising explicit hands-on reflective approaches to teaching about NoS.

The study also revealed new insights that are relevant to the teaching of primary science on a national and international basis. It was established that primary teachers who employed explicit approaches to teaching NoS as part of the Science Curriculum (DES, 1999a) utilised more hands-on, reflective constructivist approaches to teaching science and appeared to be more enthusiastic and confident about teaching science. In addition to developing more elaborate NoS conceptions amongst primary children, this study also revealed that explicit approaches to NoS resulted in an increased interest in and enjoyment of school science amongst Irish primary school children. The primary children in this study who experienced explicit methods in NoS appeared to have been given more opportunities to employ and develop their science skills than their peers who did not experience explicit instruction in NoS. Other benefits of explicit approaches to teaching about NoS apparent in the findings were improved language development and an increase in the children's ability to formulate and present arguments for discussion. Opportunities

afforded to children when explicitly addressing NoS issues appear to have facilitated them in the employment and development of their reflective and thinking skills.

The research indicates that the development of contemporary conceptions of science is an important aspect of primary science in that, amongst other benefits, it helps the learning of scientific concepts and skills and helps humanise science for children, thus making it more interesting for them to learn. Pre-service and in-service courses that provide teachers with the opportunity to develop their conceptual and pedagogical knowledge of NoS could facilitate Irish primary teachers in explicitly teaching about NoS as part of the Science Curriculum (DES, 1999a).

There are concerns in Ireland regarding the decline in the number of students taking science at secondary and tertiary level (Organisation for Economic Co-operation and Development (OECD), 2002b). The report of the Task Force on the Physical Sciences (2002) included a number of recommendations in relation to science at primary level, which included improving the quality of science teaching, in-career development for teachers and the establishment of an integrated national science awareness programme. This study revealed that incorporating explicit approaches to NoS as part of the Science Curriculum increased teachers' and pupils' interest in and enjoyment of science. If the development of NoS was included as a core aim in the Primary Science Curriculum, primary children could become more interested in science, which may in turn lead to an increase in the uptake of science beyond the point of choice.

1 INTRODUCTION

1.1 Overview of Chapter

This chapter opens with a rationale for conducting the study. The research aims and research questions are then presented and followed by an outline of the study. The chapter concludes with a summary of the structure of the thesis.

1.2 Rationale

The arrival of the ' Celtic tiger' to Ireland during the 1990s brought with it various economic, social, political and technological changes (O Rourke, 2001). The scientific enterprise contributed significantly to this 'Celtic tiger' in terms of its technological advances. Science informs many facets of life, from basic decision-making and problem solving to different thought processes about the world. An understanding of the scientific enterprise and its role in society (nature of science) is essential if we are to exist in and make informed decisions as citizens.

During the late 1990s and into 2000s primary and post-primary curricula in Ireland were reviewed and developed. Education aimed at equipping students with skills and knowledge necessary for existing in and making informed decisions in this rapidly developing society. At primary level the National Council for Curriculum and Assessment (NCCA) devised a revised curriculum that included science as a subject in its own right. Prior to this, science in the 1971 curriculum was included as a subject for fifth and sixth classes in the social and environmental studies curriculum (DES, 1971). Amongst the aims of the revised Science Curriculum (DES, 1999a) were the development of scientific concepts and skills and the development of positive attitudes towards science. The curriculum did not explicitly include the development of contemporary understandings of the nature of science (NoS) amongst its aims. Science is one of three subjects in the second phase of the review of the Primary Curriculum, being carried out by the National Curriculum Council for Curriculum Assessment (NCCA). The first phase of this review reports on teachers, principals and parents' experiences of the Science Curriculum, and is due in 2008. The second phase of this review reports on children's experiences of the Science Curriculum and the report is due in summer 2008.

Research studies have highlighted the importance of elaborate conceptions of nature of science (NoS) for facilitating the understanding of science concepts and skills. (Driver, Leach, and Scott, 1996; Lederman, 1998; Mc Comas, Clough, and Almazora, 1998; Matthews, 1994). The research also suggests that a contemporary understanding of NoS facilitates citizens in becoming scientifically literate, therefore enabling them to put science in context, contemplate various scientific issues and consider possible implications of what the scientific community is telling them (Bybee 1997; Mc Comas, 1998; Murphy, Beggs, Hickey, O' Meara, and Sweeney, 2001). Other international research has indicated that teachers tend not to hold contemporary conceptions of NoS (Bloom, 1989; Loving, 1991; Abel & Smith, 1994; Matthews 1998; Akerson, Abd-El-Khalick, and Lederman, 1999; Murcia & Schibeci, 1999; Abd-El Khalick, Bell and Lederman, 1998; Lederman, Abd-El Khalick, Bell and Schwartz, 2002; Craven, Hand, and Prain, 2002). Furthermore the literature has emphasised the significance of explicit approaches in the acquisition of such conceptions (Akerson et al., 2000, Akindehin, 1988, Carey & Strauss, 1968, 1970, Craven et al., 2002, Khishfe & Abd-El-Khalick, 2002, Lederman & Abd-El-Khalick, 1998, Lederman, 1998a Loving, 1998). This increased international discussion of the importance of developing contemporary NoS conceptions and utilising explicit approaches, contrasts with the lack of Irish research in this area. It would appear therefore that research into the development of NoS conceptions through explicit approaches within an Irish context, is timely.

As previously stated the Science Curriculum (DES, 1999a) does not include the development of contemporary NoS views amongst its aims. Research, as indicated above, suggests that the development of contemporary conceptions of NoS is a crucial component of primary science. If teachers were given the opportunity to reflect upon and develop their personal philosophies and pedagogical knowledge of NoS, they may be more inclined to teach about aspects of NoS as part of the science curriculum in an explicit way.

The literature suggests that if children leave school with contemporary understandings of NoS they could have a better understanding of science concepts and scientific inquiry, a greater interest in science and would have a better appreciation of science's role in contemporary society (Mc Comas, 1998, Matthews 1994, Lederman, 1998; Lederman and Abd-El Khalick, 1998; Driver et al., 1996; Solomon, 1994). Such contemporary understandings and knowledge of science could lead to an increase in uptake of science at second and third level in that students could find science more interesting and comprehensible and may begin to view science as a subject that is relevant to their everyday lives. However, if the development of contemporary views of NoS is not explicitly addressed as part of the Science Curriculum, Irish primary school children could continue to leave the primary school with outmoded 'traditional' views of science and the current lack of uptake of science at secondary and tertiary level may well continue. In light of the current lack of uptake of science beyond the point of choice and with the review of the science curriculum under way, this study is timely. It could inform curriculum advisors and educators of the importance contemporary conceptions of science play in the development of a scientifically literate society.

A number of international research studies have explored primary teachers' conceptions of NoS (Bloom, 1989; Craven et al., 2002; Lederman et al., 2002, Loving, 1991; Murcia & Schibeci, 1999) and their translation into classroom practice (Carey et al., Evans, Honda, Jay, and Unger, *1989; S*olomon, Duveen, and Scot, 1994; Driver et al., 1996; Akerson et al., 2000). However, there is a dearth of published research in this area within an Irish context and a paucity of research that explores primary children's conceptions of NoS. This study provides valuable insights into the effectiveness of explicit methodologies in teaching about NoS on teaching and learning science within the primary classroom.

1.3 Research Aims and Questions

The aims of this study were to explore and develop Irish pre-service teachers' conceptions of the nature of science (NoS) and to investigate the effectiveness of their translation into classroom practice. The study also explored the effects of explicitly teaching NoS on teachers' approaches to and perceptions of teaching science and on primary children's reflections of school science. There were four phases in the study. Table 1.1 outlines the phases of the study and the questions that were addressed in each phase.

Table 1.1 Overview of four phases

	Summary of Phase	Questions Addressed
Phase 1	Developing Pre-service Teachers' Conceptions of NoS	• How effective are explicit approaches to teaching about NoS in developing pre-service teachers' conceptions of NoS?
Phase 2	NoS and Pedagogy: Teaching Practice	• To what extent do pre-service teachers explicitly plan and teach about NoS? • What are pre-service teachers' perceptions about explicitly addressing NoS as part of the Irish science curriculum? • What are the effects (if any) of explicitly teaching NoS on pre-service teachers' perceptions of teaching science?
Phase 3	NoS and Pedagogy: Beginning Teachers	• Do beginning teachers explicitly plan and teach aspects of NoS as part of the science curriculum? • Which aspects of NoS (if any) do beginning teachers plan for and teach? • What are the effects (if any) of explicitly teaching NoS on beginning teachers' approaches to and perceptions of teaching science? • Do Irish primary children develop more contemporary conceptions of NoS when NoS is explicitly taught as part of the science curriculum? • What are the effects (if any) of explicitly teaching NoS on the way primary children reflect on their science lessons?
Phase 4	Preliminary Content Analysis	• To what extent do international curriculum documents explicitly address the development of NoS conceptions? • To what extent do international assessment tools explicitly assess NoS understanding?

The first phase explored pre-service teachers' conceptions of NoS and the effectiveness of using explicit methods in the development of more contemporary conceptions. The extent to which pre-service teachers plan and explicitly teach aspects of NoS over the course of their final teaching practice was explored in the second phase. The third phase ascertained the extent to which beginning teachers planned for and explicitly addressed aspects of NoS in their initial teaching year. The effects of teaching NoS explicitly on beginning teachers' perceptions of and approaches to teaching science were also considered during the third phase. A third aspect that was explored during the third phase was the development of Irish primary children's conceptions of NoS. The fourth phase established the extent to which NoS conceptions were explicitly addressed and assessed amongst international curriculum documents and assessment tools. A number of questions were addressed at each phase.

1.4 Outline of Study

A mixture of quantitative and qualitative research methodologies was used to address the research questions. A fixed research design, comprising an experimental design strategy, was utilised. However, in keeping with qualitative research, people were the focus of inquiry and qualitative research methods of data collection and analysis were predominantly used to collect and analyse the data. These methods included written reflections, open-ended questions on questionnaires and group interviews to facilitate the researcher in establishing the participants' multiple interpretations and conceptions of NoS. Some quantitative methods of collection and analysis were also used during the study. In the third phase quantitative analysis of a section of the children's questionnaire was utilised which facilitated triangulation of the data obtained from the open-ended questions on the questionnaires and the data obtained from the group interviews. A preliminary content analysis of seven curriculum documents and two international assessment tools, which generated quantitative data was also conducted. The aim of these preliminary content analyses was to establish the extent to which NoS was addressed and assessed in each document.

The first phase comprised an experiment that explored the effectiveness of a yearlong nature-of-science (NoS) course in developing pre-service primary teachers' conceptions of NoS. This course was delivered to a purposive sample of 19 final year Bachelor of Education (B.Ed) students in Ireland. The course was aimed at developing these pre-service teachers' conceptual and pedagogical knowledge of NoS. Various data were collected over the course of the year to assess the development of their NoS conceptions. In the second phase these 19 pre-service teachers explicitly addressed aspects of NoS during their final teaching practice. The aim of this phase was to explore the extent to which these teachers' conceptions could be translated into classroom practice. The third phase comprised another quasi-experiment that compared the extent to which two groups of teachers planned for and explicitly addressed NoS issues within their science classes. The test group comprised two beginning teachers who had taken the NoS course and a control group that comprised two beginning teachers who had not taken the NoS elective course the previous year. The third phase also compared the NoS conceptions of the children in the test and control group and explored the development of the pupils' NoS conceptions and perceptions of school science. The fourth phase of the study consisted of a content analysis of seven international documents and two assessment tools.

1.5 Structure of Thesis

In chapter two an extensive analysis of the relevant research literature is provided. First an overview of the development of ideas surrounding the nature of science (NoS) is provided, followed by a discussion of the literature regarding NoS in education. The subsequent sections consider the literature regarding the importance of contemporary conceptions of NoS, teachers' NoS conceptions and their translation into practice and primary children's conceptions of NoS. The chapter closes with an overview of the critical developments in primary science education in Ireland.

A discussion regarding the epistemological framework that informed the study is presented in chapter three. A description of the research design is provided which includes a discussion surrounding the suitability of employing quantitative and qualitative research methods to address the research questions. Detailed accounts of the sample and methods of data collection are provided prior to ethical considerations being outlined. Issues regarding quality assurance are considered, followed by an account of how the data were analysed. Some of the limitations of the study are then considered.

Chapter four is the first of four chapters reporting findings obtained to address the research questions. In this chapter the findings from phase one of the study, that is findings relating to the pre-service teachers' conceptions of NoS and the development of these conceptions using explicit approaches, are analysed and discussed. The significance of utilising explicit rather than implicit approaches is considered.

Chapters five and six present and discuss the data regarding NoS and pedagogy. Chapter five focuses on the pre-service teachers' teaching practice experiences (phase two) and on beginning teachers' experiences of teaching NoS (phase three). Chapter six analyses and discusses the data obtained in relation to primary children's conceptions of NoS.

A preliminary content analysis of seven international curriculum documents is provided in chapter seven. The aim of this content analysis was to establish the extent to which NoS is addressed in each document. In the second half of this chapter, data from two international science assessment projects (TIMSS and IAEP) are considered in terms of how they assessed pupils' conceptions of the nature of science.

Chapter eight opens with a recapitulation of the importance of primary teachers and their pupils holding contemporary NoS conceptions. The aims of the study are presented prior to a summary of the findings from the three phases of the study and the document analysis being provided. Limitations of the research are outlined which is followed by a discussion of the implications of the findings.

2 LITERATURE REVIEW

2.1 Overview of Chapter

In this chapter an overview of the research literature relating to the nature of science in science education is presented. The chapter opens with a brief synopsis of the development of ideas regarding the epistemology of science and the nature of science (NoS) in science education is then considered. Prior to providing a definition of what contemporary NoS conceptions in this thesis comprise, a short overview of the development of ideas regarding teaching and learning is provided. The literature pertaining to the importance of contemporary NoS conceptions in science education is considered and followed by an exploration of the literature pertaining to the development of teachers' NoS conceptions, the employment of explicit and implicit approaches and the translation of teachers' conceptions into practice. The literature relating to pupils' conceptions of NoS is reviewed and is followed by a review of some of the literature relating to the nature of science in international curricula. The chapter concludes with an overview of some of the critical developments in primary science education in Ireland.

2.2 The Development of Ideas about the Epistemology of Science

There has been and continues to be a struggle to define the epistemology of science. If science as a way of knowing is to be portrayed accurately, it should be compared to other ways of knowing and believing. For example, philosophy of science would help portray the steadfast, rational and progressive NoS. The history of science would depict science as a human endeavour, illustrating the individual and distinctive cultural aspects of science. It is important that these different but equally valued views are highlighted.

As far back as 600 BC the great philosophers depended on evidence and argument for their theories and in the process began both science and philosophy. For example 'proto' philosophy was concerned with a search for the *principium,* that is the principal element from which everything else evolved and which could explain the origin and organisation of the universe. Thales (625-545 BCE) argued it was water, Anaximander (610-540 BCE) an unlimited, unspecified matter and Anaximenes, a contemporary of Anaximander, asserted it was air. Xenophanes (580-480 BCE) devised an elaborate theory of the structure of the universe and Anaximander also proposed an explanation of the origin of people (Barnes, 1987).

Questions these philosophers posed were the focus for Copernicus, Galileo and Newton and for the scientists and many of the philosophers who followed them. Many of their questions about the world have been answered in subsequent investigations and today, we have a greater understanding of the natural world. However, we are still, two and half thousand years later, deliberating on some of the questions posed by Thales and his contemporaries. It is interesting to note that as far back as the sixth century BCE, philosophers endeavoured to explain existence by observation, imagination, deduction and speculation rather than myth. Their deliberations regarding the universe were similar to understanding the 'scientific method' that typified NoS understanding during the early 1900s (Kirk, Raven and Schofield, 2002).

Science, as a discipline, separated from philosophy at the beginning of the nineteenth century. However, the justification (verifying and testing) and discovery (generation) of scientific knowledge claims formed the basis of many philosophical arguments during the nineteenth and twentieth centuries. Those who made the distinction between these two positions (justification and discovery) argued that the way in which science secured its knowledge claims was immaterial to the question of how the claims were accepted (Losee, 1981). It was contended that accurate and permissible characterisations of science could only be made in relation to procedures employed by the scientific community to ratify or substantiate existent knowledge. It was believed that understanding science should be concerned with the justification rather than the discovery of scientific knowledge (Duschl, 1988).

Predominant views regarding the epistemology of science towards the end of the nineteenth, and the beginning of the twentieth century included views that science started with observation and that observation was a firm foundation from which knowledge could be procured. Many maintained that information observed by the senses was recorded without bias and these observations formed the basis from which laws and theories evolved. Science was believed to be objective rather than subjective and the scientific domain provided no room for personal opinion or preferences. Scientific knowledge owed its reliability to the fact that it was objectively proven knowledge. It was believed that careful and unprejudiced observation produced a firm foundation from which *probably true,* if not true, scientific knowledge could be determined (Chalmers, 1999). The superiority of scientific knowledge based on science's ability to obtain knowledge from facts and experience governed many philosophical arguments during the 1920s. One detractor, Karl Popper, did not agree with these views regarding the superiority of scientific knowledge.

2.2.1 Karl Popper and Falsificationism

Karl Popper (1902-1994) maintained that while scientific theories bring us closer to the truth, they are not totally verifiable. Popper asserted that scientists approach things with pre-conceived ideas and that scientific theories were conjectures. Good scientists for Popper, carried on the tradition of what he labelled ' objective rational criticism', that is the ability to retain a critical approach to theories while conducting every day scientific activities (Chalmers, 1999).

Popper was the founder of falsificationism. According to falsificationism, theories can be shown to be false by examining what Popper called 'basic statements' and experiments. For the falsificationist, if a statement is scientific it must be falsifiable. For example, consider the statement, "the sun never shines on Monday". This hypothesis is falsifiable because there is a logical observation statement (yesterday was Monday and the sun was shining) that is inconsistent with it. A theory should give us some account of how the world behaves, however, if a theory is to be beneficial and informative, it must be falsifiable. Popper maintained that the acceptability of observation statements should be measured by their capacity to withstand tests. Those that fail tests are rejected, and those that survive the tests to which they have been exposed are tentatively kept. This was in total contrast to the accounts of science that were distinctive at the beginning of the twentieth century, when it was believed that a scientific theory should only be part of science if it could be shown to be true or probably true.

Imre Lakatos (1922-1974), a student of Popper's, had different views regarding the nature of scientific theories. Lakatos maintained that falsification did not rely on laying down criteria for contradiction beforehand and ascertaining which observations count. He asserted that falsification should depend on theories being assessed by whether they will be maintained after new facts are introduced. Lakatos contended that the extent to which a theory could be falsified relied on whether a superior theory had arisen (Lakatos, 1970).

Paul Feyerabend (1924-1994), also a student of Popper both opposed and adopted Popper's writings. Feyerabend maintained that good science has always incorporated a mixture of faith, confusion, experiment and incoherence. Like Popper, he believed in the production of theories and that the leading theories could not have achieved their status without complacency, desire and bias.

The philosophical accounts of science that were dominant towards the end of the nineteenth and beginning of the twentieth centuries were often fragmented and did not endorse the complexity of major scientific theories, but rather focused on the connections between theories and singular basic observation statements. Thomas Kuhn's '*Structure of the scientific revolutions*' (1962) changed the emphasis from justification of scientific knowledge (verifying and testing) to the nature of discovery (generation) of it.

2.2.2 Thomas Kuhn and the Structure of the Scientific Revolutions

Thomas Kuhn (1922-1996) maintained that neither accounts of science provided by the philosophical arguments of the late nineteenth and early twentieth centuries nor falsificationist accounts of science were supported by historical evidence. Kuhn viewed science from a historical perspective that required one to embrace alternative world-views, by locating oneself in the world of a particular scientist at a particular time. History of science was paramount for Kuhn, and he believed that scientific knowledge that did not have roots in social context or convention should be regarded with scepticism. Kuhn valued scientific theories, in the particular context in which they were put forth and not as an improved or more superior version of a greater truth. According to Kuhn a theory had to be understood as part of a paradigm or tradition. (Loving 1991).

A paradigm for Kuhn consisted of the common theoretical hypothesis, laws and methodologies employed by members of an individual scientific community. This paradigm sets the standards and determines the model of work within the science it controls (Kuhn, 1962). Kuhn maintained science progresses in the following open-ended stages:

1. *Pre-science:* characterised by total disagreement and constant debate over basics. At this initial stage there will be copious hypotheses.

2. *Normal Science:* involving a detailed effort to clarify a paradigm aimed at improving the link between the paradigm and nature.

3. *Crisis and Revolution:* When a paradigm faces serious irregularities that undermine the paradigm.

4. *Revolution Resolved:* A crisis is resolved when an entirely new paradigm arises and gains the support of more and more scientists and the problem-ridden paradigm is discarded.

5. *New Normal Science:* The new paradigm directs new normal scientific activity until another crisis occurs.

Popper maintained that scientific theories are subject to falsification and that by expanding on the work of previous generations, scientists move steadily towards a more accurate understanding of the world and how it works (Chalmers, 1999). Kuhn challenged Popper's doctrine of cumulative scientific progress in that he contended that science moves through dramatic revolutions, or paradigm shifts, rather than steadfast, rational, empirically guided falsification.

Modern philosophers have debated the ideas put forward by earlier philosophers such as Kuhn, Popper and Lakatos. For example, Glymour (1980) debates that philosophers such as Kuhn and Lakatos do not address issues regarding how evidence supports theory. Glymour argues that confirmation can occur in stages.

Toulmin (1961) compared objectivity and rationality of the natural sciences with human science. Toulmin did not view scientific theories as things to be confirmed or falsified but rather viewed them as mechanisms or moulds for drawing inferences. In a similar manner Loving (1991) maintained there was an 'interpretive element' to all rationality in science.

Giere (1988) suggests prevailing scientific theories provide the best explanations and he is happy to accept that they represent the current truth. For Giere, theories relate to the real world. They provide explanations of models, as opposed to being empirical assertions. Kuhn and Toulmin maintain that a particular community or culture assesses the standards of a theory by utilising natural processes, entailing ideas and choices like judgement and illustrations of theories. These choices, according to Kuhn and Toulmin, are in the individual scientist's interest. Giere on the other hand thinks in terms of the specific methodologies individual scientists utilise and the extent to which they are fulfilling their objectives. Giere, like many contemporary philosophers, rejects logic and mathematics as the exclusive justification for good theories and acknowledges the subjective and creative components of scientific inquiry.

2.2.3 Science in Current Society

Postmodern views of science reject the notion of any final meaning and the idea of progress. Postmodernists also reject logic and reasoning and relinquish objectivity. Many postmodernists are discontented with science and are morbid about the future (Good and Shumansky, 2001). They are interested in mystical, new age ideas that challenge established 'reality'. Scientists and the majority of modern philosophers of science on the other hand tend to hold modern rather than postmodern views of science, viewing the world as something real that exists independently of humans and diverse 'philosophical' theories, rather than seeing 'reality' as a social construct (Good and Shymansky (2001). Roger Newton (1997) asserts:

> It is difficult to imagine a scientist who doubts that a real world exists independently of ourselves. We measure its properties, we observe its changes, we try to understand it, and sometimes it astonishes us. The belief in an external world, independent of the perceiving subject, lies at the basis of all natural science, Einstein insisted (Newton 1997, p.160, Cited in Good & Shumansky, 2001).

According to Good and Shymansky, W.H. Newton-Smith's philosophical view of science supports Newton's (1997) ideas:

> The realist tradition in the philosophy of science is an optimistic one. Realists do not think merely that we have in principle the power specified in the epistemological ingredient. They take it that we have been able to exercise that power successfully so as to achieve progress in science (Newton-Smith 1981, p.39).

Both scientists and most philosophers of science maintain modern science is progressive. John Dewey described science as the most competent procedure for acquiring knowledge:

> The function which science has to perform in the curriculum is that which it has performed for the race: emancipation from local and temporary incidents of experience, and the opening of intellectual vistas unobscured by the accidents of personal habits and prediction (Dewey 1916, p. 270).

In general the scientific community views science in modern terms and others including some sociologists, science educators and curriculum theorists view science in post-modern terms. Good & Shymansky (2001) assert that when a comparison is made between science as a way of knowing with other epistemologies, modern science for them is 'by far the most progressive, stable, and rational way of knowing yet devised by humans' (p. 182). They maintain that it is the modern position rather than the post-modern one that is a more accurate portrayal of the scientific enterprise.

This brief overview of the history of ideas regarding science indicates that the epistemology of science has been highly contested, that conceptions regarding the nature of science have changed continuously throughout the ages and still remain unresolved. These changes have coincided with modifications and advancements in historical, philosophical and sociological rationalisations about science. In a similar manner, the changes in understandings regarding the epistemology of science within science education have also changed continuously over the last century. Nowadays the term 'nature-of-science' (NoS) is often used among science educators when referring to the epistemology of science. The next section considers some of these different views regarding the epistemology of science within an educational context.

2.3 History of the Nature of Science in Science Education

Over the past sixty years science education organisations and curriculum documents have undergone numerous changes in emphasis regarding conceptions and descriptions of NoS. During the 1950s the emphasis in science education was on understanding conceptual knowledge and 'the scientific method'. The goal of science education was to provide students with conceptual knowledge, which in the long term would lead to the advancement of scientific discoveries (Van den Akker, 1998). During the 1960s education was hugely influenced by the work of Jean Piaget (1896-1980). NoS understanding was equated with the development of science process skills and the importance of hands-on science and inquiry-based learning was articulated. In England and Wales, the Plowden report (1967) strongly influenced the development of the Nuffield Science Courses, which were aimed at providing an open, child-orientated teaching approach, which provided room for discovery learning. However, many commentators argued that the emphasis during the 1950s and 1960s on the discipline of science excluded the personal, historical and applied aspects of science.

The term 'scientific literacy' was ascribed to numerous progressive educational aims throughout the 1970s and 1980s. There was a move towards science curricula that emphasised the importance of scientific literacy. Hurd for example, argued:

> The goal of science teaching is to foster an enlightened citizenry, capable of using the intellectual resources of science to create a favourable environment that will promote the development of man as a human being (Hurd 1969, p.14).

The emphasis changed to one that highlighted the importance of scientific knowledge that was relevant to the students, and so would be seen as something that could be used for personal and social betterment. Scientific knowledge was recognised as being imperfect and tentative knowledge. Science was seen to be a human endeavour, where creativity was employed in developing scientific explanations and theories. The influences of history, society and culture on science were recognised (Abd-El Khalick & Lederman, 2000a). The extent to which understanding NoS is important for achieving scientific literacy will be considered in more detail later in this chapter.

The American Association for the Advancement of Science (AAAS) maintains that contemporary NoS views would enable the students to become scientifically literate and in 1989 launched a National project (Project 2061) aimed at improving scientific literacy among the US population. A scientifically literate student is defined by AAAS as:

> One who was aware that science maths 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, 1990, p.4).

However, even the understanding of 'scientific literacy' is contentious. Bybee (1997) for example argued that the term 'scientific literacy' has been used in various ways, as a definition, as a slogan or as a metaphor. When 'scientific literacy' is used as a slogan it serves to provide science educators with a purpose for science education. As a metaphor 'scientific literacy' is concerned with having a good knowledge of science and being well informed on scientific issues (Murphy, et al., 2001). Bybee (1997) established a framework that delineated a number of levels of scientific literacy. Bybee maintained that it was possible that one could possess numerous levels of scientific literacy at a given time, depending on a given topic or context. Murphy and co-workers (2001) adapted this framework (Table 2.1).

Table 2.1 Bybee's Degrees of Scientific Literacy

Nominal	Token understanding of science concepts, which bears little or no relationship to real understanding.
Functional	Can read and write passages using simple and appropriate scientific and technical vocabulary.
Conceptual	Demonstrates understanding of both the parts and the whole of science and technology as disciplines. Can identify the way new explanations and inventions develop via the processes of science and technology.
Multi-dimensional	Understands the essential conceptual structures of science and technology from broader perspective, which includes, for example, the history and philosophy of science. Understands the relationship of disciplines to the whole of science and technology and to society.

(Excerpt from Murphy et al., 2001, p. 3).

During the 1990s, a view that was largely representative of conceptions of NoS around the world was presented in Project 2061: Science for all Americans, 1990, (AAAS). This document described science as demanding evidence that blends logic and imagination, explains and predicts phenomena but is unable to provide complete answers to all questions. It claimed that science is not authoritarian and scientists try to identify and avoid bias. It went on to say that science is a complex social activity that is organised into content disciplines and is conducted in various institutions. When conducting science, scientists adhere to generally accepted ethical principles and participate in public affairs both as specialists and as citizens (AAAS, 1990).

Project 2061 recommended that in order to achieve scientific literacy, students should have an understanding of NoS. Such knowledge consists of an understanding that:

> The world is understandable, scientific ideas are subject to change, scientific knowledge is durable, science cannot provide complete answers to all questions, science demands evidence, is a blend of logic and imagination, it explains and predicts, it attempts at identifying and avoiding bias, it is not authoritarian, it is a complex social activity, is organised into content disciplines and is conducted in various institutions, there are generally accepted ethical principles, and

scientists participate in public affairs as specialists and citizens (AAAS, 1990, p. 25-30,).

This definition is similar to Bybee's 'multi-dimensional' level of scientific literacy. Contemporary science educators and reform documents describe scientific literacy as the capability of students to utilise scientific knowledge to enable them to make informed decisions in society. A strong emphasis is also placed on a hands-on approach to science and children's enjoyment of science. In recent years, reform efforts in various countries have focused on enabling students to develop sound conceptions of NoS (albeit implicit in DES, 1999a) and scientific inquiry (AAAS, 1990, 1993; Klopfer, 1969; National Research Council [NRC], 1996; Ministry of Education 1993 (New Zealand), Australian Science, Technology and Engineering Council, 1997; Department of Education and Science (DES), 1999a).

There has been significant progression in the development and revision of science curricula all over the world. Some examples include the Nuffield courses in U.K (1995); Foundations for Australia's future: Science and technology in primary schools (Australian Science, Technology and Engineering Council 1997) in Australia; The New Zealand Curriculum (Ministry of Education, 1993); Primary Science Curriculum (DES, 1999a); The World Around Us, (Council for the Curriculum, Examinations and Assessment (CCEA) in Northern Ireland, 2007). The emphasis in the various curriculum documents has moved away from teaching science as a body of knowledge towards a view of science as a human endeavour, emphasising the importance of the various processes and procedures employed in scientific inquiry. Although the various reviews and developments of curricula appear to be substantial improvements to their predecessors, many of them have failed to result in the development of more elaborate NoS conceptions. For example, some studies have shown that students' attitudes and interest in science have not necessarily been improved as a consequence of the revised curricula (Gardner, 1976, Yager, 1982). Other studies assert that the emphasis on scientific processes over scientific knowledge does not seem to have had a significant effect in increasing the number of students in taking additional science courses. (Meyer, 1970; Yager & Bonsetetter, 1984). Research has also indicated that many revised curricula have not been successful in enabling students to develop more elaborate conceptions of NoS.

(Aikenhead, 1973, Bybee et al., 1980, Tobin & Capie, 1980, Yager and Yager, 1985). In order to examine this a detailed analysis of seven curriculum documents and how they address NoS is provided in chapter seven, rather than as part of the literature review. Research regarding the effectiveness of the various curricula in developing children's NoS conceptions and the challenges that face teachers, science educators and curriculum reformers will also be discussed in chapter seven.

One of the aims of this research was to explore NoS conceptions amongst pre-service and novice teachers and to establish the extent to which their pupils developed more contemporary NoS conceptions, when taught about NoS through explicit means. The study examines the effectiveness of different teaching approaches on children's understanding of NoS issues. The next section therefore provides a brief overview of some of the literature informing effective teaching and learning.

2.4 Development of Ideas about Teaching and Learning

Learning could be defined as the process through which skills, concepts and attitudes are attained, comprehended, utilised and developed. Learning by its nature is therefore partly a cognitive process and partly a social and affective one. Effective learning is cultivated by effective teaching and cannot be left to chance (Pollard and Tann, 1993).

Towards the end of the nineteenth century education began to focus on the development of personal understanding as opposed to memorisation of facts. Johann Heinrich Pestlozzi (1746-1827) and his followers had introduced new methods and ideas in education. Facts were to be presented to the children through discovery and inquiry methods of learning. Teachers were to use examples to explain principles. According to Spencer (1864):

> The mind should be introduced to principles through the medium of examples, and so should be led from the particular to the general, from the concrete to the abstract (Spencer, 1864, p. 121-122).

Spencer maintained that the learner would remember facts for longer, if children discovered the generalisations. He claimed that the process of inquiry children use to discover the new relationships and ideas would benefit children in becoming independent learners. Spencer was a strong advocate of the development of independent learners and asserted that:

> Children should be led to make their own investigations, and to draw their own inference. They should be told as little as possible and induced to discover as much as possible (Spencer, 1864, p. 124-125).

Spencer supported the growing belief at the time that children's minds were instinctively unfolding as they interacted with their environment and that children would enjoy learning if they were able to understand what they were learning. The key to education for Spencer was to give the children material that was appropriate to their level of understanding.

Spencer's views of science education derived to a large extent from the ideas of Heinrich Pestalozzi. Pestalozzi who studied much of Jean Jacques Rousseau's (1712-1778) writing, was interested in education that was based on sense impressions, experimentation and reasoning. He disagreed strongly with meaningless rote learning. Pestalozzi asserted that investigation and experimentation were more important than memorising facts and active learning was more important than passive learning. He maintained that the main objective of education should be the development of independent self - activity. Through the influence of Pestalozzi and his followers the role of the teacher was to present the child with ideas and materials that were important, meaningful and relevant to the natural growth and development of the child. At the close of the nineteenth century educators contended that good education viewed teaching as a process of bringing meaning to children through objects and words in a way that children could enjoy learning. Child-centred education dominated educational thinking.

A theory of learning that contrasts with these foregoing ideas, that was hugely influential in primary education during the first half of the twentieth century was behaviourism. Behaviourist learning theories placed the pupil in a comparatively passive role. The teacher on the other hand had the responsibility for selecting, pacing, instructing and evaluating the lessons. The teacher transferred subject matter to the pupils in a clear, ordered and logical manner and teacher controlled explanations and question-and-answer sessions were core. As the children were obliged to listen, the teacher was in control of the class. Teaching that had been influenced by behaviourism can be seen in primary schools today.

Behaviourist models have been hugely influential on what is commonly referred to as 'traditional' teaching methods, often associated with whole-class subject-based teaching. While behaviourist models may be suitable for teaching large groups or whole class teaching there are issues regarding the appropriateness of behaviourist theories of learning regarding the extent to which teachers actually relate to their pupils' existing knowledge.

Constructivist models of learning on the other hand assert that learning occurs when there is connection between thought and experience. One of the most influential constructivist theorists was Jean Piaget (1896-1980), who asserted that a child's previous knowledge affected subsequent learning. Piaget maintained that when a child is faced with a new concept or experience, they try to fit it into an appropriate model or theory that already exists in their minds. He called these existing patterns or concepts 'schema' and the process of 'fitting' the new knowledge into the schema 'assimilation'. When the new knowledge was organised into the schema with a new understanding of the knowledge, Piaget asserted the child had 'accommodated' the new knowledge (Piaget, 1933). In a similar manner Ausubel (1968) proposed that knowledge is structured as a framework of specific concepts. He emphasised the role of meaningful learning over 'rote' learning. He maintained that meaningful learning occurs when new knowledge is related to prior knowledge:

> The most important single factor in influencing learning is what the learner already knows. Ascertain this and teach him accordingly (Ausubel, 1968, p. 304).

Constructivist theorists view students as active learners, constructors of understanding, where they try to make sense of a new concept by trying to fit it into their own experiences. This construction of meaning is an ongoing process where learning may involve a shift in conceptual understanding and where learners have the final responsibility for their learning. In some cases learners share these constructed meanings through a process of social constructivism (Driver et al., 1985).

Social constructivism has had a significant influence in education since the early 1980s and is implicit in many curriculum documents (Department of Education and Employment, England, 2000; Government of Ireland, 1999a). Lev Vygotsky's (1896-1934) work is central to the development of social constructivist theory. Amongst Vygotsky's most significant influences on education were social interaction and the role of language in children's learning. Social interaction is central to Vygotsky's model of learning, the 'zone of proximal development' (ZPD). He maintains that children operate on two levels when presented with any task. In the first instance, children work at their own level of actual development when independently engaging with a task. He calls this the 'intramental' plane. When adults or more competent peers support children, children operate at a higher level, which Vygotsky refers to as the 'intermental plane'. The ZPD links what is known and what can be known (Vygotsky, 1978).

Social constructivist approaches to learning evidence themselves in primary schools through various approaches to group work and group discussions. For example, in science class, pupils are given the opportunity to conduct investigative work, which often requires groups of children to work collaboratively to solve a particular problem or answer a particular question. When given the opportunity to discuss and defend their ideas, children can help 'scaffold' one another's ideas. Language therefore plays a vital role in learning, as it is the means of thinking and learning. Children have the ability to engage in 'meta-cognition', that is they are able to reflect on their own thinking (Flavell, 1970, Feuerstein, 1979, Fisher 1990). Vygotsky maintained that in addition to the help provided by more capable adults and peers, learners could utilise their thinking skills to facilitate them in understanding and crossing their ZPD.

Pupil discussion is particularly important because it is an essential component in the interchange of their ideas and understandings and Pollard and Tann (1993) argue that it is central to a reflective teaching-learning process. However, research on novice teachers, indicates a focus on classroom management issues, teacher-centred teaching and instructional planning not to mention surviving student teaching placements or initial teaching year experiences (Fuller and Brown, 1975). Menter (1989) maintains that novice teachers are cautious and possess limited knowledge of the various situations they encounter throughout their early teaching careers. Symington (1980) asserts that if pre-service teachers lack confidence in teaching science they tend to employ methodologies that enable them to retain control over the flow of knowledge. Symington contends that these strategies are not in keeping with more progressive and contemporary curricula that advocate engaging the children in a more hands-on approach to science. Research in England (Harlen, 1997; Abell and Roth, 1992) confirmed these findings.

It appears therefore that while the literature highlights the importance of affording pupils opportunities for reflection and discussion in the development of pupils' ideas and understanding, novice teachers tend not to provide their pupils with such opportunities. These findings have implications for the development of contemporary NoS conceptions amongst pupils. Reflection and discussion are important processes in the development of elaborate NoS conceptions (Abd-El Khalick and Lederman, 1998a; Matthews, 1994; Mc Comas et al., 1998). If beginning teachers tend not to afford their pupils opportunities for reflection and discussion, they therefore may not be in a position to facilitate their pupils in developing more contemporary NoS conceptions. A description of what contemporary NoS conceptions are considered to entail in this study is given in the next section.

2.5 Defining the Nature of Science

It still remains difficult to define exactly what NoS comprises as philosophers, historians, sociologists and science educators cannot collectively agree on one definition. Mc Comas, Clough and Almazroa, (1998) assert that the term 'Nature of Science' for the science educator is used to describe:

> The intersection of the issues addressed by the philosophy, history, sociology and psychology of science as they apply to and potentially impact science teaching and learning. As such, the nature of science is a fundamental domain for guiding science educators in accurately portraying science to students (Mc McComas et al., 1998, p. 5).

While there is still no one universally agreed definition of the nature of science (NoS), it can be deduced from the extant literature that it embraces aspects of the following:

1. Science is a body of knowledge that has been ratified by numerous processes that are largely accepted throughout the scientific community. This knowledge (theories and laws) is testable and developmental, (i.e. tentative and subject to change).

2. Science is a human endeavour and therefore creativity and imagination are an intricate part of the derivation of scientific knowledge. Observations and inferences are involved in the process of arriving at theories and laws and although scientists are objective in their observations, inferences drawn from similar sets of data are subjective.

3. Society and culture affect science. Ethical and moral values within societies have huge influences on scientific development.

(Lederman, 1992a, 1992b, 1999; Ryan and Aikenhead, 1992; AAAS, 1993, Matthews 1994, Mc Comas et al., 1998).

The characteristics of NoS outlined above are aspects that have been deemed developmentally appropriate and learnable for primary and secondary pupils (Abd-El-Khalick, Bell and Lederman, 1998; Liu & Lederman, 2007). This thesis explores the NoS conceptions of pre-service and practising primary teachers and their pupils and it is with these characteristics in mind that the following description of NoS will be utilised throughout.

Contemporary conceptions of NoS comprise: An understanding of science as a reliable body of knowledge that provides information about the world and explains various occurrences. It accepts that scientific knowledge is reliable, as it has been obtained by scientists, who are practised in the subject matter of science and who have knowledge and experience in the application of various scientific processes that are approved throughout the scientific community. Contemporary conceptions affirm that there is not one 'scientific method' that comprises a fixed set of steps and procedures that all scientists follow when addressing all scientific questions but rather there are numerous accepted processes that are utilised throughout the scientific community. Those who hold contemporary conceptions of NoS understand that scientific knowledge is testable and developmental and therefore subject to change. That science is a human endeavour involving subjectivity, creativity and imagination in determining scientific knowledge is central to contemporary conceptions, as is knowledge regarding the figures and landmarks in the history of science. Contemporary conceptions of NoS comprise knowledge about how society and culture have affected scientific development in the past and how science and society are influenced and affected by one another in contemporary society. Throughout this thesis 'contemporary ' or 'elaborate' conceptions of the NoS will be ascribed to those views that perceive science as described above.

In a similar manner to Lederman (1992a) and Abd-El-Khalick & Lederman (2000a), the terms 'traditional' and 'inadequate' or 'simplistic' views will be used intermittently throughout the thesis to describe views that are discordant with the 'contemporary' NoS conceptions outlined above. Those who hold more 'traditional' views have a more one-dimensional view of science and often consider scientific knowledge as absolute, static and derived from a common 'scientific method'. The 'Scientific Method' is a belief that there is a fixed set of steps and procedures that all scientists follow when addressing all scientific questions. Those who hold more simplistic NoS conceptions often do not take cognisance of the fact that scientists have different ideas and make different decisions and choices during scientific inquiry and therefore do not always follow identical steps and procedures.

Having provided an account of what contemporary NoS conceptions, in this thesis, are considered to entail, the literature pertaining to the significance of such conceptions in science education will now be considered.

2.6 Implications for Science Education

There is widespread agreement among science educators that students at all levels should have a good understanding of NoS. (Driver et al., 1996; Lederman & Niess, 1997; Mc Comas et al., 1998; Murcia & Schibeci, 1999; Abd-El-Khalick, 2005; Moss, 2001; Craven et al., 2002). Much research has been conducted on the importance and benefits of student teachers having sound conceptions of NoS, (Lederman 1997; Murcia & Schibeci, 1999; Abd-El-Khalick & Lederman, 2000a; Moss, 2001; Craven et al., 2002). Driver and colleagues (1996) argue for example, that developing primary pupils' NoS conceptions provides them with more dynamic views of science. They classified 'dynamic' views as those that perceive science as tentative and that demonstrate an understanding of what scientific ideas mean. These were in comparison to 'static views' that perceive science as a group of facts that are best memorised.

Poole (1995) contends that when considering the aims of school science, educators and curriculum developers need to consider whether curricula are to fulfil 'educational' (science for educated citizens) or 'vocational' (science for preparing students to fulfil industrial needs in country) aims. He also maintains that teachers should view curriculum science in the light of science in a wider cultural context where ideas have been developed and influenced by views held in society at a particular time. Traditionally science was not deemed to be a subject affected by values or beliefs, however studies into the history and philosophy of science have shown how values and beliefs are dispersed throughout the scientific enterprise (Poole, 1995). Poole asserts that teachers should also take their own values and beliefs into account as these affect the way they teach science.

Mc Comas et al. (1998) suggest that if students view science as a process of improving our understanding of the world, the tentative NoS would be viewed as a positive trait. They assert that incorporating NoS as an integral part of a curriculum makes the students aware of the developmental NoS and humanises the subject, making it more interesting for them to learn. Mc Comas et al suggest for example, that if teachers and students were to understand the differences between religion and science, then the tension sometimes caused by discussions of issues (for example the current creation versus evolution debate in the USA) could be reduced.

In many science classes, however, the prevailing views of NoS that exist reflect an authoritarian view; a view in which scientific knowledge is presented as absolute truth and as a final form (Duschl, 1988). Holton (1978) refers to such teaching as 'the traditional' way we teach science. Duschl argues that this 'traditional' approach can be beneficial if those who are being educated by it are pursuing science careers. However, for the general population of students, who do not intend to pursue science careers, a more flexible pedagogy needs to be employed. Such an approach to teaching science should include issues regarding science and society, science as a human endeavour and should examine how science and technology have developed. Students need to be made aware of how scientific knowledge has developed and need to be aware of its limitations.

Duschl (1988) refers to 'scientism', an ideology that promotes an authoritarian view of science. Scientism is a belief that the magnitude of scientific knowledge holds no limits and is beyond reproach.

> Scientism implies an attitude toward science that sees it not only as an activity involving special knowledge, because of its specific and time-tested method of solving problems, but as one with a cognitive basis that is beyond question. Scientific activity is thus immune to criticism, because if any criticism, is to be considered scientifically valid, it must itself be scientifically based (Nadeau & Destautels, 1984, p.13).

Duschl proposes that the tendency towards scientism in secondary school curricula can lead to 'traditional' NoS conceptions.

The process of justifying knowledge tends to dominate science education today. That is, students tend to learn facts, hypotheses and theories in relation to how they have contributed to current knowledge. While this information may be necessary in a curriculum, it is important that knowledge regarding the discovery and development of knowledge claims is not omitted. Students need to be made aware of issues surrounding the tentative and developmental nature of science. To omit such information could lead students to believe that science is a static subject that is absolute.

Therefore, in order to facilitate students in the development of more contemporary NoS conceptions, students could be given time to discuss the limits of scientific knowledge and procedures. It is important that students become aware that science is a human endeavour, that possesses unique methods and procedures, is tentative and developmental and is one of many sources that provides information about the world. There could be consequences if students left the science class with the perception that science is absolute and the only way of providing us with information about the world. For example, this inaccurate perception of science could be used in a selective or biased way by politicians as a means of influencing peoples' opinions on various issues (Eichinger, Abell & Dagher, 1997).

Driver et al. (1996) maintain that an understanding of NoS supports successful learning of scientific content in that, it permits the development of understanding about the behaviour of the natural world. Lederman (1999) also argues that in order for students to understand science content matter, they need to understand NoS. Lederman (1999) refers to the picture of the atom that is found in textbooks. He raises the question about whether students are aware that this is a model that has been devised by scientists to explain the behaviour of matter rather than something that has been observed. If students are not aware, Lederman claims they do not have a profound understanding of the atom. If students do not have an understanding of the derivation of scientific knowledge, they will never have a true understanding of what the knowledge means, because it has not been contextualised. Students need scientific knowledge to be contextualised, otherwise the knowledge will be meaningless and they will be unable to use this knowledge to make informed decisions (Driver et al., 1996).

Duschl (1987) and Osborne and Freyberg (1985) contend that if students were to be made aware of how scientists have changed and developed their ideas around science, their views may in turn change.

> An understanding of the critical historical experiments, which led to scientists changing their ideas, may also have implications as to how children's views might be changed (Osborne and Freyberg, 1985, p.108).

Knowledge of science, rather than scientific knowledge, is knowledge of why science knows what it does and how science has come to think this way. Duschl (1988) contends that science education at post-primary level should address issues regarding how scientific knowledge has developed as well as learning what is known by science. Students need to be made aware of the tentative NoS. Teachers therefore need to be exposed to contemporary NoS views and be given opportunities to reflect on and develop their own conceptions. Teachers must at the very least be aware that contemporary views of NoS exist. Matthews (1994) concludes that:

> the learning <u>of</u> science needs to be accompanied by learning <u>about</u> science ... (This) is basic to liberal (contemporary) approaches to the teaching of science (p. 213).

If teachers have some understanding about the epistemology of science they will be in a position to transfer this knowledge to the children they teach. Another factor that Shulman (1986) maintains is crucial in developing pupils' NoS conceptions is teachers' pedagogical content knowledge (PCK). For Shulman, a teacher's PCK not only includes conceptual knowledge about a discipline, but should also comprise knowledge about the structure of a discipline, how it has evolved and the theoretical framework of the discipline. Some knowledge regarding the historical and philosophical aspects of the discipline should also be central components of a teacher's PCK. Not only will the PCK facilitate teachers in teaching the subject matter, it will enable them to transfer knowledge into a form and context that make it relevant and comprehensible for their students.

In this section the literature regarding the importance of contemporary conceptions of NoS in science education has been presented and the importance of teachers' possessing good understandings of NoS considered. A definition of what contemporary NoS conceptions entail has also been provided. The next section considers the literature regarding prospective and practising teachers' conceptions of

NoS and whether the theoretically desirable teacher knowledge of NoS is seen in practice.

2.7 Teachers' NoS Conceptions

Research has been conducted in the field of assessment and development of teachers and students' conceptions of the NoS (Bloom, 1989; Loving, 1991; Abell & Smith, 1992; Matthews 1998; Akerson et al., 1999; Murcia & Schibeci, 1999; Abd-El Khalick & Lederman, 2000a, 2000b; Lederman et al., 2002; Craven et al., 2002). Research on post-primary school students in the USA, (Klopfer and Cooley, 1963; Miller, 1963; Rubba and Anderson, 1978; Rubba, Horner & Smith, 1981) and in Australia, (Mackay, 1971), concluded that post-primary school students did not hold elaborate views of NoS. These and other studies pertaining to the assessment and development of students' NoS conceptions are considered and deliberated in section 2.8. In more recent years, the translation of teachers' NoS conceptions into classroom practice has been researched (Abd-El Khalick et al., 1998, Lederman, 1999, Bell et al., 2000) and will be discussed in section 2.9.

Abd-El Khalick and Lederman (2000a) conducted a review of the literature on research that has been carried out on NoS in science education from the early 1900s to 1990. Within this review, they reported on research that aimed at establishing teachers' conceptions of NoS. Anderson (1950) for example, surveyed 58 biology teachers and 55 chemistry teachers in the USA and revealed that both groups of teachers possessed serious misconceptions regarding NoS. He maintained that these teachers were pre-occupied with imparting factual information to their students and therefore did not address any issues regarding NoS. Another study conducted by Behnke (1961) with 400 biology teachers, 600 chemistry teachers and 300 scientists (with science degrees but not teaching science) revealed that over 50 percent of the teachers and indeed 20 percent of the scientists did not believe scientific findings were tentative. Miller (1963) conducted a study in the USA that compared high school biology teachers and their students' conceptions of science. Miller concluded that many of the teachers did not understand NoS as fully as their students, and did not understand NoS well enough to teach it. Schmidt (1967) attempted to replicate Miller's (1963) study and concluded that teachers still possessed inadequate conceptions of NoS and recommended that techniques to facilitate the development of practising teachers' NoS conceptions be devised. However, it is worth noting that these are very old studies that would have accorded with very didactic curricula dominant pedagogies at the time, therefore the results of these studies are perhaps not very surprising.

These studies indicated that post-primary school science teachers tended not to hold adequate conceptions of NoS. Studies also revealed prospective science teachers in post-primary schools did not hold adequate conceptions of NoS. King (1991) for example investigated beginning teachers' knowledge of the history and philosophy of science in the USA. He reported that while these teachers believed the history and philosophy of science to be important, they did not have sufficient knowledge of the areas to enable them to incorporate it into their science lessons.

More research on the assessment of teachers' NoS conceptions has been conducted on post-primary teachers than on primary (Murcia & Schibeci 1999). Bloom (1989) was amongst those who assessed primary teachers' conceptions of NoS. She conducted a study with 80 pre-service primary teachers in Canada. An open-ended questionnaire, which examined their knowledge of science, scientific theories and evolution, was administered at the beginning of the study. The participants held perceptions of NoS that were not consistent with contemporary ones. The majority of the respondents gave vague and misinformed definitions of theories, which became evident in their attempts to discuss the topic of 'evolution'.

Abell and Smith (1992) conducted another study on the exploration of 140 primary teachers' conceptions of NoS, in the USA. The teachers were asked for a written response to the question 'How would you define science?' and the following categories emerged: discovery; knowledge; processes of science; explanation and education. The majority, 61 percent, depicted science as 'discovering or finding out about the world'. The second most frequent category was 'knowledge' with 58 percent of the teachers responding in this category. The category 'processes of science' was frequently mentioned in conjunction with other categories. These findings were compared with Bloom (1989) and with the characterisation of science as outlined in Science for All Americans (American Association for the

Advancement of Science, 1990). The authors concluded that the respondents did not hold elaborate conceptions of NoS.

Pomeroy (1993) conducted a study in the US comparing scientists, post-primary and elementary teachers' beliefs about NoS. She used a 50-item survey that contained agree-disagree statements, which reflected different views of NoS. The participants in this study were 71 scientists and 109 teachers, (33 percent of whom were primary). The results of this study revealed that scientists held more traditional views of science than the teachers; the primary teachers agreed with significantly fewer of the traditional statements about science than the post-primary teachers and the primary teachers scored significantly higher than the post-primary teachers in the non-traditional category. Pomeroy recognised that the more contemporary views of NoS held by the primary teachers might have been explained by in-service courses some of them had taken, that addressed new approaches to teaching science. The traditional views of science held by the scientists and post-primary teachers may have been related to the science programmes they experienced in third level education, which, according to Pomeroy are often heavy in science content with little room for philosophy and reflection.

However another reason why the primary teachers may have had more contemporary NoS views could have been due to the more creative approaches through which science methodology courses may have been taught at third level. These more creative methods could have placed less emphasis on rote learning of facts and procedures and more emphasis on how children learn and various teaching methodologies. Such approaches may have left the prospective primary teachers 'freer' to think about NoS, resulting in more contemporary NoS views.

The results of Pomeroy's (1993) study have implications for teacher education in Ireland. Pomeroy suggests that an emphasis on a constructivist approach to teaching might have had a positive influence in the formation of these primary teachers' conceptions of science. If research were to confirm this supposition and positively link constructivist teaching approaches with the development of more contemporary conceptions of NoS then, the inclusion of such approaches on pre-service and in-service courses would be of fundamental importance.

Spector and Strong (2001) conducted a study with 31 traditional undergraduate (those who entered college directly from school) and 18 non-traditional (those who were changing careers or concurrently teachers' aides for special education schools) pre-service elementary science methods teachers in the USA. They compared the 'culture' of these pre-service elementary teachers with the 'culture of science and utilised Aikenhead's (1996) definition of 'culture', that which describes patterns evident in a group even though individuals come and go from the group. The patterns they referred to include the values, norms, beliefs, expectations and conventional actions of scientists generating knowledge. They outlined these from three perspectives; ethical, teaching and learning and social psychological profiles (Appendix A).

Spector and Strong (2001) found that the culture (and subsequent worldview) of the majority of traditional students in these pre-service elementary methods classes did not conform to the culture of science. Numerous 'clashes' were identified and are outlined in Appendix A. For example, with regard to the ethical traditions in science, the culture of science views science as a way of knowing and understanding, it values peer review, makes work public and its ideas and products are open to criticism. According to Spector and Strong, this is unlike the culture of the traditional pre-service methods students in their study. These students viewed science as a fixed body of knowledge, did not value peer review, only the review from their, instructor mattered. They kept their work private between themselves and their teacher, and criticism of their ideas or products was found to be offensive and was something that was not permitted in a group or class (Spector and Strong, 2001, p13). This study indicates that the pre-service teachers' classroom culture was different to the culture of science. It would appear therefore, that in order for pre-service teachers to develop contemporary conceptions and understandings of NoS, their classroom culture needs to be altered to be more in keeping with the 'culture' of science. The findings of Spector and Strong's study have implications for pre-service primary teacher education in terms of informing strategies that could potentially enhance pre-service primary teacher education, in the development of inquiry- based learning, meaningful learning and the development of contemporary NoS conceptions.

It is worth noting that some research contends that the situation regarding teachers' 'inadequate conceptions of NoS' may be a little more complex than simply ascribing them traditional, empiricist NoS views. Lederman et al. (2002) for example asserted that questionnaires being utilised to establish NoS conceptions might be contributing to inaccurate portrayals of teachers' conceptions. They contend that many of the standardised tests assessing NoS conceptions have often reflected the developers' views and frequently have had particular philosophical stances in mind. Lakin & Wellington (1994) also contend that the situation is more complex than simply ascribing certain empiricist traits to teachers. They maintain that few teachers appear to be comfortable with many of the suggested strategies for teaching about NoS. Such strategies included group work, reading for learning, role-play or drama and Lakin & Wellington suggest that teachers may not fully understand these approaches, could be unsure how to implement them effectively and in general appeared to lack confidence in them.

Many research studies have revealed that primary and post-primary teachers do not possess elaborate NoS conceptions, and that their science backgrounds are not necessarily pertinent to their conceptions of science (Bloom, 1989; Carey et al., 1989; Lederman, 1992a; Lederman et al., 2002; Matthews, 1994; Pomeroy, 2003). Klofer & Cooley (1963) were amongst the first to develop a curriculum that was designed to improve students' conceptions of NoS. They utilised material from the history of science to reveal important issues regarding science and concluded that such an approach was effective in developing understandings regarding science. In another study, Carey and Strauss (1989) investigated the effectiveness of a science methods course in improving conceptions of the NoS amongst 17 prospective post-primary science teachers. They concluded that a methods course that was 'specifically orientated towards the NoS' could significantly improve the teachers' understandings and recommended that courses in the history and philosophy of science be included in pre-service education. However, studies have also revealed that despite such attempts many teachers still possessed naïve NoS conceptions (Abel and Smith, 1992; Bloom, 1989; King, 1991; Moss et al., 2001). Whether science was learned through undergraduate, postgraduate, in-service, or professional practices, it didn't seem to have any effect on establishing modern NoS conceptions among teachers.

It emerged that curricula alone could not be responsible for the development and improvement of students' conceptions and that the role of the teacher in aiding the enhancement of students' NoS views was critical. A change in emphasis in research on NoS conceptions came about, which began exploring alternative approaches to aid the improvement of conceptions of science among teachers.

Two broad approaches for developing NoS conceptions were researched, implicit and explicit approaches. These will be discussed in more detail in the following section.

2.8 Implicit or Explicit Approaches?

Advocates of implicit approaches (Barufaldi, Bethel and Lamb, 1977; Haukoos & Penick, 1985; Riley, 1979; Scharman, 1990) assumed that modern conceptions of NoS could be developed as long as students were engaged in hands-on activities. Those who employ implicit approaches assume that students will develop modern NoS conceptions by applying the process skills and 'doing science' and that direct instruction or discussions related to the different aspects of NoS are not necessary. It is assumed that pupils will assimilate NoS ideas through conducting scientific inquiry. Barufaldi et al. (1977) maintained that teacher education should aim at enhancing students' understanding of the tentative nature of scientific knowledge. They explored the effectiveness of an elementary science methods course on junior and senior elementary majors in Texas. The course did not explicitly teach about the tentative nature of science, rather implicit methods that included the employment of hands-on activity-based, inquiry-orientated experiences were utilised. Barufaldi et al. concluded that the treatment groups who had taken the hands-on activity based methods course had significantly increased their philosophical understanding of the tentative nature of science. However, one must be cautious about the authors' findings as the difference between the post-test mean scores for the test and control groups was very small and therefore it was difficult to establish that the gains reflected meaningful improvement in the students' understanding of the tentative nature of science.

Riley (1979) also maintained that teachers' understandings of and attitudes towards science could be developed if they experienced hands-on scientific experiences. Riley's study also investigated the influences of a hands-on versus a 'non-manipulative' science course on teachers' NoS conceptions. Unlike Barufaldi et al. (1997) however, Riley concluded that there was no significant improvement in NoS conceptions as a result of taking part in hands-on inquiry orientated experiences. It would appear from these studies that implicit methods to teaching about NoS were not very effective in the development of more contemporary NoS conceptions.

Those in favour of explicit approaches on the other hand (Akerson et al., 2000; Akindehin, 1988; Carey & Stauss, 1968, 1970; Craven et al., 2002; Khishfe & Abd-El-Khalock, 2002; Lederman & Abd-El-Khalick, 1998; Lederman, 1998; Loving, 1998), argue that NoS conceptions cannot be 'caught' by merely participating in science class, but rather need to be explicitly addressed. Explicitly teaching about NoS does not mean lecturing about it or enforcing particular positions about NoS. However, it does mean intentionally designing lessons that address particular NoS issues. Providing students with opportunities to discuss, debate and reflect on various NoS issues is considered equally important and the importance of teachers' roles in facilitating discussions and debates to ensure that contemporary views of NoS are being developed rather than 'unsophisticated ' views being reinforced has been highlighted (Khisfe & Abd-El-Khalick, 2002).

As mentioned above research has indicated that implicit approaches to teaching about NoS have not been effective (Abd-El-Khalick, 1999, Lederman, 1998). Some of the literature relating to the effectiveness of explicit approaches in the teaching of NoS to pre-service and practising primary teachers will be now be considered.

Akerson and colleagues (2000) conducted a study aimed at assessing the effectiveness of explicit reflective approaches in teaching about the NoS with 25 postgraduate prospective primary teachers in the USA. In this study the students' views were assessed at the beginning and end of the course using questionnaires and follow-up interviews. The intervention included the students participating in ten activities that explicitly addressed different tenets of NoS (See Lederman & Abd-El-Khalick, 1998) and guided classroom discussions that included children's literature and videos as stimuli. As with previous research (Abd-El-Khalick & BouJaoude 1997, Bloom 1989, Carey & Strauss 1968, King 1991, Abell & Smith 1992) the participants in this study held unsophisticated conceptions of NoS at the beginning. The participants held significantly more elaborate NoS conceptions by the end of the study, indicating that the explicit reflective approach to teaching about NoS was effective in enhancing the participants' NoS conceptions. However, the question arises as to whether these changes in conceptions may be temporary. Follow up studies that would examine the permanence of these changes towards more contemporary NoS conceptions would therefore be informative.

In a similar manner, Craven and co-workers (2002) study of 27 Australian pre-service primary teachers assessed the effectiveness of explicit approaches in addressing NoS in a science methods course. The participants in this study were engaged in a number of individual and group tasks that included both written assignments and oral discussions. Again consistent with the research on science teachers' conceptions of NoS, the participants in this study held 'traditional' conceptions of NoS at the beginning of the study, largely depicting science as facts, methods and answering questions. At the end of the study the students had developed more elaborate conceptions of NoS. This was evident in their more complex and multi-dimensional written descriptions and oral deliberations about science. The authors also concluded that the explicit approach did improve students' NoS conceptions. It would be interesting to know whether a follow-up study a year or so later would reveal that these students still held more contemporary conceptions of NoS.

Murcia & Schibeci (1999) recommended that prospective primary teachers be given more opportunities to reflect and consider NoS issues, to facilitate the development of NoS conceptions. Their study examined 73 prospective primary teachers in Western Australia. A questionnaire comprising three sections was administered during the first week of the semester prior to any science instruction. In the first section of the questionnaire the students were required to read an article from a newspaper and answer seven questions relating to their views of NoS. The seventh question asked them to answer the question 'What is science?' The final section sought background information on any science they might have studied at second level. The participants in this study predominantly viewed science as a means of searching for explanations of every day life and as a process of discovering the 'truths' about the world. These findings were similar to those of Bloom (1989) and Abell and Smith (1994). Murcia and Schibeci (1999) recognised that while the use of media reports was a useful stimulus for establishing participants' NoS conceptions, there was little evidence that the participants were critically able to question media reports from a scientific perspective. They concluded that the participants held 'positivist' views (science as an absolute, static body of knowledge, facts to be learned, the way of discovering knowledge about our world). Murcia and Schibeci (1999) concluded that, given more opportunities to reflect upon and discuss the nature of the scientific enterprise, prospective primary teachers would develop more contemporary conceptions of NoS.

Smith and Scharmann (2006) conducted a study in the US that compared explicit and implicit approaches to NoS instruction. Their investigation comprised a multi-year action research agenda aimed at developing an instructional model for teaching NoS. They supported the uses of explicit reflective methodologies. Their methodologies included Kuhn's (1974) learning by 'ostention' and they considered science as a continuum. Defining a concept by 'ostention' simply means clarifying 'the meaning of the term by pointing to examples of things to which it applies' (Bonevac, 1999). Kuhn (1974) argued that ostention is the principal device through, which children learn the concept labels for natural families of objects in everyday life. Kuhn pointed out that children typically learn these labels when they are presented and are exposed to examples in each category, rather than merely learning lists of concept characteristics.

> Anyone who has taught a child under such circumstances knows that the primary pedagogic tool is ostention. Phrases like 'all swans are white' may play a role, but they need not' (Kuhn, 1974, p.309).

Repeatedly throughout the course the students in the Smith and Sharmann study were given pairs of examples (claims) and were asked to classify them as more or less scientific. For example:

If you break a mirror, you will have seven years of bad luck

If hair colour is inherited, then identical twins should have the same hair colour (Smith and Scharmann, 2006 p.14).

The authors established the extent to which the NoS conceptions held by these fifteen pre-service science teachers in the USA changed and developed as a result of participating in the instructional model. Initially the pre-service science teachers in this investigation considered evolution as something that was at odds with their Christian heritage. They did not consider evolution as a legitimate scientific theory. By the end of the course all of the students placed evolution as most scientific when compared to intelligent design and a fictional area of study 'umbrellaology' (Boersema, 1998, p. 255).

Akindehin (1988) was another advocate of explicit approaches. He asserted that the improvement of students' NoS conceptions "should be planned for instead of being anticipated as a side effect or secondary product" of varying approaches to science teaching (p.73).

The foregoing literature suggests that pre-service teachers tend not to hold elaborate NoS conceptions and that explicit approaches in addressing aspects of NoS appear to be effective in developing their NoS conceptions. The literature comparing the effectiveness of employing explicit approaches over implicit approaches to NoS has been considered. The next section will consider the implications of the research that has been conducted on the effectiveness of history (HoS) and philosophy (PoS) of science courses on pre-service and practising teachers' NoS conceptions.

2.8.1 The Importance of History and Philosophy of Science Courses

There is a tendency for 'science for scientists' to dominate curricula, but if one maintains that science is developmental, an important part of NoS is the History of Science (HoS). There are many supporters for the inclusion of HoS as part of science curricula (Abd-El Khalick & Lederman, 2000b; Driver et al., 1996; Jenkins, 1996;

Klopfer, 1969; Matthews, 1994). Matthews (1994, 1998) a strong advocate of a historical approach to teaching about NoS, asserts that the inclusion of HoS components in science curricula is important because it:

- promotes a better understanding of science concepts and procedures,
- links the development of individual thinking with the development of scientific ideas,
- is intrinsically worthwhile and important historical episodes should be familiar to all students.
- humanises the sciences
- allows connections within topics and disciplines of science as well as with other disciplines

(Matthews, 1994, p. 50).

The inclusion of philosophy of science (PoS) as an integral component in science education is something Matthews (1994) has also supported. He argued that PoS enables pupils to develop a better understanding of science and that by making PoS more explicit the goals of science education can be advanced. One cannot expect primary school teachers or indeed post-primary science teachers to be expert philosophers, historians, or sociologists of science as such an expectation is 'unrealistic' (Matthews 1998). However, the provision of PoS courses at pre-service and in-service level could provide teachers with the opportunity to reflect on and discuss various NoS issues that in turn could empower them to develop their own NoS conceptions. Such courses might afford teachers the opportunity to examine their existing views about NoS and enable them to alter these views as appropriate to be in keeping with more contemporary conceptions.

Mellado (1997) conducted a case study with four prospective primary and post-primary school teachers in Spain at the end of their initial training year. The aim of this study was to compare the pre-service teachers' conceptions of NoS with their classroom practice. Two of these were pre-service elementary school teachers, 'specialist science maestro', who were taking a general three-year primary teaching degree. The other two participants 'science graduates', were prospective post-primary school teachers and were enrolled in a degree course in science. This course was not directed towards teaching. In general, all four prospective teachers in this study had not been given the opportunity to reflect on their conceptions of NoS over the course of their degrees. Despite sitting pedagogical courses during their degree, the prospective primary teachers' pedagogical knowledge regarding the development of NoS conceptions was not superior to the graduates who had received no classes in methodology. Mellado asserted that this was because both sets of teachers had received academic knowledge that was not transferable to the classroom situation. Microteaching, questionnaires, semi-structured interviews, personal documents and classroom observations of teaching practice were utlised to obtain the data. Mellado (1997) concurs with other research regarding the effectiveness and importance of PoS courses. He suggests that such pre-service PoS courses include a component that introduces knowledge of procedures and schemes of action, which would enable prospective teachers to assimilate methodologies, and combine these with their own personal constructs and classroom behaviours. Such courses, according to Mellado, would facilitate teachers in developing their own and their pupils' conceptions of NoS.

Abd-El-Khalick's (2005) study with 56 undergraduate and graduate pre-service post-primary school science teachers in the USA revealed that the responses of students who had taken an additional PoS course were more reflective and coherent when reflecting on questions regarding the scientific enterprise. The 'PoS' students supported various responses with appropriate examples from the HoS. They also went beyond discussing whether or not they should be taught about NoS in their pre-service courses, to discussing changes they needed to bring about in their own teaching behaviour and language to ensure that they are in keeping with their new-found NoS conceptions. Substantially more 'PoS' students transferred their newfound NoS into practice, by explicitly addressing NoS issues in their lesson plans.

The author did warn that the results should be viewed with a certain degree of caution in that the number of students who had taken the PoS course was small and they had elected to take the course, thereby showing an interest in science. The PoS course was not representative of other such courses as it was specifically geared towards addressing the needs of science educators, which included exploring their NoS views and the translation of these views into pedagogical practices. While the author recommended that the results of this study could not be generalised due to the small numbers involved, the study supports the assumption that courses in PoS are effective in the development of more contemporary NoS conceptions amongst pre-service teachers. However, it is difficult to verify whether it was the actual PoS course that contributed to the students developing more elaborate NoS conceptions, or was it the fact that they were given more time to discuss and reflect on NoS issues. The effectiveness of the PoS course therefore would need to have been established more clearly. Also if the control group had sat an additional NoS course, and been given additional time to discuss science, this could have been as effective as the PoS course.

The benefits of employing explicit reflective approaches in developing prospective and practising primary teachers' NoS conceptions can be seen from the literature. Whether and how these new found contemporary conceptions can be transferred to their pupils will now be considered.

2.9 The Translation of Teachers' NoS Conceptions into Classroom Practice

Research to date on the translation of teachers' NoS conceptions into classroom practice has largely been concerned with post-primary school teachers and students (Lederman & Zeilder, 1987; Abd-El-Khalick & Lederman, 2000a; Lederman, 1999; Gallagher, 1991). A study conducted in the USA by Brickhouse in 1990, for example, explored the relationship between the conceptions of science amongst three middle school (10-15 year old pupils) science teachers, and their classroom practice. The findings revealed that not only did teachers' conceptions about NoS influence their explicit lessons about NoS, they also moulded the implicit curriculum regarding the nature of scientific knowledge.

In a similar manner Gallagher's (1991) study explored post-primary school science teachers' classroom practice. This study also concluded that teachers' conceptions of NoS affected their classroom practice. The teachers held 'traditional' views of NoS and in their classes there was a strong emphasis on the transmission of knowledge and memorisation of facts within a traditional classroom context. Cachapuz (1994) and Ballenilla (1992) found similar connections between teachers 'inadequate' NoS conceptions and 'traditional' classroom practices amongst Portuguese post-primary chemistry teachers and Spanish post-primary biology teachers respectively. A factor that could be influential in determining whether or not post-primary school teachers explicitly address NoS is the nature of state examinations that students are required to take at second level. This issue will be considered in greater detail in the document analysis in chapter four.

These studies suggested that teachers' conceptions affected their teaching and linked 'traditional' conceptions of NoS with 'traditional' teaching methodologies, which concentrated on memorisation of facts and procedures. In only one case (Brickhouse, 1990) the teacher held contemporary conceptions and more dynamic teaching methodologies were employed.

On the other hand, there are studies that found no direct link between teachers' NoS conceptions and classroom practice. For example, Duschl and Wright's (1989) study with high school science teachers revealed that while the teachers held contemporary NoS conceptions the teachers did not address NoS issues in a comprehensive way. Lederman, Abd-El Khalick, Bell and Schwartz (2002) acknowledged that there seemed to be no significant relationship between teachers' NoS conceptions and their science teaching. They found that there were numerous factors, other than the teacher's NoS conceptions that seemed to impede the development of pupils' understanding of NoS conceptions; examples would include curriculum constraints, administrative policies, class sizes and resources.

Various other studies have also revealed factors that inhibit the development of NoS conceptions amongst children. Some of these factors include pressure to cover content (Duschl and Wright, 1989; Hodson, 1993), management and organisational factors (Hodson, 1993; Lantz and Kass, 1987; Lederman et al., 2002), concerns over pupils' ability and motivation (Brickhouse and Bodner, 1992; Duschl and Wright, 1989; Lederman, 1995), institutional constraints (Brickhouse and Bodner, 1992) and teaching experience (Brickhouse and Bodner, 1992; Bell, Blair, Crawford & Lederman, 2003). Rubba, Horner and Smith (1981) assert that it is textbooks and teacher behaviours that often contradict NoS, and that these are two of the main factors contributing to students' inaccurate conceptions of NoS. They contend that the textbooks used in post-primary schools often include statements that portray unalterable and static truths, as factors that embody science.

The results of Meichtry's work (1992) revealed that the nature of scientific knowledge was not always being directly conveyed to students through their curriculum or teachers. She found that even though students devised and conducted investigations in which they utilised their creativity, neither the textbooks nor teachers referred to the fact that scientists use creativity when they are generating scientific knowledge. Meichtry concluded that if teachers did not draw their students' attention to the different aspects of NoS while they were conducting investigations, students themselves might not make these connections. It would appear therefore that Meichtry also advocates the importance of explicitly teaching about NoS.

Research indicates that one cannot assume that students will automatically acquire contemporary NoS conceptions implicitly, as a by-product of 'doing' science-based activities. (Akerson et al., 2000; Akindehin, 1988; Carey & Strauss, 1968, 1970; Craven et al., 2002; Lederman & Abd-El-Khalick, 2000; Lederman, 1998; Loving, 1998). Neither can one assume that teachers with contemporary NoS conceptions will automatically teach science in a manner that is in keeping with these 'modern' views (Duschl & Wright, 1989; Lederman, 1998). Therefore, it is important that, NoS must be dealt with as a 'cognitive' objective rather than 'effective' outcome. That is, teachers must plan, explicitly teach and indeed specifically assess the development of their students' conceptions of NoS (Bell et al., 2000).

As mentioned above, pressure to cover content (Duschl and Wright, 1989; Hodson, 1993) and institutional constraints (Brickhouse and Bodner, 1992) are amongst the factors that appear to impede learning of NoS. If the development of children's NoS conceptions is to be deemed an important aspect of school science, it is essential that the enhancement of NoS understanding is given the same status in education documents as that of learning about science concepts, and that therefore it should be addressed through explicit means. Without explicit instruction students will:

continue to learn subject matter without context and the visions of reform in science education will progress no further than they have in the past (Lederman, 1998, p.18).

Trumbull, Scarano and Bonney (2006) explored the relationship between conceptualisations of NoS and success in teaching students to conduct inquiries with a practising and novice teacher. The novice teacher's responses to the NoS questionnaire and subsequent interview, revealed that while she held many conceptions of science that were in keeping with current NoS views, they were distal views, that is views about the scientific enterprise as a whole and she was not able to execute these in her teaching. The novice teacher made every effort to minimise student confusions and mistakes through meticulous structuring of activities and as a result she impeded opportunities for inquiry.

On the other hand the experienced teacher in the Trumbull et al (2006) study, unlike the novice teacher, was not afraid of confusion. She observed her pupils' learning and changed methodologies accordingly. Her responses on the questionnaires and interviews were more proximal in nature; that is they were based on her experiences. She acknowledged the importance of empirical work, was aware of the role of creativity and insight in the recognition of patterns and the formulation of hypotheses. Trumbull and her co-workers noted that simply experiencing an inquiry-based setting is not a guarantee for profound understandings of NoS. The experienced teacher's understanding of the learning process as something uncertain and developmental facilitated her in developing an understanding for scientific inquiry. When she was working with her pupils she provided them with opportunities to formulate and explore interesting questions.

The authors concluded that, like many beginning teachers, the beginning teacher was still focused on her own performance rather than on her pupils (Fuller & Brown, 1975). These findings are relevant in that they highlight some of the issues regarding beginning teachers and their approaches to teaching science. Beginning teachers often experience hands-on scientific inquiry and obtain pedagogical knowledge of science during their education courses. The novice teacher in this study held contemporary NoS conceptions, however, issues such as classroom organisation and classroom management appeared to be factors that affected her approaches to teaching science.

Hogan (2000) defined distal views of NoS as pronounced knowledge held regarding NoS. A distal view of science is one that conceives science as a social and cultural activity, where norms of practice are shared and communicated. This is compared to proximal knowledge that incorporates personal understandings, beliefs, and commitments that students possess about their individual scientific experiences and the scientific knowledge they acquire or confront in their classrooms. Proximal views are more personal views that are formed through individual experiences. The findings in the Trumbull and colleagues (2006) study were similar to Akerson and Abd-El-Khalick, (2003) and Hogan (2000) who asserted that the possession of knowledge regarding NoS does not automatically mean that teachers will be able to implement inquiry projects. Trumbull et al. concluded that simply acquiring propositional (distal) knowledge about NoS may not be relevant and applicable to the classroom setting and suggested that that pre-services courses need to pay more attention to teachers' underlying philosophies of learning and teaching.

Some studies have reported a link between 'traditional' conceptions of NoS with 'traditional' teaching methodologies (Gallagher, 1991; Ballenilla, 1992; Cachapuz, 1884). Other studies on the other hand have found no connection between teachers' contemporary NoS conceptions and classroom practice (Duschl and Wright, 1989; Lederman et al., 2002). Teachers' classroom practice ultimately impacts on pupils, therefore it appears from the literature that pre-service courses that explicitly address teachers' conceptual and pedagogical knowledge of NoS are required if students at all levels are to acquire and develop contemporary NoS conceptions.

Having considered the extent to which teachers address NoS as a component in science classes the next section reviews some of the literature regarding primary and post-primary pupils' conceptions of NoS.

2.10 Pupils' Conceptions of the Nature of Science

Research findings to date suggest that many primary and post-primary aged pupils perceive the scientist's role as one of making discoveries about the world through careful observation. In this role experiments are conducted to find out what happens, either in general or when specific factors are manipulated. Very few children appear to view science as centrally concerned with developing explanations (Driver et al 1996, Kuhn et al., 1988; Larochelle and Desautels, 1991; Solomon, et al 1994). Science is commonly viewed as a means of improving the human condition, finding cures for diseases and inventing new devices (Aikenhead et al., 1987, Driver et al., 1996, Solomon et al 1994)). In general, children tend not to differentiate between science and technology unless specifically asked (Fleming 1987).

Children's ideas regarding NoS are influenced by various factors in their immediate environment. It is unlikely that children have direct experience of the scientific enterprise, however, various images of science and scientists will have been portrayed to them through the media or through discussions with adults and peers about current issues in science. Many children may also have developed conceptions about science from different experiences of science encountered in school (Driver et al. 1996).

There are a limited number of studies regarding young people's conceptions of NoS and the majority of these studies examine post-primary pupils' conceptions. In this section studies that explore primary, post-primary and tertiary pupils' conceptions of NoS will therefore be considered.

One study that was conducted in the UK with lower post-primary pupils (age 11-14 years) was the Solomon, Scot & Duveen (1996) study that focused on pupils' understandings of NoS. In this study a number of science topics were taught using an historical context. The findings reported seven images of scientists that were held by the pupils. One was the 'cartoon' image, where the children depicted scientists as not knowing what to expect when they conducted experiments. This image also ascribed a degree of danger and surprise to scientists' experiments. In a similar manner the 'vivisectionist' image, or 'animal rights' image portrayed scientists as experimenting and testing things, often hurting and killing animals. Those who held 'vivisectionist' images often believed scientists had no expectation of the results of their experiments.

The 'authoritative' image portrayed scientists as knowing everything and being certain about knowledge. Those who held 'authoritative' views of scientists believed that all science experiments that are performed accurately yielded 'correct' results. A fourth image of scientists portrayed in the data was the 'technologist' image. Scientists work and produce useful artefacts, which they 'test' to make sure they work and alter and 'make them better'.

Most of the pupils in this study viewed their teachers as scientists, providing them with knowledge and experiments that 'would work'. One child referred to pupils themselves being scientists who are aware that a right answer exists but that they are not always able to find it, as experiments don't always work. The seventh image of scientists presented scientists as entrepreneurs, searching for new knowledge and developing valuable products. Often these scientists were depicted as competitive. The authors noted that the pupils held several of these images of scientists and often moved from one image to another in a conversation.

The results of this study revealed that the intervention, the use of historical units by the teachers within the school science curriculum, contributed significantly to the development of the pupils' conceptions of NoS. The findings indicated that after the intervention, the pupils had begun to move towards more elaborate understandings of NoS. For example, when asked about why they thought scientists did experiments, between 50 and 60 percent of the students chose the 'discovery' option in the initial questionnaires with only 20-30 percent choosing it in the exit questionnaires. This suggested that more pupils had begun to realise that scientists have a purpose in mind and have some knowledge of what the outcomes of an investigation will be, as opposed to a more naïve understanding of scientists 'discovering' something new 'by chance'. This was corroborated in another question where a higher percentage of the pupils at the exit stage maintained that the purpose of scientists' work was the 'explanation' of phenomena. The exit questionnaires and interviews also revealed a significantly higher percentage of pupils viewing scientists as having some knowledge regarding the outcomes of their investigations.

While the results reveal changes towards more contemporary NoS conceptions amongst the pupils, the authors do not claim that the results show that earlier more simplistic views have disappeared altogether. The authors do contend, however, that the use of historical stories is a valuable tool for creating epistemological ideas in young pupils' minds. The authors also assert that the results indicate that the inclusion of some history of science in science class helps pupils to understand scientific content. The teachers unanimously agreed that their pupils learned some concepts better through studying them through historical contexts.

The authors suggest that studying the history of change in theory made the process of conceptual change easier for pupils to comprehend. This, they maintained, may have helped the pupils see that even mature scientists struggled with seeing and understanding phenomena in different ways, something similar to what they may be encountering in school science.

While the authors corroborated data obtained from the questionnaires with follow-up interviews, there are some issues that need to be considered in relation to the multiple-choice nature of the questionnaires. Primarily, the questionnaire required the students to select one of three views, offered by the researcher. While these views were varied, they may not necessarily have represented or captured the pupils' views, therefore forcing the students to tick a view that may not accurately portray their own. The pupils may have agreed or disagreed with parts of the statements offered, or may have disagreed with all statements and ticked one which with they agreed most. Secondly, the pupils may have not interpreted the questions as the authors intended them, again possibly leading them to tick boxes that may not accurately portray their views.

Understanding the relationship between science and society and how they affect and are influenced by one another is an important component of contemporary NoS conceptions. Aikenhead, Fleming and Ryan (1987) conducted a large-scale survey that explored 10,800 students' conceptions regarding the relationship between science and society issues in Canada with 17-22 year old students. Both science and non-science students completed a survey, indicating whether or not they agreed with a number of statements regarding science and were required to write a short paragraph at the end to justify their responses.

One of the questions on the survey sought to establish the students' ideas regarding the motivation of scientists in their work. Some students indicated that they believed scientists worked to satisfy their own curiosity and others maintained scientists worked in order to improve the world in which we live. This suggests that the pupils held naïve conceptions of NoS in that they did not appear to be aware of how society and science are influenced and affected by one another.

The findings in this study also illustrated the fact that students did not distinguish between different aspects of scientific inquiry and tended to treat science and technology as the same entity, aimed at improving the world. The authors referred to this as 'techno-science', where societal issues comprised issues that were related to technology and science's role was to solve these problems. Thus those holding 'techno-science' views would have limited conceptions regarding the relationship between science and society.

Ryan (1987), drawing on the findings of the Canadian survey reported on the students' views on the honesty and objectivity of scientists. The study revealed that the majority of the students maintained that scientists were trained to act in a logical objective manner and these attitudes would automatically transfer into their work. An overwhelming majority of the students believed that scientists should be concerned with the possible effects of their discoveries, particularly for discoveries that were potentially harmful. The majority of the students believed that in general scientists considered the effects of their discoveries. When asked whether or not they believed scientists should be held responsible for their discoveries some maintained it was part of a scientist's job to make sure a discovery is safe and others believed that it was the 'user' of the artifact who should be held responsible. These findings appear to indicate that the students held a mixture of contemporary and traditional conceptions regarding the honesty and objectivity of scientists.

Aikenhead (1987) examined the findings of the same Canadian study to determine whether the students believed that social contact with the community would be beneficial to scientists' work. A significant majority of the students believed that social contact with the community would improve scientists' work. They defended their views by claiming that this social interaction would inform scientists' research and improve progress. A small number of the students believed that scientists should interact with their communities in an attempt to gain better understandings of the society. The students maintained that such understandings and knowledge would familiarise scientists about the communities their work aims at developing. Aikenhead (1987) maintains that this view is as a result of views that perceive scientists as loners, working in isolation. These views of science therefore appear to be more indicative of more traditional understandings of the nature of science in society.

Fleming (1987) again drawing from the Canadian survey, sought to establish the students' views regarding the nature of the interaction of science, technology and society, the role both science and technology play in securing quality of life and the extent to which society should control the direction of both scientific research and technological development. Fleming maintained that the Canadian students could distinguish between science, the process of understanding natural phenomena, and technology, the process of designing techniques and instruments to satisfy human needs, when they were specifically asked to do so. One of the students wrote:

> As science develops new theories and techniques, technology can progress further and further. As technology increases, it can improve on the information that science has given and give it back to science in the form of new processes and instruments' (p.168).

However, when the students were not asked to distinguish between the two, the students did not differentiate between science and technology. Rather, science and technology were considered as a unified enterprise, ('technoscience') that affects society.

When asked to respond to a question 'in order to improve the quality of life in Canada, would it be better to invest money in technological research rather than scientific research?', 31 percent of the respondents adopted a position where the roles of science and technology were unclear and indistinct. Curing disease was the most common social benefit referred to by the students, and scientific research was invariably associated with finding cures for diseases. Rarely were other examples of scientific research given. Again these results appear to suggest that the students in the Canadian study held limited understandings of the relationships between scientific communities and other social groups.

Contemporary conceptions regarding NoS incorporate knowledge about the empirical nature of science (scientific inquiry), and the (tentative) nature of scientific knowledge. Post-primary pupils' ideas regarding what 'scientists do', their ideas about theories and their tentative nature and how theories and experiments correlate with their experiences of school science were explored in the Solomon, Scott and Duveen (1996) UK study. The findings reported that only small samples of the pupils revealed an understanding of the explanatory NoS and the role of imagination and modelling in scientific theories. The strong influence of a teacher's NoS conceptions on their pupils' conceptions of NoS, regardless of whether or not NoS issues are explicitly addressed was also reported.

A questionnaire was administered to smaller samples of younger pupils (ages 12 - 13 years) and older pupils (age 16-18 years) in an effort to contexutalise the developmental status of the 15 year olds. This comparison revealed that the pupils tended to move from the cartoon image of science (Solomon et al., 1994) to that of experimental science. This was evident in the manner in which the pupils began to abandon the idea that scientists discover things 'by chance' and move towards a more informed understanding of science, where scientists possess knowledge about the potential outcomes of their experiments. The study revealed that by year 10 (age 15 - 16 years) just over half of the pupils seemed to have moved away from the 'cartoon image' towards viewing science as a deliberate search for explanation.

There was a strong link between how the teacher related practical work with theory and the pupils' abandoning of the 'cartoon images'. The authors contend that the way in which teachers link practical work with understanding theory, is a significant contributing factor to the development of contemporary NoS conceptions among pupils. However, the authors concluded that few teachers seemed to be dealing with practical work in this way, and suggest that special strategies need to be employed and encouraged if pupils are to develop contemporary conceptions of NoS.

The studies discussed so far are predominantly concerned with post-primary and tertiary pupils. Primary school pupils' conceptions of NoS were explored in an in-depth study conducted by Driver, R., Leach, J., Millar R. & Scott, P. (1996) in the UK. The aim of this study was to elicit and describe the extent and characteristics of 180 school children's conceptions of NoS. The study focused on three features of the children's views of NoS; the purpose of scientific work, the nature and status of scientific knowledge and their understanding of science as a social enterprise (Solomon et al., 1996). Semi-structured interviews were conducted with 30 pairs of children in each of three different age groups (ages 9, 12 and 16 years). Six research probes were devised, which provided stimulus material and associated tasks, which were the focus of the interviews.

The findings revealed that the children typically characterised empirical testing as a simple process of observation, where resulting outcomes would be obvious. The fact that empirical testing may involve finding out mechanisms or testing theories was something of which the older children tended to be more aware. All students tended to exclude social phenomena from scientific inquiry, which generally included aspects of physics and biology. Many of the students believed the purpose of scientific work was the provision of solutions to technical problems rather than providing powerful explanations.

Driver et al. (1996) asserted that the younger children tended to draw on school experiences, whereas the older children tended to draw on a more diverse range of encounters. In relation to the characteristics of scientific work, many of the younger children referred to the stereotypical image of scientists and didn't distinguish between scientists' personal and professional interests. The authors noted that the stereotypical view of scientists was not prevalent among post-primary school students. It appears therefore that the primary aged children held less elaborate understanding of the nature of scientific work than the post-primary school children. This perhaps is due to the fact that they presumably had been given fewer opportunities to engage in scientific inquiry.

The ways in which the students perceived the nature and status of scientific knowledge varied. At a simple level the children depicted scientific inquiry as a process of making observations about the world. A more profound view, which was evident amongst the three age groups, was one that acknowledged scientific inquiry as involving the creation of generalisations from observations. The view of scientific inquiry encompassing the testing of models or theories was a view that was not commonly held by any of the age groups. The findings of the Driver et al. (1996) study again have implications for pre-service and in-service courses. If teachers were provided with conceptual and pedagogical knowledge of NoS they would be in a better position to facilitate pupils in developing elaborate conceptions of NoS. Furthermore, the findings have implications for curriculum developers. The primary children in this study revealed a more limited understanding of the nature of scientific inquiry than the older pupils. If primary curricula were to explicitly include aims relating to the development of NoS conceptions, primary children potentially could be afforded more opportunities to reflect on and develop more elaborate understandings of science.

In a similar manner to Aikenhead et al. (1987), the Driver et al. (1996) study also revealed that while the children believed scientists conduct investigations that are relevant to society, they did not seem to be aware of how society influences and prioritises various scientific research projects. That is they did not tend to elaborate on how society as a whole undertakes decisions. In general the children believed that scientists themselves choose to work on projects that were relevant and beneficial to society. Driver et al. (1996) suggest that the portrayal of science in the media and/or the way science is presented in school are potentially factors that contribute to the children's conceptions of science. The current emphasis in schools in the UK is on the learning of scientific knowledge and skills and the authors contend that teachers tend not to address issues regarding how scientific knowledge is generated. They suggest that issues relating to the nature of scientific inquiry and science as a social enterprise be explicitly addressed in primary science curricula in the UK.

Numerous interventions regarding the development of pupils' conceptions of NoS at post-primary and tertiary level have been explored and their effectiveness examined (Bloom, 1989; Loving, 1991; Abell & Smith, 1992; Matthews, 1998; Akerson et al., 1999, Murcia & Schibeci, 1999; Abd-El Khalick and Lederman 2000a; Lederman, et al., 2002; Craven et al., 2002). In contrast there is a scarcity of studies aimed at exploring the effectiveness of interventions on the development of NoS conceptions amongst primary school children (ages 4 - 12 years old).

One study that focused on the development of primary children's NoS conceptions was conducted by Carey and co-workers (1989) with 76 pupils, in five mixed ability Grade 7 (12 years old) classes in Boston, Massachusetts. The study aimed at exploring the effectiveness of a constructivist teaching unit specifically designed to develop these pupils' epistemological views of scientific knowledge and inquiry (NoS). A third of the pupils were interviewed at the beginning and end of the study in an effort to seek the pupils' conceptions of NoS prior to and after the intervention. The results revealed that the three week long NoS unit enabled the pupils to begin developing more contemporary NoS conceptions.

In the initial interviews the pupils perceived the role of scientists as one of endeavouring to discover facts about nature through observations and experiments (trying things out). The authors referred to this 'theory' of science as a 'copy theory' of knowledge, where knowledge is seen as an absolute copy of the world that is imparted to the knower when they experience the world (Carey et al., 1989, p527). In this view of the world, the only way scientists can be wrong is by being unaware or by overlooking a particular aspect of nature.

It was evident from the second interviews that the pupils had begun developing more elaborate conceptions about science in that many of them illustrated an understanding about the importance of questions and ideas in guiding scientific inquiries. Some of the students revealed understandings of the role of science as testing ideas in order to develop explanations. The authors, advocates of constructivist approaches in teaching science, also advocate the importance of affording pupils ample opportunities to reflect on the processes of developing scientific knowledge during school science.

Another study that explored younger children's NoS conceptions was conducted by Meichtry (1992) who considered the effectiveness of a new innovative science curriculum, aimed at developing students' understanding of the creative, developmental, testable and unified NoS. The study was conducted in the USA with 6^{th}, 7th and 8^{th} grade students (ages 11-14 years). The experimental group comprised 1004 students in one school who were taught science using the new programme and the control group comprising 603 students, who experienced a science curriculum that had been used in the district for 10 years. A pre and post-test using a modified version of the Nature of Scientific Knowledge Scale (NSKS) (Rubba, 1976) was administered to students in both groups. Results revealed a decreased understanding in the developmental and testable NoS amongst the experimental group. The control group showed a significant decrease in their understanding of the creative NoS. In addition to this the control group possessed significantly better comprehension of the testable NoS than those in the experimental group. These results indicated a move towards more 'traditional' NoS conceptions amongst children in both test and control groups.

One thing the findings of this study revealed was that simply utilising an innovative science programme, that aims at developing students' NoS conceptions did not automatically result in the development of the pupils' NoS conceptions. Meichtry advised that in order to enable the development of students' NoS conceptions, all aspects of NoS be explicitly represented in curricula and that teachers be provided with instructional methodology on NoS. The conceptual and procedural learning that the children are experiencing in schools must be directly related to the various aspects of NoS as one cannot assume that the children will make the various connections themselves. Meichtry suggests that special strategies need to be employed and encouraged if pupils are to develop contemporary conceptions of NoS.

Other suggestions put forward by Meichtry (1999) were that curriculum materials used in schools explicitly relate school science to the various aspects of NoS. In addition she contends that children's ideas be the starting point for science lessons and that teachers assess their students' ideas and then design instructional strategies to help students modify and develop their ideas. The development of conceptions regarding the creative, developmental, testable and unified aspects of NoS requires complex and abstract thinking and reasoning on the part of the student. Using individual or group interviews in addition to the MNSKS (Modified Nature of Scientific Knowledge Scale) paper tests may have provided more informed, detailed and perhaps more accurate accounts of the pupils' understanding of these tenets of NoS.

The history of science is an important aspect of the nature of science as science is tentative and developmental. Studies have indicated that incorporating

HoS in science class enhances student's conceptions of NoS (Klopfer and Cooley, 1963; Klopfer, 1969; Lederman, 1998; Khisfe and Abd-El Khalick, 2002; Clough, 2006). Klopfer (1969) contends that history enriches an understanding of contemporary events and issues and therefore the history of science enables students to acquire a better understanding of science. He warns however that casual references to scientists' names, years they were born and died and their major inventions will not provide students with the valuable insights into science that the history of science can provide. He maintains that teachers need to plan carefully how they are going to utilise and include history of science material in their science lessons and suggests a number of teaching strategies that could be employed to incorporate HoS into the science class. These included; case study approaches, utilising supplementary reading on biographies of scientists followed by teacher guided classroom discussion, providing students with scientists' original research papers to analyse and discuss and using an historical approach that would provide the framework for a science unit (Klopfer, 1969).

In a similar manner to Klopfer, Lederman, (1998), Khisfe and Abd-El Khalick, (2002) and Clough, (2006) also contend that students do not learn about NoS aspects by the inclusion of historical episodes in their science classes alone or by casual references to them by their teachers. Students can read short vignettes regarding different landmarks and figures in the history of science that relate to aspects of NoS. However, it is rare for such descriptions, often found in science textbooks, to specifically refer to NoS. It is essential therefore, that the multiple aspects of NoS are accompanied by explicit discussions of the tenet in question rather than assuming that the students have acquired an understanding of the connection. If students are not given the chance to link the historical vignette with the NoS aspect explicitly, while they may find it interesting, they may not necessarily make the connection between it and NoS (Tao, 2003; Mc Comas, 2007).

Huann-Shyang, Jui-ying and Su-chu (2002) conducted a yearlong study with two eighth grade classes (74 students) in Taiwan. The aim of the study was to establish the effectiveness of integrating history into science teaching. The study focused on students' qualitative understanding and application of scientific concepts. The same teacher taught the two classes for an equal amount of time. The teacher used the science textbook as her main reference for one class (control group) and a pack of historical-rich supplementary material as her main reference with the other group (test group). The findings indicated that the employment of a variety of teaching strategies results in improved teacher - student and student -student interactions and increased student motivation amongst the test group. Huann-Shyang et al. (2002) also asserted that this type of approach enabled students to make sense of scientific conceptions, particularly when the activities were related to a scientist's previous experiment. While the authors concluded that the HoS had the ability to enhance students' problem - solving abilities, they noted that a short time of intervention of this approach might not be effective in student achievement in science. It was strongly recommended continuing intervention or implementation of at least two historical cases in a row.

Teaching science through story is another approach that has been used to address issues regarding NoS (Bybee et al., 1991; Solomon et al., 1992; Tao, 2003). Tao (2003) reports on the effectiveness of using story to teach about NoS. She conducted a study in Hong Kong with 36 science students in their first year of post-primary school and investigated how these students reacted to a selection of stories relating to NoS and whether they were able to draw out tenets of NoS that were presented in them.

A number of interesting findings emerged from Tao's study. Firstly, it revealed that some students had interpreted the science stories as portraying new scientific discoveries rather than outlining the process of discovery, where scientists test their hypotheses through experimenting. Secondly, many students asserted that scientists carry out experiments to test their ideas but many of them claimed that scientists did not know what might happen prior to their experiments. Solomon et al. (1992) refer to this as 'serendipitous empiricism' or 'shot in the dark' attitudes towards experiments. Tao's students believed that if scientists conducted experiments carefully and accurately unexpected results would automatically be obtained. Thirdly many of the students recalled aspects of creativity and imagination and their role in scientific discoveries when discussing the stories. The findings of the Tao study therefore revealed views that accorded with both contemporary and traditional understandings of NoS.

Tao asserts that while using story to explicitly address NoS issues is a beneficial process, teacher intervention is crucial. During dyad discussions the students tended to pay more attention to the aspects of NoS that were in keeping with their own (often inadequate) views. With little teacher intervention, this approach, according to Tao, had a tendency to confirm and reinforce both adequate and inadequate NoS conceptions amongst the students. Tao acknowledges that a teacher's role in scaffolding and guiding pupils' perceptions is therefore paramount. Whole class discussion, question and answer sessions should be an integral part of the lesson, after the pupils have read and discussed a story. It would therefore appear that while the use of historical stories is a useful tool to facilitate students in considering, reflecting on and discussing NoS issues, the teacher's role is crucial in monitoring and guiding discussions.

The impact of historical stories on children's enjoyment of school science was evident in Tao's (2003) study. With teacher intervention stories can provide students with numerous opportunities to conflict and co-construct adequate and inadequate NoS views during discussions. Discussing historical stories can provide students with the opportunity to draw on prior knowledge and experiences and to defend arguments. Driver and co-workers (1996) assert that this process of arguing is a core activity of the scientific community and aids in the creation, validation and refutation of scientific knowledge.

The Science Curriculum (DES, 1999a) outlines the importance language plays in science class and maintains that affording children opportunities to discuss and reflect on scientific investigations helps them develop their understandings of scientific knowledge and inquiry. The curriculum recommends that language should be an integral part of teaching and learning science and should be included in planning and implementing the curriculum (DES, 1999a).

In order for children to develop elaborate conceptions of NoS and to begin developing their own philosophies about NoS, they need to be provided with opportunities to consider and to reflect on various scientific ideas. Children therefore need to be afforded time for thinking and reflection during science class. Regardless of the level of question being posed in a primary class, it is vital that teachers provide time for the students to reflect. This is one possible starting point for the introduction of PoS in the primary classroom. Children should be given time to ask questions, time to reflect on and discuss various issues as according to Donnelly (2004), they combine imaginative and rational thinking in order to understand.

Donnelly discusses a process called ' thinking time[1]' which involves children as young as four years of age doing philosophy in school. In this process various questions are discussed in the pursuit of answers. Donnelly suggests that children are not only capable of but are interested in reflecting on and discussing philosophical questions. Primary children therefore could begin philosophising about NoS when learning science. However, there is no need to overwhelm primary children with difficult philosophical questions about NoS (Matthews, 1994). Initially they could be given the opportunity to answer basic questions about NoS (for example: How does the sun know it's morning? Where does the tide go?) As they become more familiar with reflecting and discussing NoS, more abstract and thought provoking questions could be discussed (for example: What do think an investigation is? Do you think the results of an investigation will always be the same? Do you think different groups might come up with different conclusions to your investigation? Why / why not?).

Some of children's scientific ideas regarding light and vision are similar to the ideas of pre-scientific philosophers (Selly, 1996). Plato, for example, discussed the notion of light being reflected from the eye and the inability of this visual ray to permeate total darkness. If children were given the opportunity to see how a particular concept in science has developed over the course of history of science, and afforded time to reflect on their own 'inaccurate' ideas, they might begin to move towards accepting the more advanced models and explanations that are accepted

[1] Thinking Time: The children and teacher sit in a circle with no designated places. The child opening the discussion makes his/her statement and then tips the child next to him/ her. If this child wishes to speak she/ he does so, and then tips the next child, if not she/ he passes on the tip. This continues with the teacher participating when the tip comes to him/ her. When it is the teacher's turn to speak she/ he can model dialogical languages such as 'I agree with... I disagree with...' etc. In speaking children become conscious of their own minds and learn that there can be many answers to a question. The Thinking Time session ends with a final tip around when the children can make a final statement on what has been discussed, maybe attempt to offer an answer to the question on which the conversation was based or maybe offer a definition. There is no one conclusion accepted above another nor is there a vote for or against. All thoughts and ideas have been accepted and are left to further internal reflection.

today (Huann-shyang et al., 2002). Pupils whose teachers provide them with opportunities to engage in discussion, role-play, debates and hands-on activities, are more likely to construct their own understandings as opposed to those pupils who are compelled to memorise facts.

A number of studies have explored pupils' language and reasoning skills in science. Kuhn et al. (1988) for example conducted a large-scale study in the UK, with several hundred participants ranging in ages from 10 years to adult. The study also included a group of philosophy graduates, which was deemed 'expert' in co-ordinating theory and evidence. The research revealed that pupils under the age of 12 experienced difficulties with all types of reasoning involved; however, their reasoning skills developed, as they got older. Many students of all ages interpreted data sets in different ways with regard to theories they supported and those they rejected. Kuhn and colleagues (1988) maintain that pupils need to apply a set of general thinking skills to come to better understandings of the relationship between theory and evidence and that these general thinking skills develop with age.

Samarapungavan (1992) does not support Kuhn and colleagues' (1988) claim that general thinking skills that facilitate students to equate theory and evidence develop. Rather she contends that these thinking skills come about as a result of a pupil's understanding of a concept in a particular context. Samarapungavan's (1992) US study, explored the ability of 150 elementary students (6-11years) to apply four criteria in a number of experimental tasks. The four criteria were: range of explanation, non-ad hocness, inconsistency with empirical evidence, and logical consistency. In the experimental tasks the children were initially shown a set of observations and were then given two different explanations that attempted explaining the observations. The children were asked which explanation they agreed with and why. The findings revealed that 85-90 percent of the children were able to make and explain theory choices in relation to the four criteria. Samarapungavan therefore maintained that students' development of reasoning skills came about as a result of understanding a concept in a particular context rather than age as suggested by Kuhn et al. (1988). However, Samarapungavan cautions that simply displaying the ability to select the better of two theories using the four criteria does not necessarily mean that children will effectively use the criteria when learning science.

While heeding Samarapungavan's warning about the children's ability to effectively use criteria when learning science, it would still appear from her study that these young children illustrated an ability to reflect on and consider a number of scientific ideas equating theory and evidence. This appears to illustrate their ability to consider and philosophise about ideas relating to NoS. The findings of this study are therefore informative in terms of the ability of primary pupils to reflect on and consider scientific ideas and in terms of the benefits of reflection in the development of elaborate NoS understanding.

2.10.1 Implicat ions

Many of the studies explored in this section reported naïve or inadequate conceptions amongst the pupil samples at the beginning of the studies. This fact in itself is quite worrying given the importance the literature has placed on the development of NoS conceptions over the past fifty years. However, many of the studies have produced positive results, where pupils have begun to move towards more elaborate and contemporary conceptions of science as a result of the various interventions. The research indicates that utilising explicit approaches in addressing different aspects of NoS, including the historical, sociological and philosophical aspects of science have been successful in developing more elaborate conceptions of NoS. It would therefore appear that if international curriculum documents were to explicitly include the development of NoS conceptions amongst their general aims and objectives, teachers and pupils would benefit. This issue will be considered in the following section.

2.11 Nature of Science in Curricula

While the importance of contemporary NoS conceptions has been highlighted in research, there still appears to be a continuous pattern of non-uptake of this aspect of science in school curricula (Bell et al., 1995; Hipkins, Barker and Bolstad, 2005; Rennie, Goodrum and Hackling, 2001). So why is there a persistent lack of uptake of NoS in science courses? Some studies blame the content dominated curriculum at tertiary level (Kouldaidis and Dimpooulos, 2002). Others suggest that beginning teachers who might like to implement innovative teaching methodologies, are influenced by or have to copy approaches and curricula of their more experienced teachers who are not employing innovative approaches (White, 2003). Matthews (1995) maintains that the national assessment tests administered in England and Australia do not include test items that specifically assess NoS. He suggests that teachers are possibly teaching to the 'test' and that if 'it' were not on the tests, teachers would not teach 'it'.

Hodson (1988) referred to a report published in 1971, by the Association of Science Education (ASE) in England which stated that:

> most science teachers, who are themselves products of a science education that places a light premium on scientific knowledge and pays lip service to the history and philosophy of science, share with many practising scientists a scant understanding of the nature of scientific knowledge itself (ASE, 1971, cited in Hodson, 1988, p.21).

Another worrying assertion made by Hodson (1988) was that he maintained that the only conclusion one could draw about the success of implementing current curricula is that ' some teachers are successful in achieving some of the goals using some of these curricula, with some children.' (p.20). Hodson (1988) also asserted that there appeared to be two main factors that were contributing to science courses not achieving their intended aims of developing students' conceptions of NoS. These were:

1. Teachers' own inadequate views about NoS

2. A degree of confusion in the philosophical stance implicit in many contemporary science curricula (1988, p.20).

Research has shown that even when NoS strands and objectives are explicitly mentioned in curriculum documents, this does not automatically mean that they will be addressed in science classes and the 'actual' curricula being taught could be quite different from the 'intended' curriculum. (Rennie, Goodrum, & Hackling, 2001; Hipkins, 2005; Loveless and Barker, 2000; Mc Gee et al., 2003).

Rennie et al. (2001), for example, conducted a large-scale study that investigated the quality of learning science in Australian primary and post-primary schools. The aim of the research was threefold. Firstly, they described the ideal practice in the teaching and learning of school science, secondly they described the actual nature of the teaching of science in the schools and thirdly, they gave recommendations to move what was actually happening in Australian schools to what ideally should be happening. Their findings revealed that in general the actual curriculum being taught in most Australian schools was different from what is outlined in the intended curriculum frameworks. The intended curriculum focused on the development of scientific literacy and facilitating students in their progression towards achieving the outcomes presented in the curriculum documents. The results of this study revealed different findings for primary and post-primary teachers and students. The results regarding the primary sector are outlined below.

Rennie and co-workers (2001) found that where science was taught in primary schools it was generally taught in a child-centred manner with hands-on activities. The students were provided with the opportunity to conduct investigations. In general in these schools, there were high levels of pupil satisfaction. Student responses indicated that group work and discussion were common activities. However, it appeared from the Rennie et al. study that science in primary schools tended to be predominantly classroom-based. For example, one-third of students commented on the fact that they never went on science trips, 50 percent said they never visited zoos or museums while 6 percent revealed they never had science speakers in to talk to them about science. These findings were corroborated by the data obtained from the teachers.

Hipkins et al. (2005) conducted a detailed review of the New Zealand research literature in an effort to ascertain some of the factors that seemed to be inhibiting successful implementation of NoS learning within Science in the New Zealand Curriculum (Ministry of Education, 1993). Hipkins and co-workers refer to the Wellington (1998) study. Wellington (1998) asserted that despite 'Making Sense of the NoS and its Relationship to Technology' being one of two integrating strands in the science curriculum, the framework places considerable attention on 'fair testing' and does not provide a clear definition or description of what the NoS actually entails. Wellington contends that this is one challenge leading to the lack of uptake of NoS teaching in primary schools. Hipkins et al. (2005) noted that with the exception of McKinley (1997) there has been no New Zealand publication that has attempted to provide clarification regarding the conceptions of NoS that should be addressed and developed as part of the New Zealand Curriculum Framework.

Another study was undertaken in New Zealand by Bell and co-workers (1995), who conducted a substantial review of Science in the New Zealand Curriculum. This review indicated that additional curriculum development and teacher professional development would be required to facilitate teachers in the successful integration of 'the making sense of the NoS and its relationship to technology' strand with the other strands (Bell et al., 1995, p. 90). Baker's (1999) large scale-study established primary and post-primary school teachers' views about science in the New Zealand Curriculum. He discovered that a large number of these teachers found it difficult to understand what the 'Making sense of the Nature of Science and its Relationship to Technology' strand entailed. Baker also maintained that some of these teachers were omitting this strand because they believed it was overlapping with the technology curriculum. Loveless and Barker's (2000) study reported that the 'Making sense of the Nature of Science and its Relationship to Technology' strand became the pages teachers turned over. Another survey conducted in New Zealand with over 900 primary and post-primary school teachers found that over two-thirds of these teachers believed that there was inadequate information in the curriculum documents regarding the implementation of the Making sense of the Nature of Science and its Relationship to Technology (Mc Gee et al., 2003).

Hipkins et al. (2005) found that despite the recent developments in science education and curriculum development, there still appeared to be a lack of teachers' personal philosophies of NoS, lack of pedagogical content knowledge and classroom constraints that were still impeding the development of NoS conceptions in New Zealand. They maintained that pre-service and in-service courses aimed at developing teachers' personal philosophies and pedagogical knowledge of NoS could improve the extent to which teachers explicitly address NoS as an integral component in primary science. Bell and co-workers' (1995) review of science in the

New Zealand Curriculum also indicated that additional curriculum and professional development would be required to facilitate teachers in successfully integrating 'the Making Sense of the NoS and its Relationship to Technology' strand with the other strands (Bell et al., 1995, p. 90).

The findings of the New Zealand research literature appear to imply that even though the development of NoS conceptions is one of two integrating curriculum strands, this strand in general is not being implemented fully. The science content knowledge appears to be dominating science teaching and often its importance is highlighted by the assessment procedures (Hipkins et al., 2005). Gilbert (2003) contends that in order for appropriate curriculum change in science that reflects the importance of the development of contemporary NoS conceptions is to be achieved, the importance of what is presently seen as 'peripheral' in curricula needs to be emphasised. He maintains that less emphasis should be placed on the acquisition of science content knowledge, which currently appears to be receiving most attention. White (2003) agrees with Gilbert (2003) but argues that these changes for the development of more elaborate NoS conceptions should be in keeping with the practical realities of the classroom. Hipkins et al. (2005) suggest that reducing curriculum content in many cases would ease the strain of 'coverage' of various curricula. In addition they suggest that long-term sustained classroom research, that investigates how students' learning is progressing and what beliefs teachers' hold regarding the nature and characteristic of science and the purpose of science education is needed. They also suggest that strategies for teaching about NoS are required and assessment of the impact of pedagogies on students' perceptions and beliefs about science and on the engagement and achievement of all students should be conducted. Hipkins et al. (2005) made these recommendations in light of a review of the New Zealand science curriculum.

Lederman (1998), suggests that perhaps the misunderstanding that NoS and scientific inquiry are perceived as 'affective' objectives rather than 'cognitive' objectives that address the acquisition of subject matter is the reason for the lack of uptake of NoS in schools. He asserts that NoS and scientific inquiry objectives should be considered as subject matter. However, in general, objectives regarding NoS tend to provide context to the subject matter being addressed. If national and international assessment tools explicitly assessed conceptions of NoS, curriculum documents would then be wise to explicitly include NoS amongst the aims. Teachers may be more inclined to teach NoS if it were explicitly addressed in curriculum documents and if it were explicitly assessed. Prior to considering these recommendations in relation to primary science in the Republic of Ireland a brief overview of the critical developments of primary science education in Ireland will be presented.

2.12 Critical Developments in Primary Science Education in Ireland

Prior to the beginning of the 20th century primary science was included as an optional extra subject on the Irish primary curriculum. After the outbreak of the First World War in 1914, science was introduced in schools as 'Rural Science and School Gardening', to encourage the production of fruit and vegetables during the war. The Board of Commissioners supplied equipment to those schools that were willing to teach this subject in their schools. In 1922 however, science was taken off the curriculum as a compulsory subject, in order to 'raise the status of the Irish language' (Matthews 1992, p. 6.). ' Rural science' was re-introduced into the curriculum as a compulsory subject in 1926, to certain types of school. Guidelines issued by the then Department of Education suggested that rural science should ' appeal to the senses and thereby develop habits of careful observation, enquiry and clear thought', (Matthews, 1992, p. 6-7) and that the effectiveness of the instruction should be judged ' less by the amount of acquired knowledge than by the success of the teaching in arousing the children's curiosity and in stimulating their interests in the facts of nature' (Matthews, 1992, p.7).

Although science was recognised as an important component in the primary curriculum it was not until the 1971 curriculum that Social and Environmental Studies became a compulsory subject in the Irish primary curriculum. Elementary science was a component of this programme for fifth and sixth classes. Unfortunately the science element was overlooked in most schools (Matthews, 1992). A survey conducted by the Irish National Teachers Organisation (INTO) in 1987 indicated that although 87 percent of primary teachers questioned had a nature table in their classrooms, only 31 percent involved their pupils in conducting science experiments (INTO, 1987). In 1990 the National Council for Curriculum and Assessment's (NCCA) review of the 1971 curriculum also revealed that there was a lack of emphasis on basic science in the middle and senior classes and an apparent lack of confidence amongst teachers regarding teaching science (NCCA, 1990). The NCCA (1990) and INTO (1987) reports both recommended the provision of in-service courses in science to facilitate teachers in implementing new science programmes, 'the transmission of new science programmes will have only minimal impact unless they are accompanied by a genuine commitment to provide in-service education for all teachers' (INTO, 1992, p.46). In addition to this the INTO report also recommended that a nationwide programme of in-service education be established prior to the implementation of any new science curriculum. The International Assessment of Educational Progress (IAEP, 1988) report revealed that Irish children aged 9 and 13 years performed less well in science-related activities than their counterparts in other countries and that Irish girls had the lowest average science proficiency score of any group involved in the survey. This was largely to do with the neglect of science in primary schools. At the time this report also recognised the inadequacies of the 1971 curriculum and that teachers lacked confidence in teaching science.

During the period known as the ' Celtic tiger' that occurred in Ireland during the 1990s many economic, social, political and technological changes transpired (O' Rourke, 2001). There were concerns in Ireland regarding the decline in the number of students taking science at post-primary and tertiary level (Childs 1995, 2006). A number of initiatives were undertaken to address this apparent decline in interest in science. In 2000, for example, the Department of Education and Science established a Task Force on the Physical Sciences. Amongst the recommendations made by the Task Force regarding primary science in the 2002 report were: providing support for school science planning at local level; increased funding to support planning; the provision of science resources in schools; improving the quality of science teaching, including in-career development for teachers, and, the establishment of an integrated national science awareness programme (Task Force on the Physical Sciences, 2002).

Curricula at all levels were reviewed and developed, and aimed at providing students with the skills and knowledge to become scientifically informed citizens. At primary level the revised Primary Curriculum and Curriculum Guidelines (DES, 1999a, 1999b) were published, and 'science' was included as a subject in its own right. This science curriculum aimed at improving the level of achievement in science and science related activities amongst Irish primary school children. The revised primary science curriculum does not explicitly address the development of NoS conceptions amongst its general aims and objectives. With the introduction of the revised primary science curriculum, the Department of Education and Science (DES) provided a number of supports for teachers. These included provision of grants to schools for science resources and equipment, and the provision of summer courses for primary teachers in science. The DES also set up the Primary Curriculum Support Programme (PCSP), which initially provided teachers with in-service courses in planning and teaching the science curriculum. Support for primary teachers from the PCSP is still ongoing today and provides teachers with ideas and support in planning and implementing the science curriculum.

Forfás is a government-funded organisation with the responsibility for managing the development of science and technology on behalf of the DES. In 2002, Forfás introduced a pilot programme of *'primary science clubs'* throughout primary schools in Ireland. The aim of the science clubs was to introduce primary children to science in a fun and hands-on way by means of engaging in a number of science activities as part of the 'club' over the course of a number of weeks. The 'primary science clubs' initiative has developed considerably since 2002 and 3,652 schools from all over Ireland took part in this initiative in the 2007/2008 school year (http://www.primaryscience.ie/site/about_background.php)

Numerous other initiatives aimed at increasing interest in science amongst primary children have also been developed in Ireland. These include:

- 'The K'NEX Challenge', devised by Steps to Engineering, which is, aimed at providing primary school children with an introduction to the world of engineering and design. The pupils taking part in the challenge work in teams to design and build a model using K'NEX kits. (http://www.steps.ie/Knex.htm)

- The Science Bus: a fully interactive mobile science laboratory devised by the Irish Centre for Talented Youth (CTYI) in DCU. The bus aims at providing primary children with the opportunity to engage in fun hands-on activities in science (http://www.dcu.ie/alumni/winter02/news3.html).

- Eureka, a weekly primary science magazine, which has been published for the past four years by The Irish Independent Newspaper. The magazine addresses aspects of each Primary Science Curriculum strand during the year. In the current academic year 2007-2008, 20,000 primary school pupils from all over Ireland have subscribed to Eureka through their schools.

In 2005 the NCCA and DES conducted a review of the Revised Curriculum (DES, 1999a). This review focused on the implementation of the English, Visual Arts and Mathematics curricula (DES, 2005 and NCCA, 2005). Science is one of three curriculum subjects under review in the second phase. The interim report on the first phase of the science review reported on teachers' experiences of the revised Science Curriculum (NCCA, 2007). Although over 95 percent of the 1,380 respondents reported using hands-on activities either sometimes or frequently, the findings indicated that the teachers in general found the hands-on collaborative learning aspect of the science curriculum to be challenging. The teachers also indicated that they were concerned with issues regarding assessment, namely determining whether, to what extent and to what extent their pupils had grasped or understood the scientific concepts and skills that had been taught. The second part of the science review is focusing on the children's experiences of the Science Curriculum and is due to be published in Spring/ Summer 2008. As mentioned earlier, NoS is not explicitly addressed in the revised science curriculum. Nor is NoS explicitly addressed in the first phase of the science curriculum review. Although the K'NEX challenge aims at showing pupils the links between science and engineering, the other initiatives (primary science clubs and the science bus) do not explicitly address NoS issues with the pupils.

2.13 Conclusions

This literature review chapter opened with an overview of the development of some of the philosophical arguments regarding NoS and their relevance to science education. The literature relating to the importance of primary teachers and their pupils' holding elaborate conceptions of NoS was discussed and the effectiveness of explicit rather than implicit methods in developing teachers and primary pupils' NoS conceptions considered. The literature relating to the uptake of NoS in international curricula was considered and a short overview of some of the critical developments in primary science education in Ireland was provided. Some of the benefits of contemporary NoS conceptions outlined in the research include increased interest and enjoyment of science and better understanding of scientific concepts and skills.

The literature reviewed in this chapter has revealed numerous benefits of explicitly teaching about NoS. These include humanising science for pupils, making it more interesting for them to learn and making science concepts and skills easier for pupils to learn to learn (Matthews, 1994). In Ireland today there is considerable concern regarding the lack of interest in science at second and third level (OECD, 2002). If pupils were to be given the opportunity to develop more contemporary NoS conceptions, they may become more interested in science, perhaps leading them to pursue science beyond the point of choice. It is also evident from the literature reviewed that while the development of post-primary and tertiary pupils' NoS conceptions has been examined, there appears, however, to be a paucity of international studies regarding the development of primary children's NoS conceptions. There also appears to be a paucity of studies that 'follow through' from pre-service primary teacher education courses to the impact on primary pupils; many of the studies reviewed tended to explore one or the other.

The current study is therefore timely. It endeavours to explore and explicitly develop Irish pre-service teachers' conceptions of NoS and to investigate the extent to which these pre-service teachers explicitly teach about NoS in their initial teaching year. It also endeavoured to establish whether explicitly teaching NoS affected beginning teachers' approaches to and confidence in teaching science and the effects of explicit approaches on primary pupils' NoS conceptions and their perceptions of school science. The means by which the evidence to address these issues was gathered and analysed is provided in the next chapter.

3 METHODOLOGY

3.1 Overview of Chapter

In this chapter an overview of the theoretical perspectives that inform this study and that were utilised to address the research questions is provided (Table 3.1). A fixed research design, with a set of predetermined research questions was employed and qualitative and quantitative methods of data collection and analysis were largely utilised throughout. A mixed methods design (Johnson and Onwuegbuzie 2004) was utilised in that the researcher drew from a mixture of qualitative and quantitative strategies and methods. A detailed discussion surrounding the research methodologies employed to gather and analyse the data is presented in this chapter. The position of the researcher within the study is explored and issues regarding quality assurance are considered in-depth. Ethical issues arising as a result of utlising qualitative methods are considered and limitations acknowledged.

3.2 Aims of the Research

The aims of the research were to explore the effectiveness of explicit methods in developing Irish primary teachers' NoS conceptions and to investigate the effectiveness of their translation into practice. There were four phases in the study. The first phase explored pre-service teachers' conceptions of NoS and the effectiveness of explicit methods in the development of more contemporary conceptions. The extent to which these pre-service teachers planned for and explicitly taught about aspects of NoS during their final teaching practice was established in the second phase. The second phase also sought to establish whether utilising explicit approaches to teaching NoS affected these pre-service teachers' perceptions of teaching science. The third phase ascertained the extent to which beginning teachers plan for and explicitly address aspects of NoS in their initial teaching year. This phase also explored whether explicitly teaching NoS affected beginning teachers' perceptions of and approaches to teaching science. The development of Irish primary children's conceptions of NoS was also considered in the third phase as were the effects of explicit approaches to NoS on primary children's reflections on school science. The fourth phase comprised a content analysis of primary science curriculum documents from seven countries/ states and a content analysis of two international science assessment tools. The aim of the content analyses was to establish the extent to which NoS was explicitly addressed in the curriculum documents and assessment tools.

3.3 Theoretical Framework

Two main positions that frame understandings of research are positivism and phenomenology (Maykut and Morehouse 1994). Positivism has evolved to mean objective explorations, that are grounded in measurable variables and conjectures that are easily verified. Explanations, predications and proof are pivotal in positivism (Kincheloe, 1991). Quantitative research falls under the positivistic position.

Phenomenology is one of many labels utilised to indicate the current position of qualitative research. However, it is also commonly called 'constructivism' (Robson 2002), 'interpretive' (Schwandt, 1994) or 'naturalistic' (Lincoln and Guba, 1985). Denscombe (2003) compares the phenomenological tradition with the positivist one by asserting that it emphasises subjectivity over objectivity, description rather than analysis, interpretation rather than the measurement of data and autonomy rather than structure. Phenomenology deals with perceptions or meanings, attitudes and beliefs, and feelings and emotions (Denscombe 2003). Maykut and Morehouse (1994) assert that qualitative studies ascertain what can be discovered about a particular occurrence of interest, especially social occurrences where people are the participants. In qualitative research the participants' words and actions are examined. The qualitative researcher then presents a descriptive account that depicts the participant's perspective and experiences (Maykut and Morehouse, 1994). Qualitative research focuses on natural settings and emphasises the importance of "understanding things from the point of view of those involved" (Denscombe, 2003, p.69).

Lincoln and Guba (1985) consider how qualitative and quantitative researchers approach questions in different ways. For instance they assert that in qualitative research the knower and the known are interconnected and therefore the thoughts of the qualitative researcher are enveloped in the research. Qualitative research by its nature therefore can never be truly objective. This is in comparison to quantitative research where the knower can be separated from the known and objectivity is conceivable. Lincoln and Guba (1985) also compare qualitative and quantitative research in terms of generalisation in that they assert that in qualitative research only tentative explanations can be made for a particular time and place. The qualitative researcher therefore tends not to generalise, rather places an importance on understanding particular phenomena in all their complexity and within a given situation. In quantitative research generalisations are possible, explanations from one situation can be generalised and utilised in another situation. Lincoln and Guba (1985) also compare quantitative and qualitative methods in terms of verification. They contend that unlike the positivist approach, which endeavours to prove proposals, qualitative researchers tend to aim at revealing positions through observation and cautious examination of patterns that emanate from the data. Although qualitative researchers may create hypotheses, they tend to be unsure of what they are seeking prior to conducting their research.

In social science there has been a long debate regarding the nature of inquiry. On the one hand, those supporting positivistic approaches assumed more objective and quantitative positions and largely concentrated on the verification of theories. On the other hand those supporting more 'constructivist' or 'naturalistic' approaches tended to assume more subjective, descriptive and interpretive positions and handled data that were not quantifiable (Robson, 1993). However, in recent years many social scientific researchers have begun supporting the concept of pragmatism as a suitable paradigm for mixed methods research (Patton, 1991; Johnson and Onwuegbuzie, 2004). Robson (1993) defines pragmatism as ' an approach which makes practical consequences the test of truth. It seeks solutions demanded by the problems presented by a particular situation' (p. 550). A pragmatic epistemology embraces aspects from both positivist and phenomenological epistemologies. This study assumed a pragmatic epistemological framework in that it handled data that were objective and quantifiable. It also verified a theory, namely the effectiveness of explicit approaches in developing contemporary NoS conceptions.

From the constructivist or phenomenological position the study utilised more subjective qualitative data that could not be quantified, but which provided greater depth to the study. The study also assumed an exploratory focus, which permitted unexpected patterns and relationships to be revealed in the data.

The current study utilised mixed methods research, in that the researcher drew on strategies and methods from both quantitative and qualitative positions in an effort to address the research questions. Johnson and Onwuegbuzie define mixed methods research as:

> The class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study (2003, p.17).

Johnson and Turner (2003) assert that a fundamental principle of mixed research is that researchers collect multiple data using many strategies, approaches and methods in such a way that the combination is likely to result in complementary strengths and non-overlapping weaknesses. A fixed quasi-experimental design strategy that employed qualitative and quantitative methods of data collection and analysis was utilised in the current study. Purposive and convenience sampling rather than randomised control type sampling (RCT) was utilised, therefore employing a quasi-experimental rather than an experimental design. Fixed quasi-experimental design strategies are generally associated with positivistic research. However, in this study the nature of the questions being investigated required in-depth accounts of what the participants' NoS conceptions and perceptions of teaching and learning science in the classroom. With the exception of one section in the children's questionnaire, administered during phase three and the content analysis conducted during phase four of the study, qualitative methods of data collection were utlised. However, the data were analysed using both quantitative and qualitative methods.

In keeping with the positivistic tradition on the one hand, the current study adopted a fixed research design. That is the design was pre-specified before the data were collected. The 'intervention' conducted during phases one and two was piloted, as were the questionnaires and interviews that were utilsed during phases one and three. The piloting of the various instruments and methods will be discussed in more detail later. Fixed designs are theory driven and therefore investigators are required to have a reasonably articulated theory of the phenomenon they are researching. In the literature review (chapter two) of this thesis, a detailed account of the literature and ideas regarding the effectiveness of explicit approaches to teaching about NoS was provided. In the review numerous studies and ideas or theories regarding the effectiveness of explicit over implicit approaches were presented and analysed. The ideas and arguments put forward in the literature review provided an in-depth background of the different aspects of NoS and were informative in terms of the effectiveness of explicit approaches.

While the fixed design utilised was primarily a confirmatory task, that is establishing that explicit approaches were effective in developing NoS conceptions, the design also assumed an element of exploratory focus. The exploratory analysis of the data permitted unexpected patterns and relationships that appeared in the data to be revealed and potentially provide the basis for follow-up research. In this way the study was more in keeping with qualitative approaches. It may appear unusual that a study that utilises a fixed research design would utilise qualitative methods of data collection and analysis. However, as outlined in the literature review chapter, issues surrounding descriptions and understandings of NoS are philosophical and subjective and therefore qualitative methods of data collection and analysis were more suited to establish more in-depth understandings of the participants' NoS conceptions.

Fixed designs are generally concerned with group properties and tend to focus on the general rather than the specific (Robson 1993). In the traditional sense experiments are reported in terms of group averages rather than individual achievements. One weakness of fixed research designs cited by Robson (1993) is their inability to apprehend the subtleties and complexities of individual behaviour, as numerical data are typically collected. In this study while the focus of inquiry was to establish the effectiveness of the intervention (cause) on NoS conceptions (effect), data that focused on people's words and meanings were required. Qualitative methods of data collection and analysis that were dependent on participants' words and meanings were sought and therefore largely utilised.

As mentioned earlier, the study had an exploratory and descriptive focus and deeper understandings of the participants' multiple conceptions, perceptions, attitudes and experiences regarding NoS and teaching science were sought, outlined and interpreted. Again, for this reason qualitative research methods of data collection were generally used. In-depth analysis of people's conceptions of NoS and experiences of explicitly learning about and teaching NoS was therefore possible. It is worth noting that Robson (1993) contends that although phenomena in fixed research designs are typically quantified this is not an essential feature. He asserts 'there is no reason in principle for particular fixed design studies to be linked to specific data collection technique. Non-experimental surveys could well be carried out using observation, the effect of an experiment assessed through questionnaire responses' (p. 93). In a similar manner Oakely (2000) asserts that 'there is nothing intrinsic to fixed designs that rules out qualitative methods or data' (p. 306).

A quasi-experimental strategy approach was used to investigate the research questions, namely the effectiveness of explicit approaches in the development of NoS conceptions. Typically, an experimental strategy is associated with positivistic (quantitative) research. However, in this study while an experimental strategy was utilised, both qualitative and quantitative methods of data collection and analysis were employed. Robson (1993) outlines the central features of an experimental strategy:

> The researcher actively and deliberately introduces some form of change in the situation, circumstances or experience of participation with a view to producing a resultant change in their behaviour (p. 88).

Spector (1981) asserts that 'experiments' occur when the subjects (people or social systems) and conditions (events or situations) to be studied are manipulated by the investigator (p. 7). To 'experiment' or to conduct an experiment in general terms is concerned with trying something new and seeing what happens. In an experiment there is a change in something and the experimenter measures the effects this change has on something else. When an experimental strategy is utilised, the design details are pre-specified prior to data collection and piloting of research instruments and strategies is vital, to establish the feasibility and suitability of the instruments.

Denscombe (2003) asserts that experiments are generally concerned with establishing the cause of any changes that occur to what is being studied and contends that it is important that the dependent and independent variables are clearly identified.

Robson (1993) provides the following outline regarding what an experimentation research strategy entails:

- The assignment of participants to different conditions,
- Manipulation of one or more variables (independent variable) by the experimenter,
- The measurement of the effects of this manipulation on one or more other variables (dependent),
- The control of other variables (p.110).

During the first two phases of the current study the test group, a sample of B.Ed students, chose to take the year-long NoS elective course (assignment to conditions). The participants experienced explicit instruction in NoS throughout the year (manipulation of variable). At the end of the year the extent to which the B.Ed students' conceptions had developed as a result of taking the NoS elective was established (measurement of the effects of the manipulation). In this research experiment the NoS elective course was the 'independent' variable and the effects of the NoS elective was the 'dependent' variable. In a similar manner in phase three, the NoS conceptions of the children in the test and control groups were the 'dependent' variables and the 'type of NoS instruction' they received was the independent variable.

As mentioned earlier a quasi-experimental design strategy was employed as purposive and convenience sampling rather than randomised control type sampling (RCT) was utilised. A quasi-experimental design follows the experimental approach to design, however, it does not involve random allocation of participants to different groups. Two different types of quasi-experimental designs were utilised in the study.

During the first two phases a pre-test post-test single group design (Robson 1993) was utilised. In this design the single experimental group was given a pre-test, received a treatment (the NoS elective course) and was tested again at the end of the treatment. There was no control group in the first two phases.

Robson (1993) contends that such a design can be vulnerable and subject to threats of lack of validity. In the first instance he suggests that other incidences aside from the treatment occurring could effect the change, and secondly that the group could mature and develop in between the pre and post-test, making it difficult to establish the validity of the intervention. Robson also asserts, however, that it can be possible to indicate that this design is interpretable if the potential threats to internal validity have not occurred in practice. With regard to the experiment conducted in phases one and two, the group who received the treatment (the NoS elective course) did not sit any other science course during the intervention. It is therefore likely that the elective course was responsible for any changes or developments in their conceptions of NoS. Robson also contends that a pre-test post-test single group experiment is appropriate if the aim of the experiment is to establish whether there is an improvement in performance after the intervention. The aim of the experiment conducted in the first two phases was to establish the effectiveness of explicit approaches of NoS in the development of NoS conceptions, therefore meeting Robson's criteria for suitability.

In phase three a pre-test post-test non-equivalent groups design (Robson 1993) was utlised. In this design a test and control group, comprising primary school children (9-11 years) was chosen through purposive sampling (which will be discussed in more detail later). Both groups completed pre-test questionnaires and interviews. The test group were 'given the treatment', namely taught about NoS through explicit means and the control group were taught about NoS through implicit means, as part of the science curriculum. Both groups completed pre and post-test questionnaires and interviews. To assess whether the intervention was effective, the pre and post-test questionnaires and interviews were analysed. Robson asserts that a general rule of quasi-experimental designs is 'that not only is it necessary to consider the design of a study, but also the context in which it occurs, and the particular pattern of results obtained, when trying to decide whether a treatment has been effective' (p. 139-140). According to Robson, quasi-experiments stress the importance of 'what works, for whom and in what circumstances' (p.140). To this extent, quasi-experiments require detailed information regarding the particulars of study. Qualitative methods of data collection and analysis are therefore suitable in facilitating the acquisition of more detailed information regarding the context of the study and a more in-depth knowledge of the outcomes.

Before issues regarding sampling, data collection and analysis, quality assurance, ethical considerations and limitations are discussed my role as researcher will be considered in terms of how I situate myself within the study.

3.3.1 Situating the Researcher within the Study

Traditionally the researcher in an experimental research design assumes an unobtrusive role and quantitative methods are utilised. However, in this study, although an experimental design was employed, qualitative methods of data collection and analysis were utilised. Unlike quantitative research where the knower can be separated from the known and objectivity is conceivable, qualitative research by its nature can never be truly objective (Lincoln and Guba, 1985). A researcher's values in qualitative research perform a vital role in moderating and shaping what is understood. According to Maykut and Morehouse (1994) values are embedded in the research and are apparent in the way the researcher investigates the issues.

Kilburn (2004), when discussing subjectivity amongst researchers quotes Eisner (1998):

> Each person's history, and hence world, is unlike anyone else's. This means that the way in which we see and respond to a situation, and how we interpret what we see, will bear our own signature. This unique signature is not a liability but a way of providing individual insight into a situation (Eisner, 1998, p. 34).

My personal history includes ten years teaching in a primary school, and seven years teaching curriculum science at tertiary level to pre-service primary school teachers. The curriculum science courses I currently teach at third level are aimed at preparing pre-service primary teachers to teach and implement the Science Curriculum (DES, 1999a). These courses predominantly provide pre-service teachers with pedagogical knowledge of science, with a particular emphasis on science as a skill-based process and an active-learning environment. Constructivist approaches to teaching science are utilised and the students are given opportunities to test and investigate various scientific ideas. As part of these courses I address the students' conceptions of different aspects of NoS explicitly. I have also taught modules on explicit approaches to NoS as part of a Masters in Education degree and have given workshops on NoS in other universities in Ireland. My professional experience and my wide reading of the literature have provided me with firm grasp of the issues being examined.

Peshkin (1988) maintains that it is better that researchers are aware of their subjectivity and the role this subjectivity takes in research rather than assuming that it can be omitted altogether. Being aware of my subjectivity entails knowing the qualities I possess that will enrich the research as well as being aware of ideas and beliefs I possess that could potentially distort my portrayal of the data, if I were not aware of them. My experiences as a primary teacher have taught me to be a good listener and have afforded me numerous opportunities to observe, be aware of and to interpret various situations in the classroom. These experiences have been beneficial to me as a researcher when 'listening' to and interpreting different documents and data, in that they permit me to assimilate new information in an unbiased way and with an open mind. In addition to this I have read widely around the area of NoS and therefore have a good grasp of the issues relating to the development and assessment of people's NoS conceptions. This knowledge enabled me to interpret issues in the data rather than simply recording them. However, in an effort to prevent bias during analysis, the data were submitted to a colleague and her alternative explanations and suggestions sought. My seventeen years of teaching at primary and tertiary level have also taught me the importance of flexibility and adaptiveness, as often things do not end up exactly as planned and procedures or plans have to be changed if the unanticipated happens. These qualities were important to me during the first phase of the study, when teaching the NoS elective and in the third phase when interviewing the children.

I have previous experience in utilising qualitative research methods. I have interviewed primary children and teachers in the past and have transcribed and analysed the data obtained from these interviews. My experience as a primary teacher has also provided me with experience and skills in listening and talking to young children and has increased my awareness of the importance of dealing with difficult situations in a sensitive manner. I also have experience in designing, delivering and analysing questionnaires for pre-service teachers and primary school children.

As mentioned earlier, this study utilised a fixed research design, employing a quasi- experimental design strategy. A brief overview of the four phases of the study is provided in the next section. Detailed accounts of the sample and qualitative research methods of data collection and analysis that were utilised are then outlined.

3.4 Research Design

An overview of the questions that were addressed at each phase and the time span for each phase is outlined in Table 3.1

Table 3.1 Questions addressed and time span for each phase

	Questions Addressed	Time Span	Instruments	Sample
Phase One	How effective are explicit approaches to teaching about NoS in developing pre-service teachers' conceptions of NoS?	**Pilot: Oct - Dec 2003** **Phase One: Sept. 2004 - May 2005**	• Science is statements • Long range experiment reflections • History of science reflections • Nature of science questionnaire (NOSQ)	• 2nd year pre-service teachers (pilot) • 3rd year pre-service teachers (NoS elective)

Phase Two	To what extent do pre-service teachers explicitly plan and teach about NoS? What are pre-service teachers' perceptions about explicitly addressing NoS as part of the Irish science curriculum? What are the effects (if any) of explicitly teaching NoS on pre-service teachers' perceptions of teaching science?	**March - April 2005 (Four weeks)**	• Teaching practice reflections	• Pre-service Teachers (NoS elective)
Phase Three	Do beginning teachers explicitly plan and teach aspects of NoS as part of the science curriculum? Which aspects of NoS (if any) do beginning teachers plan and teach? What are the effects (if any) of explicitly teaching NoS on beginning teachers' approaches to and perceptions of teaching science? Do Irish primary children develop more contemporary conceptions of NoS when NoS is explicitly taught as part of the science curriculum? What are the effects (if any) of explicitly teaching NoS on the way primary children reflect on their science lessons?	**September 2005 - April 2006**	• Teachers' reflective journals • Initial and exit questionnaires • Initial and exit group interviews	• Four beginning teachers • 104 Primary children (9 - 11years)
Phase Four	To what extent do international documents explicitly address the development of NoS conceptions? To what extent do international assessment tools explicitly assess NoS understanding?	**April - June 2005**	• Seven primary science curriculum documents • International assessment tools – TIMSS – IAEP	

3.4.1 Overview of Phases

Phase One: Developing pre-service primary teachers' conceptions of nature of science

The aim of the first phase of the study was to establish the effectiveness of explicit approaches to teaching about NoS in developing pre-service primary teachers' conceptions of NoS. The following question was addressed:

- How effective are explicit approaches to teaching about NoS in developing pre-service teachers' conceptions of NoS?

During this phase an elective course in the Nature of Science (NoS) was designed and delivered to a group of nineteen final year B.Ed students. A sample of the NoS activities was piloted the previous year with a sample of 74 second year bachelor of education students over a period of ten weeks. The piloting will be discussed in more detail later. The NoS elective course (Appendix I) was not aimed at philosophy students or science students, rather at primary school pre-service teachers, without any specialisms in science. The aspects of NoS addressed therefore were those that are generally accepted amongst science educators, philosophers, sociologists and scientists outlined in the literature review (Abd-El-Khalick and Lederman, 1998a, 1998b; Lederman 1992a, 1992b; Ryan and Aikenhead, 1992; AAAS, 1993; Matthews, 1994; Mc Comas et al., 1998). The values and epistemological assumptions underlying science rather than specific scientific theories and processes were explored. For example, when the skills of observing and hypothesising were discussed, the importance of these being based on theories was delineated. However, the subjective nature of observations was also discussed and the influences that personal experiences and knowledge have on observations were outlined. The role that imagination and creativity play in the formation of hypothesis was also emphasised. Different aspects of NoS were addressed and various activities were conducted to explore and develop the students' conceptions of these elements of science.

With regard to the history of Science (HoS) a number of workshops that provided the students with opportunities to explore and discuss some of the significant figures and events in the history of science were provided. During these sessions the students were encouraged to discuss the issues that were related to various aspects regarding NoS, for example the influences of society and religion on scientific development, the developmental nature of science or science as a human endeavour.

The data gathered from the long-range experiments (LRE) and history of science (HoS) assignments were analysed to establish whether these pre-service teachers' conceptions of NoS had developed over the course of the year. Questionnaires were also utilised at the initial and exit stages of phase one, to assess the extent to which these pre-service teachers' conceptions had changed over the course of the elective.

Phase Two: Nature of science and pedagogy: Teaching practice

The second phase of this study addressed the following research questions:

- To what extent did pre-service teachers explicitly plan and teach about NoS?
- What are pre-service teachers' perceptions about explicitly addressing NoS as part of the Irish science curriculum?
- What are the effects (if any) of explicitly teaching NoS on pre-service teachers' perceptions of teaching science?

In the second phase all the pre-service teachers who had taken the NoS elective were required to plan and explicitly address at least one aspect of NoS as part of their science lessons on their final Teaching Practice (TP).

Phase Three: NoS and pedagogy: Beginning teachers

In phase three, the extent to which four beginning teachers explicitly planned and addressed aspects of NoS as part of the Science Curriculum (DES, 1999a) was explored. It also established the effects of explicitly teaching about NoS on beginning teachers' approaches to and perceptions of teaching science. Two of these beginning teachers had taken the NoS elective the previous year and two had taken different elective courses. The four teachers were informed about the purpose of the research and had contact details of the researcher if they required help or additional resources. All four teachers were permitted to use any resources they wished and could teach any aspect of science outlined in the Science Curriculum (DES, 1999a). At the beginning of the second term all four teachers agreed to complete a reflective journal and to provide a copy of their science schemes to the researcher.

Phase three also established whether the pupils who were taught by the two beginning teachers who had taken the NoS elective the previous year (test group) had developed more elaborate NoS conceptions than the pupils who were taught by two beginning teachers who had not taken the NoS elective the previous year (control group). The third phase also sought to find out whether explicitly teaching NoS had any effects on the way these primary children reflected on their science lessons.

The following questions were addressed in phase three:

- Do beginning teachers explicitly plan and teach aspects of NoS as part of the science curriculum?
- Which aspects of NoS (if any) do beginning teachers plan and teach?
- What are the effects (if any) of explicitly teaching NoS on beginning teachers' approaches to and perceptions of teaching science?
- Do Irish primary children develop more contemporary conceptions of NoS when NoS is explicitly taught as part of the science curriculum?
- What are the effects (if any) of explicitly teaching NoS on the way primary children reflect on their science lessons?

Phase Four: Preliminary content analysis

In this phase a preliminary content analysis was conducted on seven international curriculum documents. The findings of the first three phases had revealed numerous positive effects of explicitly teaching NoS on teachers and pupils' conceptions of NoS and on their approaches to and perceptions of school science. The literature suggests that amongst the factors necessary for successful implementation of NoS is its explicit inclusion amongst the aims and objectives in curriculum documents (Bell et al., 1995; Hipkins et al., 2005; Lederman, 1998). The aim of the content analysis therefore was to establish the extent to which each document explicitly addressed NoS, therefore facilitating teachers in implementing NoS. A preliminary content analysis of two international assessment tools was also carried out to establish the extent to which NoS was explicitly assessed.

3.4.2 Sampling

Pre-service Teachers

A NoS elective course was specifically designed to address the research questions in the first two phases of this study. Students were not obliged to take this elective course, rather they chose to do it. In the first two phases a convenience sample of 19 pre-service teachers who had chosen to take the NoS elective course as their specialised third year elective option was utilised. All 19 students had studied at least one science subject at second level, one had completed a one-year biology course in their first year of the Bachelor of Education (B.Ed) degree and all 19 had taken a compulsory forty-eight hour curriculum science course in their second year. This course was given in the form of weekly two-hour workshops. Curriculum methodologies and basic science concepts are covered during these workshops. The curriculum science module in the Bachelor of Education degree provides the students with the opportunity to use a range of methodologies in the teaching of science with particular emphasis on science as a skill-based process and an active-learning environment. The course was aimed at familiarising the students with the cognitive development of the child, with emphasis on the child's scientific understanding and common alternative conceptions. The course also aimed at developing the students' own conceptual and procedural knowledge in science. (From 'Science Curriculum Course Outline', St. Patrick's College, Dublin, Ireland, 2004). The Nature of science is not explicitly addressed on this curriculum science course.

While all 19 of the elective pre-service teachers expressed an interest in taking part in the third phase, only two of them obtained full-time positions in senior classes in their initial teaching year. These two beginning teachers and their third and fourth classes (9-11 years) formed the test group in the third phase. Two beginning teachers who had graduated in the same year, who had taken different electives and were teaching the same class levels were sought as the control teachers. The researcher contacted a suburban school and a beginning teacher who met the above criteria volunteered to take part in the study. This beginning teacher gave the researcher details of another beginning teacher who had a senior class and who had just graduated from the same college. The second beginning teacher was contacted and agreed to take part in the study. These two beginning teachers who had not taken the NoS elective the previous year formed the control group. This purposive sample was utilised in an effort to compare whether there were any differences between the test and control teachers' practices regarding explicitly teaching NoS and to establish whether there were any effects on the teachers' perceptions of and approaches to teaching science as a result of explicitly teaching about NoS. The test group represented beginning teachers who had taken the NoS elective and therefore were considered to hold elaborate conceptual and pedagogical knowledge regarding NoS. The control group represented beginning teachers who had not taken the NoS elective and therefore had not been given explicit opportunities to develop their conceptual or pedagogical knowledge of NoS during their course. All four teachers had obtained honours in their final teaching practice. The purposive sample helped ensure that variability amongst the participants was represented in the data (Patton, 1991; Maykut and Morehouse, 1994). Maximum variation strategy (Lincoln and Guba, 1985; Patton, 1991) was utilised. That is the researcher selected a sample that represented considerable differences in the teachers' experiences of explicit teaching of NoS. These considerable differences according to Maykut and Morehouse (1994) and Lincoln and Guba (1985) provided the researcher with a means by which variability, a feature of random selection, could be addressed, while acknowledging that generalisability was not an objective. The test and control group also included the children in the classes that the four teachers were teaching.

Children

It was decided that the third phase of the study would be conducted with children in the more senior classes of primary school (ages 8 - 11) as the older children would have had more experience of school and science and would also be more able to complete written questionnaires. A total of 104 children from four primary classes, two third classes (fifth year of primary school) and two fourth classes (sixth year of primary school) took part in the third phase of the study. The children were aged between eight and eleven years. Three of the schools were urban based and one was a rural based school. Three out of the four classes were mixed sex and the fourth was a boys' school. Table 3.2 summarises the children's data.

Table 3.2 Children involved in phase three of study

Test 1 (T1)	**Test 2 (T2)**	**Control 1 (C1)**	**Control 2 (C2)**
Third Class (Fifth year in primary school)	Fourth Class (Sixth year in primary school)	Third Class (Fifth year in primary school)	Fourth Class (Sixth year in primary school)
Mixed	Mixed	Mixed	Boys
Rural	Urban	Urban	Urban

Each teacher also selected eight children of a range of academic abilities to take part in a group interview at the beginning and end of the third phase of the study.

3.4.3 Methods

As the research questions demanded data that captured people's words, thoughts and actions, qualitative methods of data collection were for the most part employed. These included group interviews, open-ended questionnaires, and the collection of various written reflections. This would facilitate triangulation and increase the validity of the findings. Quantitative data were also collected which included a preliminary content analysis and closed questions on the children's questionnaires. The quantitative methods of data collection facilitated the gathering of more objective knowledge and triangulation. In this section the various methods of data collection used in each phase will be discussed. The preliminary content analysis of seven curriculum documents will then be outlined.

Phase One

The first phase explored the effectiveness of utilising explicit approaches in the development of more elaborate NoS conceptions amongst these pre-service teachers. A number of research instruments were used to address the research issues. These are outlined in figure 3.1.

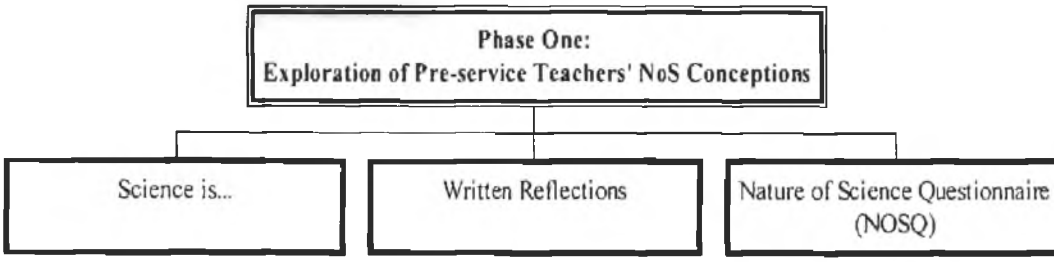

Figure 3.1 Data collection and research instruments for phase one

'Science is' statement

All 19 students were asked to write descriptions of science at the beginning and end of the academic year. They were given the words 'science is' and asked to write descriptions of what they believed science to be (Appendix B). The students were given no instructions other than asked to complete the sentence. All students completed the description statements on both occasions. The open-ended nature of the statement was to prevent the participants' responses being influenced in any way by the question posed. The elective students were given as much time as required to complete the statement, but all were completed within fifteen minutes. The pre and post-elective insights regarding science were compared.

Other research studies to examine teachers' conceptions of NoS have used similar instruments. For example Abell and Smith (1992) conducted a study on the exploration of primary teachers' conceptions of NoS, in the USA. As part of this study 140 pre-service primary teachers were asked for a written response to the question ' How would you define science?' In a similar manner the Craven et al. (2002) study used the open-ended 'what is science?' question to ascertain the tacit[2] and explicit [3] conceptions of NoS held by 27 pre-service elementary teachers in Australia throughout an elementary science methods course. A study conducted by Murcia & Schibeci (1999), with 73 pre-service teachers in Western Australian, also asked these pre-service teachers to answer the question ' What is science?' as the last item on a seven-item questionnaire.

[2] Tacit knowledge is described as the understanding and knowledge that is unarticulated yet demonstrable by use and / or action (Polanyi 1866)

[3] Explicit knowledge is described as the understandings and knowledge that the student can immediately access while communicating with others

Written reflections

Over the course of the elective the pre-service teachers were required to submit two written reflections. These reflections were in relation to conducting a Long Range Experiment (LRE) and their reflections on the History of Science (HoS).

Long-range experiment reflection

The pre-service teachers were required to conduct a long-range experiment (LRE) in groups, provide a written report and write an individual reflection on their experiences of conducting the LRE, an assignment that comprised forty percent of their overall marks for the elective. The aim of this assignment was to improve the pre-service teachers' conceptions of the processes used to generate scientific knowledge, therefore improving their understanding of NoS. The idea for the LRE assignment was taken from Meichtry (1998). An overview of the LRE assignment requirements is provided in Appendix C.

History of science reflection

The students were given time to research a famous scientist in pairs and they then gave a ten-minute presentation to the class group on the scientist. The students were given an outline of what their presentations might include (Appendix C). The group presentations were not assessed. However, each student was required to submit an individual written reflection that was assessed, on how they believed HoS could be incorporated and whether they believed it should be incorporated as part of the Irish Primary Science Curriculum (DES, 1999a). They were given questions to consider, in an effort to help them focus their reflections. Details of the HoS assessment and samples of the written reflections are also provided in Appendix C.

These reflections provided in-depth accounts of the pre-service teachers' perceptions and experiences of NoS over the course of phase one.

Nature of Science Questionnaire (NOSQ)

In addition to the 'Science is ' statements, 15 of the 19 third year students volunteered to complete a more detailed open-ended questionnaire that was administered at the end of the elective course (Appendix D). Two were absent on the day that the questionnaire was administered and two did not complete the questionnaires due to work pressures. An open-ended questionnaire was devised, in an effort to move away from the more traditional 'tick box' answer type questionnaires, where often students can be forced to select categories or responses rather then coming up with their own (Lederman and O'Malley, 1990). Lederman and O'Malley (1990) maintain that standardised tests can reflect the testers' views, and at times can create bias. They assert that more open-ended questionnaires regarding NoS conceptions, lend themselves to be freer from the prejudices or assumptions of the developer, therefore enabling respondents to answer without being influenced by the developer's opinions or proclivities. Lederman and O'Malley (1990) devised a ten item open-ended 'views of the nature of science questionnaire' (VNOS), that established third level students' views about NoS. Aspects of NoS that were addressed on the VNOS included the empirical NoS, understanding the inferential nature of scientific models, the tentative nature of scientific theories, the creative and imaginative NoS and the social and cultural influences on scientific knowledge.

In a similar manner to the VNOS, the following aspects of NoS were addressed on the Nature of Science Questionnaire (NOSQ) devised and administered in the current study:

The empirical NoS:

- Science, a body of reliable knowledge that is tentative and developmental and therefore subject to change. Scientific inquiry employs various methodologies and processes.

Science as a human endeavour:

- Science is a human endeavour therefore is subjective in nature. Scientists' past experiences and knowledge affect the way they interpret data. Scientists use their creativity and imagination.

Science and society:

- Science and society are affected by each other. The values and norms within societies have huge influences on scientific development.

The six open-ended questions in the NOSQ addressed different aspects of NoS (Appendix D). For example question two referred to the subjective NoS and question four sought the participants' conceptions about the creative and imaginative aspects of science. However, views of different aspects of NoS could have been referred to in any of the six questions on the questionnaire. For example, references to the subjective and tentative NoS, the role of observations and inferences or the various skills and processes employed by scientists during scientific enquiry, could have been referred to in response to question four.

The NOSQ was piloted the first time with a retired primary teacher, a retired scientist and two practising primary teachers to establish construct validity. Changes were made and the second pilot was conducted with one primary school teacher and two science education experts at third level. Only minor changes were made after the second pilot. Every question on the NOSQ was written on a separate page and the respondents were asked to attempt all questions and were encouraged to write as much as they could for each question. It was also emphasised that there were no right or wrong answers. The respondents were not required to put their names on the questionnaires and it took the students between 25 and 30 minutes to complete.

Phase Two

The second phase of the study ascertained the extent to which the pre-service teachers planned for and taught about aspects of NoS in their final teaching practice.

Teaching practice reflections

As part of their requirement for the elective course, the NoS elective students were required to plan and explicitly teach at least one aspect of NoS as part of their science lessons during their final teaching practice (TP). They were also required to submit a written account, which was assessed, of their experiences of explicitly planning for and teaching about NoS as part of the science curriculum and their reflections on whether they believed NoS should be included as an important aspect of the Science Curriculum (DES, 1999a).

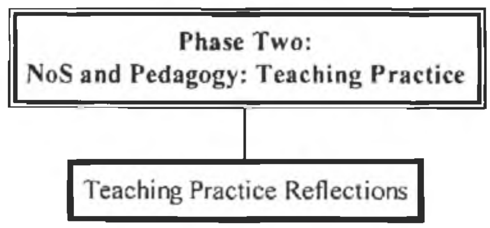

Figure 3.2 Data collection and research instruments for phase two: NoS and pedagogy: Teaching practice

The guidelines given to the students for the written reflection are provided in Appendix E.

Phase Three

A number of research instruments were used to address the research questions in phase three. These are outlined in Figure 3.3.

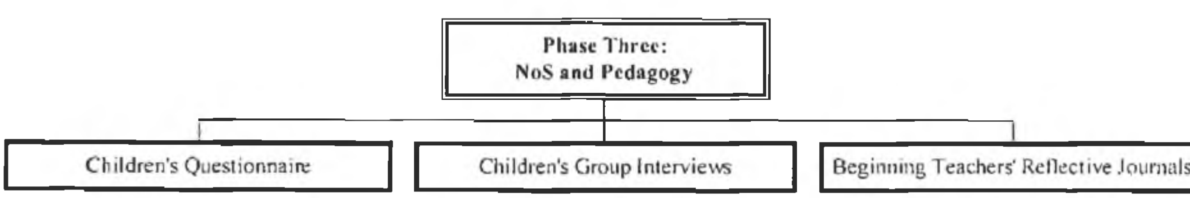

Figure 3.3 Data collection and research instruments for phase three: NoS and pedagogy: Beginning teachers

Children's questionnaires

A questionnaire was administered to the children in both test and control groups at the beginning and end of the study. The questionnaire was piloted with a focus group of six, sixth class children (ages 11 and 12) before administering it to the children in the study. The questionnaire was checked for construct validity through informal interviews with this focus group. After the first pilot, only minor changes were made to the layout of the questionnaire. There were two sections in the questionnaire (Appendix F). Section A consisted of five open-ended questions that gave the children the opportunity to write about their thoughts on science and the work of scientists. Section B of the questionnaire contained 10 Likert style statements about

NoS, where the children had to shade in a 'smiley face' indicating whether they agreed, disagreed or were 'not sure' about the statements. These statements related to the empirical NoS, science as a human endeavour and science and society.

Group interviews

Within the qualitative tradition, interviews are in-depth, comprising open-ended questions. The aim of the qualitative interview is to reveal what is important about the question being investigated. Patton (1990) asserts that 'the fundamental principle of qualitative interviewing is to provide a framework within which the respondents can express their own understandings in their own terms' (Patton 1990, p. 290).

In the present study semi-structured group interviews comprising eight children from each class were conducted at the beginning and end of the third phase of the study. The interviews were semi-structured in an effort to 'let the interviewees develop ideas and speak more widely on the issues raised by the researcher" (Denscombe, 2003, p. 167). Group interviews as opposed to individual interviews were chosen as it was hoped that the group interviews would generate more discussion about science between the participants (children).

A group of eight children was gathered together to find out their viewpoints regarding NoS at the beginning and end of phase three. These children were selected by the teacher and represented a range of abilities. All of the children who took part in the interviews did so voluntarily. It was hoped that the group interview would use the dynamics of the group to gain information and insights into the children's thoughts about NoS, something that might be less likely gained through individual interviews. During these interviews the participants were given a chance to listen to one another, which enabled new thoughts and aided the development and clarification of their existing ideas. The group interview provided the participants with the opportunity to think out loud, which in some cases facilitated them in revealing personal insights of issues and events regarding science. The researcher adopted a more unobtrusive role than would have been adopted in an individual interview. An interview schedule was designed for the initial and exit interviews. The initial and exit interview schedules comprised eight and ten open-ended questions respectively, which were aimed at establishing the children's understandings of different aspects of NoS (Appendix G).

The open-ended nature of the questions posed was in an attempt to initiate a conversation with the participants. As suggested by Patton (1990), a combination of detailed probes, elaboration probes and clarification probes were included on the interview schedules. It is important to note that because people conduct interviews there is always a potential danger of bias when conducting them. There are many factors that may contribute to this bias. For example, a slight discord arising between the researcher and the participant may occur or the inclination of the researcher to search for answers that are consistent with their ideas and perceptions surrounding the research topic (Bell, 1991). Other potential biases include the interviewee's eagerness to please the researcher or the tendency of the researcher to look for answers that are supportive of their personal conceptions or agendas. The researcher was aware of these potential biases when conducting the interviews and made every effort to eliminate them. For example, the interview schedule was adhered to throughout the interview. The researcher was aware of the possibility of the 'Hawthorne effect' (Robson, 1993) where the children might feel obliged to give a 'correct' answer to please the interviewer. Therefore, as suggested by Briggs (1986), before every interview the children were reminded that there were no 'right' or 'wrong' answers and that it was 'their ideas' that were important.

Every attempt was also made to make the children feel at ease. As recommended by Tammivaara and Enright (1986) teacher-like controlling behaviours were avoided. The children addressed the researcher by her first name and an informal chat preceeded every interview to allow the children time to form a relationship with the researcher.

Reflective journals

During their initial teaching year, the beginning teachers agreed to complete a reflective journal at the end of weeks, one, three, six, eight and eleven of the second term (January - March 2005). The purpose of the reflective journal was threefold:

- To establish if there were differences between the test and control group in terms of the planning of and methodologies used to teach science.
- To gain an insight into the aspects of NoS that were explicitly addressed and the extent to which they were addressed.
- To establish the extent to which the test teachers' NoS conceptions had changed and/or developed over the course of the study

The template for the reflective journal was adapted from Murphy et al. (2002) who utlised a reflective journal in establishing pre-service teachers' ideas regarding teaching science through co-teaching in Northern Ireland. The Murphy et al. (2002) study found that using reflective journals as a means of data collection yielded a rich insight into the teachers' ideas regarding teaching. The reflective journal utilised in the current study comprised six questions aimed at prompting the beginning teachers' thoughts on teaching science in school (Appendix H). The journals provided an account of the teachers' ideas and experiences of teaching science over the course of the third phase of the study.

Phase Four

Preliminary content analysis

Content analysis is a popular approach to documentary analysis and typically involves the quantitative analysis of what is contained in a document. Krippendorff (1980) defines content analysis as 'a research technique for making replicable and valid inferences from data to their context' (p.21). He emphasises the importance of the connection between content and context and notes that the context in content analysis includes the purpose of the document as well as organisational, societal and cultural aspects. As part of the study, a content analysis of seven curriculum documents in primary science was conducted to establish the extent to which the development of NoS conceptions is addressed in each document.

Conducting content analysis has the capacity to provide a mechanism for quantifying the contents of written text, through a logical and clear process, which in theory can be replicated by others (Denscombe, 2003). There are however, some limitations of content analysis; it can separate units of meaning from the context in which the writer originally placed them and it can be difficult to establish the implied meaning of text. Denscombe (2003) therefore asserts that content analysis is most suitable when considering documents that are more straightforward, apparent and clear. The more the text relies on subtle and intricate meanings conveyed by the writer or inferred by the reader, the less valuable content analysis becomes in revealing the meaning of the text (Denscombe, 2003, p. 223).

As part of the current study, a content analysis of seven curriculum documents in primary science was conducted to establish the extent to which the development of NoS conceptions was addressed in each document (Chapter seven). In this study an analysis of manifest content rather than latent content (Robson, 1993) was conducted on the seven curriculum documents. Robson (1993) defines manifest content as relating to items in a document that are physically present and therefore requiring a low level of inference on the part of the coder. Latent content on the other hand requires a high level of inference or interpretation on the part of the coder. Manifest content analysis according to Robson (1992) is therefore more likely to achieve reliable results because of the low-inference systems. As the text in these curriculum science documents was straightforward and did not contain 'intricate' and 'subtle' meanings, it was therefore deemed suitable for content analysis. The preliminary content analysis aimed at revealing the extent to which each of the documents prioritised learning about NoS and whether the development of NoS conceptions was determined to be relevant in primary science education in the seven countries. As suggested by Denscombe (2003) and Robson (1993) the criteria for selection of the documents was clearly set out, and categories were constructed and defined to facilitate analysis.

Curriculum documents from Northern Ireland, Scotland, England & Wales curriculum documents were chosen for the content analysis because of their close proximity to the Republic of Ireland. In addition to this the researcher, who was teaching in Ireland, was interested in comparing these documents to establish how similar they were to the curriculum in the Republic of Ireland. The New Zealand document was selected because it is a country of similar size to Ireland and after an initial reading of the document appeared to have a strong emphasis on the development of NoS understanding. It was decided to select one curriculum science document from the Australian states, because of Australia's close proximity to New Zealand. After an initial reading of the curriculum documents from the states of Victoria, Western Australia and Queensland, the Queensland document was chosen because it appeared to have placed a higher emphasis on NoS issues than the other two curriculum documents. Much of the research on developing NoS conceptions has come from the USA (Abd-el- Khalick, 2005; Abd-El Khalick et al., 1998; Abd-El Khalick & Lederman, 2000a, 2000b; Abell and Smith, 1992; Allchin, 2000; Alters, 1997; Lederman 1999). After an initial reading of three documents (Florida, California, Pennsylvania) the California document was selected because it appeared to have a stronger emphasis on the development of NoS understanding than the other two.

Factors that appear to be inhibiting the implementation of NoS in curricula include a lack of a clear definition of what NoS entails (Wellington, 1998; Mc Gee et al., 2003) and a lack of specificity regarding the intended NoS content outlined in curriculum documents (Hipkins et al., 2005). The aim of the content analysis of the seven documents therefore was to establish the extent to which the development of NoS conceptions was addressed amongst the aims and objectives in each document. The answer to the following four questions regarding the inclusion of NoS was sought.

1. Is a description of NoS provided in the introduction? What tenets of NoS are specifically mentioned in this description?

2. Is the development of NoS conceptions explicitly mentioned as a general aim?

3. Is there a unit or section explicitly dedicated to the development of NoS? Are there objectives that explicitly address learning about NoS within this unit?

4. Are there objectives that implicitly address different tenets of NoS within sections / unit? If yes, which tenets are addressed?

These questions formed the categories for analysis. In chapter two the research outlining the numerous benefits of explicitly addressing NoS was considered. The aim of this preliminary content analysis was to establish the extent to which the development of NoS concepts was addressed in each of these curriculum documents. This was in a bid to ascertain whether the documents provided teachers with sufficient information regarding what NoS entails and how they might address NoS as an integral part of the science curriculum. While the questions posed were quite general, they provided indicators of what should be included or omitted in each category. The results of the content analysis are considered in detail in chapter seven.

A preliminary document analysis of a purposive sample of two international assessment tools was also conducted to establish the extent to which these two tools assessed NoS conceptions. Research has indicated that assessment tests need to explicitly address NoS, so teachers will recognise NoS as an 'important' area that will be assessed (Gilbert, 2003, White, 2003). The two assessment tools that were selected, the International Assessment of Educational Progress 1992 (IAEP) and the Trends in International Mathematics and Science Study (TIMSS) 2003, were chosen as they were amongst the few international tools that assessed science amongst primary aged children. For both tools, the extent to which NoS was explicitly and implicitly assessed was explored. Explicit assessment and implicit assessment were the two categories in which the manifest content of these documents was categorised. The results of the content analysis of these assessment tools are also explored in chapter seven.

3.5 Ethical Considerations

Denscombe (2003) asserts that when collecting and processing data and distributing findings, it is essential that social researchers are ethical. Researchers should always respect the rights and dignity of the participants, avoid any harm happening to them while taking part in the research and always be honest and act with integrity. In addition to this it is important that participants in research are not forced to take part, rather they do so voluntarily. Participants must also have sufficient information about the research so they can make an informed decision about whether or not they should take part. For these reasons ' informed consent' is sought, particularly when the research involves personal involvement from the participant.

The pre-service teachers who took part in the study in phase one and two were informed about the purpose of the study and signed a consent form permitting the researcher to utilise their written work in reporting the findings of the study (Appendix B).

At the outset of phase 3 the children were given a letter seeking consent from their parents or guardians to complete the questionnaires and participate in the interviews. The letters informed the guardians of the purpose and nature of the research and assured confidentiality (Appendix F). The children were also informed about the purpose of the questionnaires and group interviews and were given the option of whether or not to fill in the questionnaires. Participation in the interviews was also voluntary. All the children were very enthusiastic and willing to take part in the interviews. The questions the participants were asked during the interviews were unobtrusive and did not require them to divulge any personal information. Nevertheless the children were given assurances of anonymity and the personal identities of the participants were not revealed at any stage.

The beginning teachers who took part in phase three of the study were informed about the purposes of the research and were not obliged to complete the reflective journals. However, all four teachers completed the refective journals and gave oral consent for the content to be utilised in the study. They were also given assurance of confidentiality and anonymity. All four teachers were given copies of the analysis of their journals to ensure that the researcher had accurately interpreted what they had recorded.

3.6 Quality Assurance in Data Collection

3.6.1 Role of Researcher

Traditionally in 'fixed' design research the researcher assumes a 'detached' role in a bid to prevent the researcher from having an effect on the findings. Qualitative research endeavours to document the multiple interpretations and meanings given to particular situations and events (Brock-Utne, 1996). Unlike quantitative research where the knower can be separated from the known and objectivity is conceivable, qualitative research by its nature can never be truly objective. A researcher's values in qualitative research perform a vital role in moderating and shaping what is understood. According to Maykut and Morehouse (1994) values are embedded in the research and are apparent in the way the researcher investigates an issue.

During the first two phases of the research the researcher had a high involvement in the intervention and therefore the researcher's values and beliefs performed a vital role in moderating and shaping what was understood. One of the aims of the first two phases was to develop pre-service teachers' NoS conceptions and explore the extent to which they explicitly addressed NoS during their final teaching practice. During phase one, the intervention, which was essentially the NoS elective course, was designed and delivered by the researcher. The researcher had a key role in the intervention and the researcher's values (conceptions of NoS) were embedded in the research, in an effort to influence the pre-service teachers' NoS conceptions and their teaching practices as much as possible. Therefore, the researcher had an influence on the data collected from the start and the data were affected by the researcher's stance of what NoS entails. However, this subjectivity was a feature of the research rather than a limitation in that the researcher sought to provide the students with ideas and experiences of NoS that were in keeping with current ideas and literature relating to what elaborate NoS conceptions entail. The researcher's centrality was an important component of the research in supporting and directing the pre-service teachers' conceptions of NoS. However, every attempt was made to ensure objectivity when analysing the data and a number of measures were taken to ensure reliability and validity of the data, including inter-rater reliability and triangulation. These will be discussed in detail later in the chapter.

The data obtained from the third phase of the study were more objective. The researcher did not influence the children's experiences and conceptions of NoS directly. The children's questionnaires were analysed using a mixture of quantitative and qualitative methods. Over the course of the three phases of the study the researcher attempted to analyse all data objectively and utilised inter-rater reliability analysis where appropriate. In addition to this, measures were taken to eliminate the potential of researcher's biases influencing the interview data. These are discussed in detail in the next section. The data obtained from the teachers' reflective journals during the third phase were compared to establish differences that were apparent between the test and control teachers' general pedagogical approaches and understanding of children's learning. The data obtained from this comparison were also objective in nature in that the researcher did not have any direct influence over what the teachers planned and taught during their beginning teaching year.

It is acknowledged that two of the four beginning teachers who took part in the third phase had taken the NoS elective the previous year and as a result may have wished to affirm the researcher's enthusiasm. However, the non-NoS elective teachers who took part in this phase were aware of the researcher's interest and propensity for NoS and equally may have been eager to seek the researcher's approval. In addition to this they agreed to take part in the study so they were more than likely motivated.

'Transferability' and 'trustworthiness' are terms used in qualitative research that refer to the reliability and validity of data. In the next sections the terms trustworthiness /validity and transferability /reliability will be used inter-changeably.

3.6.2 Validity

Piloting

Prior to commencing the first phase of this study a sample of seven of the NoS activities were piloted with a group of 74 pre-service teachers over the course of ten weeks as part of their curriculum science course. These students (test group) were asked to complete the statement 'science is' at the beginning and end of the first semester of the curriculum science course. An additional 74 second year pre-service teachers (control group) were also asked to complete the 'science is' statement at the beginning and end of the first semester of the curriculum science course. The initial and exit statements from both test and control group were compared to establish whether their conceptions of NoS had developed over the course of the ten weeks. The findings revealed that the test group who had received explicit instruction had developed more elaborate conceptions of NoS about aspects of NoS that had been explicitly addressed. A detailed account of this pilot study can be found in Murphy et al. (2007).

As discussed earlier the NOSQ and children's questionnaires were piloted and checked for construct validity. Appropriate changes were made prior to administration.

Unobtrusive Measures of Data Collection

Hammersley (1995) contended that qualitative research is valid if unobtrusive measures of data collection are utilised. In a bid to prevent the pre-service teachers and children's responses being influenced by the researcher's conceptions or assumptions, the NOSQ and children's questionnaires comprised open-ended questions. However, it must be acknowledged that some of the data obtained from the pre-service teachers during the first and second phases of the study were part of marked course work. As such, the pre-service teachers may have written what they thought would gain them good marks rather than their real thoughts. However, other data that were obtained from questionnaires during the first phase (science is statements and nature of science questionnaire) were not marked course work and the data obtained from these corroborated the pre-service teachers' responses in the marked course work. As discussed earlier, a number of measures were also taken to enhance the validity of the interviews. For example, a concerted effort was made to; establish trust and to maintain informality between the interviewer and interviewees, to utlise appropriate language and to reduce 'the Hawthorne' effect (Robson, 1993) when conducting the children's interviews.

Triangulation

Different methods of data collection provide different perspectives and produce data that potentially have inherent strengths and weaknesses regarding the overall aims of a particular research and/or practical obstacles the researcher may encounter (Denscombe, 2003). If researchers exclusively rely on one particular method of collecting data, their interpretation of what they are exploring may influence or misconstrue their interpretation of what is being explored (Cohen et al., 2000). In research, the term triangulation refers to the use of a combination of methods or sources of data collection. When different methods are used to collect data, each method can potentially look at something from different viewpoints, which can in turn be compared and contrasted by the researcher. Looking at things from different viewpoints and corroborating findings can improve the validity of data. While multiple methods of data collection do not verify that the researcher is correct, they do provide consistency and are not dependent on one position (Denscombe, 2003). Triangulation therefore is an effective way of illustrating coexistent validity, particularly in qualitative research (Campbell and Fiske, 1959)

Multiple methods of data collection and analysis were utilised throughout the three phases of this study and facilitated the researcher in examining different viewpoints and corroborating findings from different data. For example during the first phase data were gathered from a number of sources to establish the pre-service teachers' conceptions of science. These included written statements regarding the pre-service teachers' conceptions of science at the beginning and end of the elective (Appendix B); a number of written reflections regarding the teachers' ideas about different aspects of science (Appendix C); and the pre-service teachers' written responses to a six item open-ended questionnaire regarding their views about NoS (Appendix D). Again in the second and third phases of the study a combination of data collection methods was utilised in an effort to triangulate the data. Written responses regarding the pre-service teachers' experiences of teaching about NoS were gathered (Appendix E) in phase two and data regarding the beginning teachers' experiences of teaching science were collected in phase three (Appendix H). A combination of sources of data was also utilised to collect data concerning the children's conceptions of science. These included open and closed questions on the children's questionnaires (Appendix F) and data obtained from the group interviews (Appendices G). The data from the children's questionnaires were compared with their interview transcripts and the children's written and oral responses corroborated with the data obtained from the beginning teachers' reflective journals

These methods examined the research questions from different perspectives, which were in turn used by the researcher in measuring, contrasting and corroborating the data in an attempt to enhance the validity of the data. While it is acknowledged that these multiple methods of data collection do not necessarily confirm that the researcher's interpretations are correct, they do provide consistency and are not dependent on one position, which Denscombe (2003) argues, enhance validity. However, the examination of scenarios from different perspectives and the affirmation of the researchers' finding enhance the validity of the research.

Respondent Validation

Lincoln and Guba (1985) argue that the standard for qualitative research, where the objective is to reconstruct events and the perspectives of those being studied, is the demonstration that the findings and the researcher's interpretations are credible to those who were involved. The children's group interviews were taped, transcribed and a copy of the transcripts given to the class teachers. Sections of the interviews were played back to the groups after each interview. Copies of the findings' chapters were also given to the test and control teachers, in an effort to confirm that the researcher had accurately interpreted the data.

3.6.3 Reliability

With regard to qualitative data, the researcher is an integral part of the research tool. Reliability is ascertained by being satisfied that if a different researcher had conducted the research, they would have obtained similar results and would have arrived at similar conclusions. Denscombe (2003) maintains that while there is no sure way of knowing this, if qualitative research is to be reliable, the researcher must afford an explanation of the aims and purpose of the research, how the research was conducted, the context and the reasoning behind any major conclusion made.

In this research the aims and purpose of the research are clearly articulated throughout and a detailed description of the research instruments and how the data were collected is provided. These descriptions include information regarding piloting and administering questionnaires and conducting interviews. Extensive accounts of how the various data were analysed are presented in the next section. These descriptions help facilitate the transferability of the data.

Inter-rater Reliability

The measurement of the data from the questionnaires, written reflections and interviews in all three phases of the study consisted of responses to be categorised. Inter-rater reliability was used to ensure that two different raters (the researcher and an expert in education) gave consistent estimates of which categories the various responses fell into. A ten percent sample of the 'science is' statements, the NOSQ questionnaire responses, the long range experiment (LRE), history of science (HoS) and teaching practice reflections and the open-ended responses on the children's questionnaires was selected to establish inter-rater reliability. To establish this, the number of times each response was assigned to a particular category by two raters (the researcher and a science education expert) was divided by the total number of ratings. This provided a percentage of the consensus that existed amongst the ratings given by both raters. The 'rules for inclusion' or 'propositional statements' (Lincoln and Guba, 1985) that were devised when unitising the data also informed discussions surrounding data that could not be unequivocally categorised by two raters. The high inter-rater reliability that was established for all of the data collected, increases the trustworthiness of the data analysis.

3.7 Data Handling

3.7.1 Unitising Data

Analysing the qualitative data collected involved defining the meanings of the teachers and children's words utilising a fundamentally non-mathematical analytical procedure. With the exception of the closed questions in the children's questionnaires, qualitative methods of analysis were utilised. Denscombe (2003) asserts that whether the data is in the form of transcripts, written reflections or field notes, the first step in analysing qualitative data is to decide on the units that will be used for analysis. He refers to this as 'unitising' the data. These units are open to a continuous process of change and development over the course of the study, to facilitate the refinement of categories. Denscombe (2003) also contends that when interpreting and analysing qualitative data, the role of the researcher is to establish what meaning can be ascribed to the words and to ascertain what implications these words have regarding the topic being pursued. According to Lincoln and Guba:

> The essential tasks of categorising are to bring together into provisional categories those cards that apparently relate to the same content; to devise rules that describe category properties and that can, ultimately, be used to justify the inclusion of each card that remains to be assigned to the category as well as to provide a basis for later tests of replicability; and to render the category internally consistent (1985, p.347).

When the data from the pre-service teachers' written reflections, science statements, open-ended questions in the children's questionnaires and children's group interviews were analysed, a set of categories that provided a 'reasonable' reconstruction of the data collected was developed. As recommended by Lincoln and Guba (1985), rules for inclusion were devised as 'propositional statements'. These propositional statements communicated the meaning that was embodied in the data collected under each category name. The rules for inclusion started to divulge what was emerging from the data and provided a vital stepping-stone in reaching the conclusions. Glaser and Strauss (1967) refer to unitising data in their 'constant comparative' method of data analysis. In the constant comparative method responses are read and reread to detect units of meaning. Category names are ascribed to the units of meaning and the data is then grouped into categories with related content.

3.7.2 Nature of Science Questionnaires (NOSQ)

The nature of science questionnaires administered in phase one comprised six open-ended questions. A photocopy of the questionnaire responses was made. The constant comparative method of data analysis (Glaser and Strauss, 1967) was utilised. The data responses to each question were read and categorised by hand using number and colour coding. The responses were categorised according to a particular aspect of NoS that was referred to in each question. Two raters (the researcher and an expert in science education) rated a 10% sample of the NOSQ to establish inter-rater reliability.

3.7.3 Pre-service Teachers' Written Reflections

The pre-service teachers submitted electronic and hard copies of the LRE, HoS and teaching practice reflections. Again aspects of Glaser and Strauss's (1967) constant comparative method of data analysis were used to analyse the data. The data were studied and 'unitised' by hand using colour coding and numbering. The researcher and an expert in science education reached consensus, regarding the categories that were established and the rules for inclusion that were devised for each of these categories. Each response was carefully read to ensure that all references to each category were detected and accurately recorded.

3.7.4 Children's Questionnaires: Open-ended Questions

The completed children's questionnaires were photocopied and the responses to the open-ended questions were categorised by hand, again utlising colour coding and numbering. It was decided that when a respondent made multiple responses to a category, these were recorded accordingly. So for example, if a child referred to three different aspects of scientific inquiry, doing experiments, researching and discussing results, three marks were awarded to the scientific inquiry category. This was in an attempt to establish the extent to which the test and control groups' overall conceptions of science had developed over the course of the study. More elaborate insights of NoS were depicted by a higher percentage of responses in a particular category.

During initial analysis responses that could not be unequivocally classified into a particular category were classified through discussion amongst two researchers. For example, the children used the word 'discovering' in different contexts throughout the questionnaires. On one hand references to 'discovering' could have been coded in the 'body of knowledge' category in terms of scientists 'discovering' information or knowledge. On the other hand some children used it in terms of scientists discovering and investigating things, implying scientists doing things, which would lead to it being coded in the 'scientific inquiry' category. For example, one child wrote 'Scientists do research and discover things'. This response was discussed and the two researchers decided that the 'do research' would be coded under the 'scientific inquiry' category and the 'discover things' would be coded in the 'body of knowledge' category. In this case the child's sentence was interpreted as implying that research was conducted that produced a body of knowledge (discover things). Another child wrote, 'science is about discovering stuff and getting explanations to things we don't know'. In this case the researchers coded 'discovering stuff' in the 'scientific inquiry' category, which led to 'getting explanations to things we don't know' which was coded in the 'explaining phenomena' category.

3.7.5 Children's Questionnaires: Statements about Science

Section B of the questionnaire contained 14 statements about NoS, where the children had to shade in a 'smiley face' indicating whether they agreed, disagreed or were 'not sure' about the statements (Appendix F). The data from these were input in to Statistical Package for the Social Sciences (SPSS). For both test and control group the percentage frequencies of responses to all 14 statements were calculated. The frequency of both groups' responses was compared to establish whether there were any differences in their responses at the exit stage.

3.7.6 Group Interviews

The semi-structured group interviews that were conducted with one group of eight children from each class at the initial and exit stages were transcribed. The responses were input into a word document table. The data were read and re-read to establish and refine units of meaning to be reported and to identify any apparent links, patterns and similarities or differences. This unitising of data was conducted by hand, colour coding and numbering the different responses. Morgan (1998) asserts that when interpreting data from group interviews the amount of emphasis a particular topic receives is dependent on three factors: how many groups refer to the topic; how many people within each group mention the topic; how eager or enthusiastic the participants are regarding a particular topic. A topic therefore is worth emphasising if elements from all three factors are exhibited. With regard to the data obtained from the group interviews in this study all mentions of a given code were recorded, how many people in each group mentioned the topic and the extent to which the children discussed a particular topic was also recorded. The categories that emerged were similar to the categories that had emerged from the data obtained in phase one and two. Two raters (the researcher and an expert in science education) coded a sample of 25% of the interview transcripts to establish inter-rater reliability.

3.7.7 Teachers' Reflective Journals

The four reflective journals were transcribed and inputted onto a word document table (Appendix H). In a bid to establish an overview of the test and control teachers' experiences and perceptions of teaching NoS, the responses to each question were considered and compared in turn. Patterns that emerged during each comparison were colour coded and categorised by hand. The different accounts were compared and similarities and differences that were apparent amongst the responses were categorised in 'word' tables.

3.7.8 Preliminary Content Analysis

The aim of the preliminary analysis was to establish the extent to which the development of NoS conceptions is explicitly addressed in each document. As the text in these documents was straightforward and did not contain 'intricate' and 'subtle' meanings, it was therefore deemed suitable for content analysis. As suggested by Denscombe (2003) the criterion for selection of the documents was clearly set out, and the curricula were broken into smaller units to facilitate analysis.

3.8 Limitations

The fact that qualitative methods of data collection were mainly employed in this study may have given rise to certain limitations. Some limitations of the study have been discussed already. Other limitations are outlined as followed:

1. The researcher designed and delivered the NoS elective and therefore had strong influence over the 'intervention'. The researcher therefore influenced the pre-service teachers' responses in the written reflections. In a similar manner the beginning teachers who had taken the NoS elective may have wished to affirm the researchers' enthusiasm in planning and teaching about NoS in their initial teaching year. Equally the beginning teachers in the control group were aware of the researcher's interest in NoS and may also have wished to affirm the researcher.

2. The sample of pre-service and beginning teachers was small and therefore may not have been representative of the total population of pre-service and beginning teachers. However, a more in-depth and detailed study of the participants' views and conceptions is provided, which makes it more representative.

In this chapter the epistemological framework was presented and the research design employed was outlined in detail. Issues regarding reliability and trustworthiness were considered and ethical considerations explored. The next chapter presents the findings regarding the development of pre-service teachers' NoS conceptions, obtained during the first phase of the study.

4 PRE-SERVICE TEACHERS' CONCEPTIONS OF NATURE OF SCIENCE

4.1 Overview of Chapter

This chapter outlines the development of the pre-service teachers' conceptions of NoS over the course of the study. An overview of the general findings from the 'Science is' statement administered to the pre-service teachers will be provided. The subsequent sections consider the data obtained from the 'Science is' statement, the long-range experiment (LRE), the history of science (HoS) reflections and the nature of science questionnaires (NoSQ), to establish whether there was a change in their conceptions of NoS. The data regarding NoS conceptions of the pre-service teachers will be presented and considered under five headings. These headings are based on the aspects of NoS that were outlined in chapter two as being central to primary teachers and pupils' contemporary NoS conceptions.

- Human Endeavour
- Scientific Inquiry
- Science and Society
- Science as a Body of Knowledge

4.2 Overview of Findings

The categories from the analysis of the initial and exit 'science is' statement are presented in Table 4.1. The initial statement was written by the pre-service teachers at the very beginning of the NoS elective, prior to any instruction. On the penultimate day of the NoS elective the students completed the exit 'science is' statement. Examples of typical responses in each category are also illustrated in table 4.1.

Table 4.1 Categories and examples of responses from the initial and exit 'science is' statements

	Example of Responses Included in Each Category	
Category Title	**Initial Stage (Beginning of elective course)**	**Exit Stage (End of elective course)**
Human Endeavour (Human End.)	No comments	Each scientist has a different approach and perspective which can shed a different light on how we understand the way the world works
Scientific Inquiry	Study of the world around us through questioning, testing, estimating, making assumptions and reaching conclusions based on experiments	...it tries to determine if a crazy thought or idea is really valid and significant by investigating, gathering evidence, testing , making changes, re-testing and finally drawing conclusions
Science and Society	No comments	Science is influenced by sociology, culture, philosophy and context it is influenced by what's going on at that particular time in the world
Body of Knowledge (BoK)	Science is the study of plants, animals and various natural forces	It is a factual study with reliance on evidence and facts, which lead one to determine and understand process, which take place within the world and beyond. It allows us to comprehend the world

The responses made by the pre-service teachers to the 'Science is' statement at the initial and exit stages were compared. Table 4.1 illustrates the change in the responses given by these teachers at the initial and exit stages. Two new categories emerged at the exit stage (Figure 4.1). The same number of students responded in the *'body of knowledge'* and *'working scientifically'* categories at both stages. However, their responses at the exit stage were more indepth and revealed more elaborate understandings of these aspects of NoS.

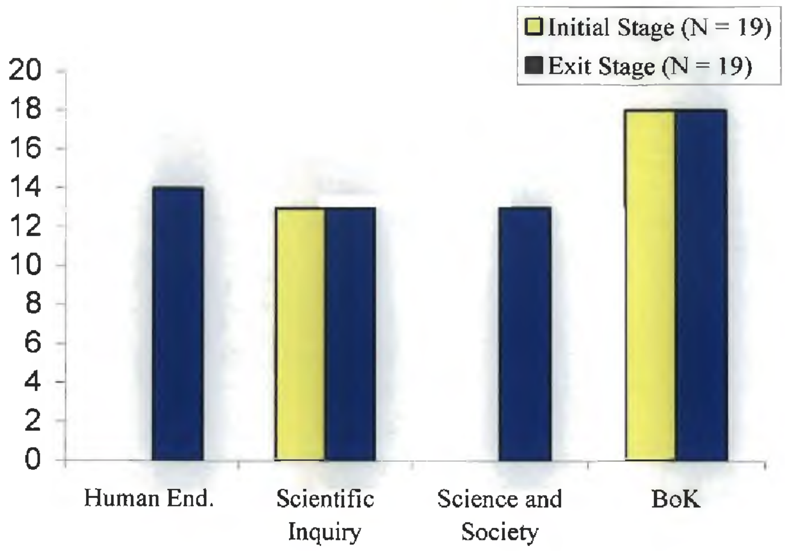

Figure 4.1 'Science is' statements: Comparison of frequency of responses between the initial and exit stages. N=19

The data obtained from the open-ended question, long range experiment (LRE), history of science (HoS) and the nature of science questionnaire (NOSQ), also indicated that the pre-service teachers had developed more elaborate conceptions of science as a human endeavour, scientific inquiry, science and society and science as a body of knowledge. The data will now be considered.

4.3 Human Endeavour

Science as a human endeavour was not mentioned by any student in the initial 'science is' statements. After the intervention however, 14 (74%) of the students wrote about some aspect of science as a human endeavour. The main aspects they mentioned were

- Subjective nature of science (53%)
- Science involves creativity and imagination (47%)

The responses at the exit stage were more elaborate and detailed, often referring to both aspects of science as a human endeavour:

> ...Science is about being creative, picking up where another scientist finished, finding flaws in other scientists' work... (Appendix B).

> Science is not just a body of facts. It is about being creative. Different people can look at science information and draw different conclusions from it. Science is subject to change. It is tentative. A science theory can change and develop throughout history..... A scientist can bring in prior knowledge and experience to draw their conclusions. It is active rather than passive (Appendix B).

These themes also emerged when the pre-service teachers reflected on their experiences gained from carrying out the long-range experiment (LRE) as part of their course work. In general they commented on what they (as people) brought to the experiment (63%), the subjective nature of data interpretation (42%) and the significance of creativity and imagination (74%). Their responses were detailed revealing elaborate understandings of science as a human endeavour (Appendix J).

Similar themes emerged in the history of science (HoS) reflections where all of the pre-service teachers maintained that incorporating HoS as part of science humanises science linking individual thinking with the development of scientific ideas. A considerably high percentage (79%) discussed how the history of science (HoS) portrays the creative and imaginative aspects of NoS. Similar to the response in the LRE, the responses in the HoS reflections regarding science as a human endeavour were comprehensive and portrayed more contemporary understandings of NoS.

> Justification for including these real life historical details stem from the fact that concepts did not happen by themselves. They came about because of man and therefore it seems logical to be exposed to the human dimension of science as it is essentially a human activity (Appendix J).

> It may not be very beneficial scientifically, to find out that Einstein formed a group of friends at college where they philosophised about life, but it shows that he was an ordinary person interacting with nature and trying hard to understand it. I am now able to put a face to the name and am aware of his contribution to science (Appendix J).

The pre-service teachers mentioned numerous scientific skills when reflecting on their long -range experiments (LRE) (Figure 4.2).

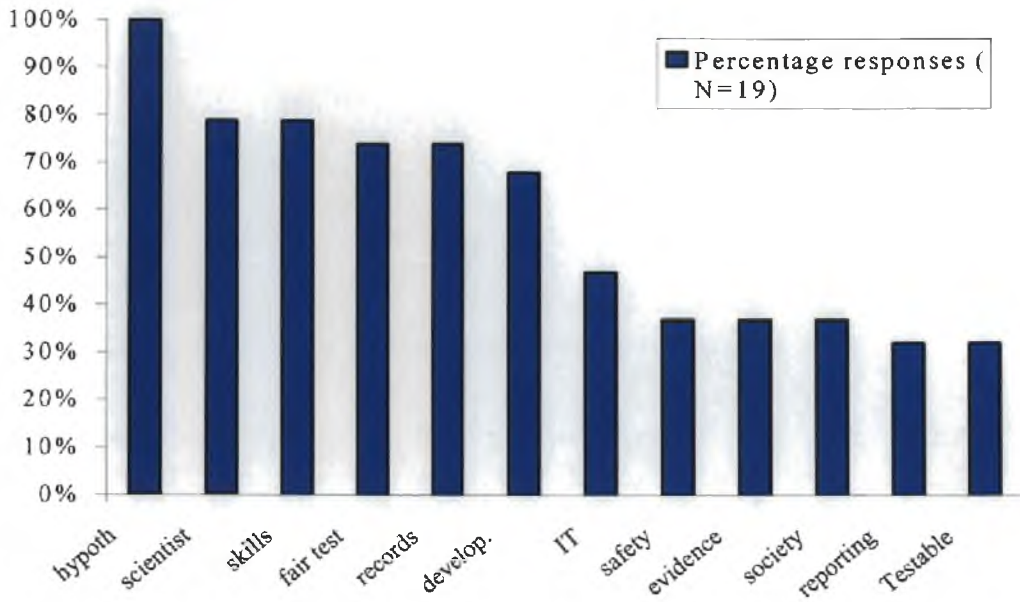

Figure 4.2 Long Range Experiment Reflections: Pre-service teachers' responses regarding scientific inquiry

However, it has to be acknowledged that some of these responses to the different categories were likely as they were suggested in the LRE guidelines (Appendix C). However, not only was there a high frequency of responses in many of the categories in the LRE reflections, the depth and detail of the responses indicated that these pre-service teachers appeared to be developing more elaborate understandings of the nature of scientific inquiry.

> I learned that initial hypotheses can be and were both rejected and accepted. I learned that the importance of identifying a rejected hypothesis as the foundation for a further hypothesis or investigation. The LRE highlighted for me the importance to reiterate to future pupils the value of rejected hypothesis, every experience has a learning opportunity (Appendix J).

> It is important to repeat experiments following strict procedures to try recreate the exact experiment and therefore the exact identical results. This needs to be done to ensure an experiment's validity (Appendix J).

In their history of science reflections (HoS), 68% of the respondents commented on how a knowledge of the HoS makes people more aware of the various skills and processes used by scientists in scientific inquiry. The HoS reflections also revealed that 89% of the pre-service teachers maintained that HoS illustrates and promotes an understanding of the tentative NoS.

> I believe that history of science…helps children discover the background and process approach of what science is highlighting …they (scientists) are both replicating and developing scientific work…through observing, inferring and concluding…(Appendix J).

In a similar manner the data from the NOSQ revealed highly elaborate conceptions of scientific inquiry. All of the pre-service teachers wrote about scientific inquiry in their questionnaires. The main aspects they mentioned were

- The differences between observations and inferences (100%)
- Science skills (87%)
- The role of evidence in establishing patterns (73%)

Responses relating to scientific inquiry in the NOSQ were also detailed and comprehensive, indicating contemporary understandings, for example:

> Scientists use evidence that they obtain from their observations of the sun using the evidence available to them the scientists have come up with a conclusion as to what the structure of the sun is, however, as more evidence, becomes available to them their ideas will change just as scientists knowledge of the different planets has changed (Appendix J).

4.5 Science and Society

There were no references to science and society in the 'science is' statement, at the initial stage, however, 68% of the pre-service teachers referred to this aspect of science at the exit stage. Typically the pre-service teachers reflected on how science and society influence and are influenced by one another, providing both negative and positive examples of each. The responses relating to science and society were also detailed and reflective, illustrating elaborate understandings of this aspect of NoS.

> It (science) relies heavily on contemporary culture and also on the values that have been passed on... The results of science weigh heavily on society and therefore everybody should have a good knowledge of what the process of science involves. If people in today's society do not understand the results of scientific decisions that were made in the past and the importance this has on culture even today, then they will not develop the ability to think about what science means, its philosophy, not just the answers it provides (Appendix J).

A small number of the pre-service teachers referred to science and society in their long-range experiment reflections. How the results of their LRE could potentially benefit society was referred to by 37% of the pre-service teachers. A slightly higher percentage (47%) of them reflected on technology they had utilised while conducting the LRE.

In their HoS reflections 89% of the pre-service teachers reflected on the importance HoS plays in raising awareness of the contributions science has made to society over the years and the influences society and culture have had on scientific advances.

> (HoS) Looks at the social and historical conditions that impacted, in a lot of cases quite severely, on the work of scientists, for example Darwin and his theories going against the bible or Galileo and his understanding of the earth orbiting around the sun as going against the church also (Appendix J).

The last question in the NOSQ required the pre-service teachers to reflect on science and society. The responses regarding science and society were elaborate. All of the pre-service teachers believed that science and society are affected by one another, and provided various examples to reinforce their viewpoints.

> I agree that science is affected by society and culture. Take the present day stem cell research. This is being directed by societal and culture influences. This most definitely is holding up scientific research in this area which no doubt would be far more advanced by this stage without societal and cultural influences (Appendix J).

4.6 Science as a Body of Knowledge

The data obtained from the open-ended question and NOSQ indicated that the pre-service teachers seemed to have developed more elaborate conceptions of science as a body of knowledge (BoK).

Science as a body of knowledge was referred to by 95% of the pre-service teachers in completing the 'science is ' statement at the initial and exit stage. At the initial stage, the main aspects regarding science as a body of knowledge mentioned were:

- Science as a body of knowledge (58%),
- Science explains phenomena (53%),

At the exit stage three aspects were referred to:

- Science as a reliable body of knowledge (74%),
- Science explains phenomena (63%),
- The tentative nature of scientific knowledge (68%).

While the data revealed the same percentage of responses at both stages, the reflections at the exit stage were more in-depth and provided more comprehensive accounts of the nature of scientific knowledge.

> Science is the study of living and non-living things. Science is the study of plants, animals and other natural forces (Initial statements) (Appendix J).

> Science is a process of understanding the world through various forms, biology, physics, chemistry and technology. It is the means by which one looks at the world... recognising understanding, how things are and how they work' (Exit statement) (Appendix J).

> Science is the search for meaning and truth through a process of questioning, philosophising...science attempts to explain all phenomena and all reactions that occur on this planet.. science is about opening your mind in an attempt to explain things (Exit statement) (Appendix J).

> Science is subject to change. It is tentative and science theory (has) changed and developed throughout history (Exit statement) (Appendix J).

The data from the NoSQ also revealed highly elaborate conceptions of science as a body of knowledge. All of the pre-service teachers referred to science as a reliable body of knowledge that was tentative and subject to change, which suggests that the pre-service teachers held more elaborate conceptions of science as a body of knowledge at the exit stage.

> Scientists cannot be 100% certain about the structure of the sun as they can't go inside it and observe it directly. However, they can use their scientific knowledge of materials, planets, reactions, theories, and come to fairly certain conclusions about its (sun) structure... through observations of the suns itself, their previous knowledge of reactions that take place they make inferences and predications on what goes on within the sun (Appendix J).

> Theories have to be able to be tested and re-tested using same procedures with the same results being drawn, if a theory is to be accepted... (Appendix J).

4.7 General Discussion

Contemporary NoS conceptions incorporate many beliefs about science. In chapter two an account of what primary teachers' and pupils' conceptions of NoS might entail was provided. Such conceptions include knowledge of science as a body of knowledge that has been validated by various processes that are generally embraced throughout the scientific community. Contemporary understandings affirm that scientific knowledge is testable and developmental and therefore subject to change. Those who hold contemporary NoS conceptions acknowledge the fact that science involves people and therefore creativity and imagination feature in determining scientific knowledge. Observations and inferences are involved in the process of arriving at theories and laws and although scientists are objective in their observations, inferences drawn from these observations are subjective (Abd-El-Khalick & Lederman, 2000a, 2000b). Those who have elaborate understandings of NoS are aware that society and culture affect science and that societal values have huge influences on scientific research and development (Driver et al., 1996). Elaborate NoS conceptions incorporate some knowledge of how the history, sociology and philosophy of science apply to and affect science (Mc Comas et al., 1998).

Many of the pre-service teachers' comments regarding science in the initial 'science is' statements were similar to Abell and Smith's (1992) findings. They reported that 61% of the pre-service primary teachers in their study depicted science as 'discovering or finding out about the world', while 58% referred to 'scientific knowledge' and the 'processes of science' frequently being mentioned in conjunction with both categories. The responses to the initial 'science is' statement made by the pre-service teachers in this study were similar in that 58% defined science as a body of knowledge, 53% described science as 'finding out about the world' and 68% referred to the 'processes of science'.

In a similar manner, in Murcia & Schibeci's (1999) study in Western Australia, 73 prospective primary teachers were asked to answer the question *'What is science?'*. The findings revealed that the participants in this study predominantly viewed science as a means of searching for explanations of every day life and as a process of discovering the 'truths' about the world. Murcia and Schibeci maintained that if students were given more opportunities to reflect upon and discuss the nature of the scientific enterprise, prospective primary teachers would develop more contemporary conceptions of NoS.

In the current study, the pre-service teachers' NoS conceptions had developed considerably after the intervention. Unlike the students in Spector and Strong's (2001) study the culture of the pre-service NoS elective students did not appear to 'clash' with the culture of science in terms of the ethical traditions of science or regarding teaching and learning. It was evident from the various individual reflections and written questionnaires, that the NoS elective students realised the tentative and developmental nature of scientific knowledge. Through the numerous class and group discussions held over the course of the NoS elective it was obvious that the pre-service teachers valued peer review. They were willing to make their work public unlike the students in Spector and Strong study, who preferred keeping their work private between the student and instructor.

As part of their course work the pre-service teachers had to give two group presentations to their peers. The first group presentation required the students to outline their Long Range Experiments (LRE) and to present their findings to the class. For the second presentation the pre-service teachers had to become familiar with the work and life of a particular scientist. They then had to make a presentation to the class regarding this scientist and discuss how various aspects of NoS affected the scientist's life and/or ideas. Although some of the student teachers were a little nervous when delivering these presentations, they embraced the tasks enthusiastically and talked about their work and findings with pride. Unlike their counterparts in the Spector and Strong study, they willingly answered questions about their LRE and were able to defend methods or decisions they had taken when questioned or challenged by their peers. The pre-service teachers reported their LRE results truthfully, drawing on their evidence, regardless of whether their hypotheses had been correct and acknowledging limitations of their experiments. Many of the issues that were raised by their peers during the oral presentations were addressed in the written reflections. The 'culture' of the elective students did not appear to 'clash' with the 'culture' of science in that they reported methods, procedures, and outcomes of their LRE truthfully rather than expecting to accommodate methods, procedure and outcomes to arrive at the 'right answer'. It is worth noting that the students did not receive any marks towards their final grade for the presentations. It is therefore likely that they provided genuine information about their experiences rather than information that they believed they should have been providing, to please the lecturer and to obtain 'high grades'. The elective students' empirical standards rather than personal beliefs and their explanations were consistent with data rather than their prior beliefs.

> I learned that the fact that some of our hypotheses were rejected does not make our LRE any less scientific...(Appendix J).

> We tried to make sure there was enough evidence to back up our inferences (Appendix J).

> Scientific knowledge should be supported by evidence (we used observation, record keeping and took photographs)(Appendix J).

With regard to teaching and learning again unlike the Spector and Strong study the culture of the NoS elective students did not appear to 'clash' with the culture of science in terms of teaching and learning. Over the course of the NoS elective the students were encouraged to challenge ideas put forward in the literature or by the lecturer. In every class the students were encouraged to ask questions. They were given the opportunity to conduct investigations to answer questions raised, again something that was not expected of the learners in the Spector and Strong study.

Group work and discussion were central features of the NoS elective and divergent thinking was encouraged. The elective students were exposed to numerous perspectives and interpretations regarding the nature of science, which they listened to and considered. The students written responses to the LRE, HoS, NOSQ and 'Science is' statements were in-depth and reflective indicating that the students' ideas had indeed been challenged and had developed (Appendix J).

The majority of the NoS elective students referred to the subjectivity of science and the value of multiple perspectives in their written and oral presentations of the LRE and HoS, whereas perceptions amongst the Spector and Strong sample, were that there was only one way to think about something. When conducting and reporting the LRE, the elective students were accountable for testing their explanations and the group dimension required the students to co-operate with each other in order to solve problems. This was in comparison to Spector and Strong's sample that tended to view scientific knowledge as static with the teacher's interpretation being the important one, and one that must be matched.

The written reflections and discussions gave the NoS elective students the opportunity to reflect and engage in meta-cognition. The depth of their responses in the written reflections over the course of the year revealed that their philosophies and conceptions regarding NoS had developed considerably after the intervention.

The data from the 'science is' statements, the LRE, the HoS and the NOSQ indicate that the pre-service teachers had begun developing more elaborate conceptions regarding the various aspects of NoS after the intervention. In a similar manner to their counterparts in other countries, (Akerson, Abd-El-Khalick, & Lederman 1999; Smith and Scharmann 2006; Craven et al., 2002), the use of explicit reflective approaches in teaching about NoS appear to have resulted in the development of more sophisticated conceptions of NoS amongst these Irish pre-service teachers.

5 NATURE OF SCIENCE AND PEDAGOGY

5.1 Overview of Chapter

The first section in this chapter presents and considers data gathered from the pre-service teachers over the course of their final teaching practice (Phase two), to ascertain their experiences and perceptions of explicitly teaching about NoS in primary schools. In the subsequent section data obtained from the reflective journals of four beginning teachers (two of whom had taken the NoS elective course in their final year and two whom had not) is compared (Phase three). This comparison considers the differences that existed between the test and control teachers' planning and teaching of science. The final section explores the extent to which the two test teachers' NoS conceptions changed and developed from their initial conceptions of science in phase one, to their final teaching practice and finally into their initial teaching year.

5.2 Phase Two: Teaching Practice

At the end of the second semester in the final year of the bachelor of education degree (B.Ed.), the pre-service teachers completed a compulsory four-week teaching practice. As part of the requirement for the elective course, the NoS elective students were required to plan and explicitly teach at least one aspect of NoS as part their science lessons during their final teaching practice. The pre-service teachers were teaching a range of classes from the initial to the final year of primary school.

As part of their NoS elective assessment the students were obliged to write an account of the aspect(s) of NoS they had addressed and the methods they had employed to teach and assess the development of their pupils' NoS understanding during teaching practice (Appendix, E). They were also required to submit a written report on their experiences of explicitly teaching NoS issues and comment on whether they believed NoS was an important aspect of the Science Curriculum (DES, 1999a).

The following aspects of NoS were included in the written plans and were explicitly addressed by the pre-service teachers over the course of their final teaching practice. It is important to note that despite only being asked to address one aspect of NoS, some of the pre-service teachers included more than one aspect in their written lesson plans:

- Scientific Inquiry 16 *(84%),*
- Human Endeavour 15 *(79%),*
- History of Science 15 *(53%),*
- Science and Society 6 *(32 %),*
- Science as a body of knowledge 4 *(21%).*

Within each of these categories the pre-service teachers explicitly referred to different aspects of the particular tenets. Out of the 16 students who explicitly addressed scientific inquiry in their final teaching practice, 15 of them referred to the development of scientific skills and processes and six of them explicitly addressed the testable and developmental nature of scientific inquiry. All of the pre-service teachers specifically referred to the children conducting hands-on investigations over the course of their final Teaching Practice:

> I got the children to hypothesise what they think an electric circuit would look like. They found this quite unusual as they were used to teachers just showing them diagrams of various science equipment and explaining it to them… (Appendix K).

> Scientific methods were referred to (by the children), ' making, finding, discovering, testing and creating things' along with 'mixing, making and inventing' and 'cool mixing chemicals (Appendix K).

The majority of these pre-service teachers (15) explicitly addressed science as a human endeavour in their teaching practice reflections. Out of these 15 students, 12 of them planned and addressed the subjective nature of science while 13 addressed the creative aspects of scientific inquiry:

> … I wanted to address how scientists infer and can draw different conclusions. The ambiguous pictures (tricky tracks, Lederman & Abd-El Khalick, 1998, p. 85) hit the nail on the head when it came to choosing an activity to teaching this concept to the children. Evaluating the ensuing discussion I judged that the objective for the lesson was achieved, by all the children in the class, by the way they agreed that scientists, just as they themselves had done, can infer and draw different conclusions… (Appendix K).

How science affects society was an aspect of science and society that was explicitly addressed by six of the students (32%), who referred to this aspect of NoS in their lesson plans:

> Regarding the debates we discussed regarding habitats, the children were not familiar with this side of science. They understood how 'plants and animals' are sometimes used for the advantage of humans. They are able to cite examples such as; the killing of animals for meat, how zoos are cruel in that they are there for human enjoyment. Through this way could see how science is part of social traditions, a major characteristic of the NoS (Appendix K).

History of science (HoS) was explicitly addressed by 10 (53%) of the students. Within this category aspects that were explicitly addressed included: Significant figures and events in the history of science, the development of technology, HoS humanising science, the tentative nature of scientific knowledge, and the history of science in society.

> Initially I focused on the history of science with the children. The lesson I taught on Volta and Edison was a high interest lesson for them. A full lesson was devoted to the topic as I felt I would not have been able to adequately cover the history of science tenet of the NoS teaching it as part of ongoing instruction i.e. alongside electricity. If I had the class for a year that would be different but not when I only had them for 4 weeks… during the next lesson I made reference to Volta and Edison.. This helped the children make the connection between our science lesson today (making circuits) and the hos lesson from the last

> day... I think the children looked at the resources in a different way because of the previous lesson and with a greater awareness, interest and appreciation of what they were working with (Appendix K).

We can see from the responses quoted above that these pre-service teachers addressed various aspects of NoS during their final teaching practice. Their reflections indicated that they had a good understanding of the various aspects they addressed. Their responses also suggest that they were aware of how to explicitly address aspects of NoS as part of the Science Curriculum. The specific examples regarding how and when they had explicitly addressed a particular aspect is evidence of this (Appendix K).

The pre-service teachers utilised different methodologies for teaching science and for explicitly teaching about the different aspects of NoS. These included; the use of pictures and photos, the children designing and making artefacts, discussion, games, Abd-El Khalick & Lederman's NoS activities (Abd-El Khalick & Lederman, 1998, p. 83-136; Appendix 9) hands-on investigative work, circle time, story and discussion. Many of them reflected on constructivist approaches to teaching science, referring to finding out the children's ideas, letting the children test their ideas through investigation. They also referred to various methods of assessment they had employed, including; 'think and draw' activities, discussion, question and answer sessions, concept mapping, brainstorm sessions, written explanations and language development:

> I also found out the children's prior conceptions and views of science at the start. I asked the children to draw me what they thought a scientists looked like...when I asked the children why they drew the scientists the way they did one girl replied. That's what they look like in cartoons, they are kind of weird...However, in the last discussion that I had with the class I noticed a significant change in the children's attitudes towards science. This change of attitude could also be recognised in some of the comments made by the children for example... I know that you don't have to be weird or really smart to do science, 'cos we can even do it.... (Appendix K).

> I found the constructivist approach effective when teaching the NoS i.e. starting with prior knowledge and original ideas, doing activities

> and altering conceptions if misconceptions originally held or reinforcing original ideas if contemporary notion of the NoS originally held by the children (Appendix K).

The reflections show that these teachers were utilising methodologies that they had been introduced to during their second year curriculum science course (e.g. different ways of finding out ideas, hands-on investigation, and assessment methods) and the third year elective (e.g. NoS activities, discussion, debates, HoS). They had the confidence to try new ideas when teaching science. All of the students attempted group work and facilitated their students in hands-on investigation. The students were confident about trying new methodologies and many mentioned that they felt more confident in teaching science as a result of taking the NoS elective:

> I found the teaching of science so much easier this time than on any other teaching practice as I felt more confident teaching since doing the science elective. I never included such concepts as the NoS before and I often just relied on the textbook material.. (Appendix K).

Another factor that was particularly pertinent in the teaching practice reflections was the ability of these pre-service teachers to reflect on their own teaching. Many of their reflections were in-depth and perceptive illustrating reflection skills that were perhaps more typical of practising than pre-service teachers:

> The characteristic of NoS that I choose to explore with my class was the tentative NoS. Looking back now I feel that I could have approached this aspect in a more effective way. I could have maybe had the lesson on Galileo validating Copernicus's theory near the start of my scheme instead of the end as I felt it would have been a more concrete and clear way to introduce the NoS...(Appendix K).

> On reflection I would have assigned more time, if not the majority of the lesson, to discuss the role of scientists and the worthiness of their jobs. While I did not rush this part of the lesson I didn't afford it or the children the time they deserved. I felt the discussion was of a high level and intense nature and could have continued on for longer had I permitted it...(Appendix K).

> What I did find difficult about NoS in the classroom was assessing it. The assessment I completed with the children really told me more about how their scientific knowledge changed rather than how their understanding of NoS had changed. (Appendix K).

These responses illustrate the capacity of these pre-service teachers to reflect on their own teaching. As well as reflecting on organisational issues, which is typical of novice teachers' reflections, (Fuller & Brown, 1975; Pollard & Tann, 1993) the elective students reflected on pedagogical issues. Their reflections illustrated the importance these pre-service teachers placed on assessment, reflection, and discussion as essential components of science classes. While all the teachers were positive about explicitly addressing NoS as part of the Science Curriculum they were realistic regarding the extent to which their pupils' NoS conceptions had developed over a limited period of a month:

> It would be naïve to think that their conceptions have developed to the maximum possible in such a limited time period, however, I do feel their opinions and conceptions have become more 'in tune' than at the beginning of teaching practice... I believe that as a result of their exposure to the various (NoS) activities their views did change. Perhaps changed is not the correct word, instead maybe the reviews are now more in tune with what they already innately know and are aware of. From overhearing different conversations while they experimented, I believe that the children are definitely more aware of the interconnectedness of NoS. For example how technology, history and creativity and imagination are interwoven throughout (Appendix K).

All of the pre-service teachers maintained that explicitly teaching about NoS as part of the Science Curriculum was important and numerous benefits for explicitly addressing NoS aspects as part of the Science Curriculum (DES, 1999a) were cited. Figure 5.1 summarises their responses.

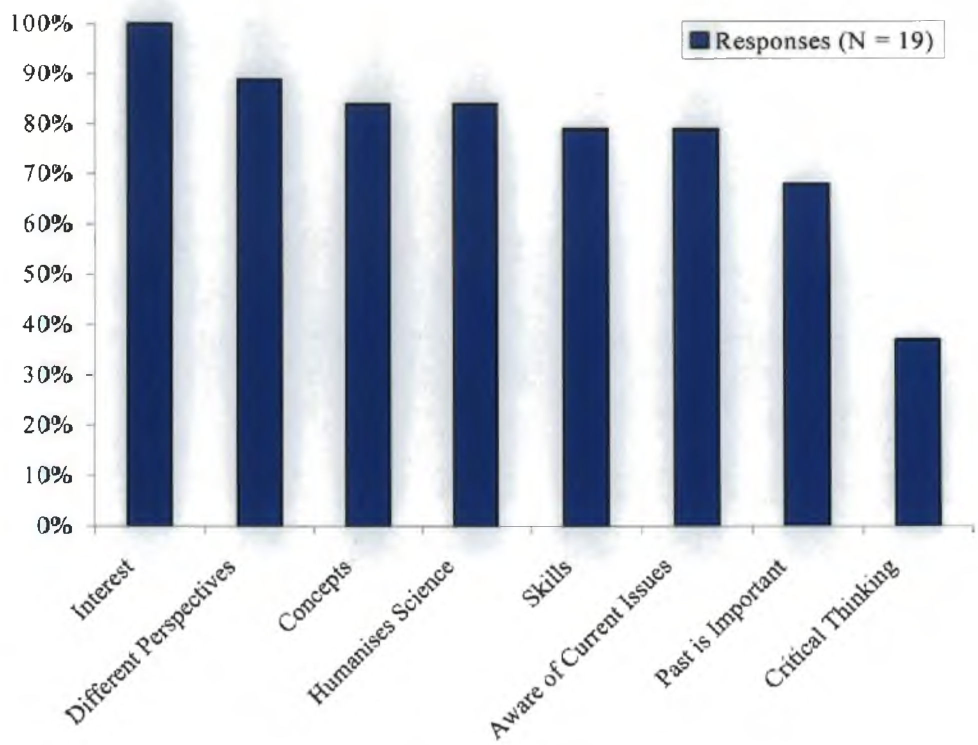

Figure 5.1 Teaching practice reflections: Why is NoS important in the primary science curriculum?

The pre-service teachers' written reflections show a strong consensus regarding the numerous benefits of explicitly addressing NoS as part of the 1999 Science Curriculum (DES, 1999a). Many of the advantages of explicitly teaching NoS that the pre-service teachers cited are in keeping with findings in the research literature. For example explicitly addressing NoS as a means of helping students to become aware of science as a human endeavour was something that Lederman et al., 2002; Matthews, 1994; Mc Comas, 1998; Abd- el Khalick, 2005 asserted. A very high percentage (84 percent) of the elective students referred to this in their teaching practice (TP) reflections.

> I took cognisance of the fact that it humanised the concept for the children. It helped the children make the connection between the development of individual thinking with the development of scientific ideas making it more engaging for them and therefore aiding scientific understanding. (Appendix K)

Explicitly addressing NoS in science classes, making science interesting and therefore enabling students to learn scientific concepts and skills with greater ease was mentioned by all of the elective students in their responses and affirmed by Abd-El-Khalick (2005), Huann-shyang et al. (2002) and Matthews (1994).

> I think that it (NoS) evokes the interest of the children in the subject and that it helps them engage with and learn science content more successfully and in a more enjoyable way... I also feel that it helps students develop a more open mind towards the subject and they can make connections within the subject and it doesn't appear to be 'airy-fairy'... makes the subject seem real and something that they can engage with and do. I also think it helps them see the impact of science throughout the world today and in the past... more aware of and understand scientific issues... but above all I feel teaching the NoS would lead to the children learning, understanding and enjoying science more (Appendix K).

Explicit reflective approaches to teaching about NoS and the advantages of these approaches in developing students' personal philosophies and thinking skills were referred to by the elective students, and were benefits of explicit NoS instruction outlined in Abd-El-Khalick (2005), Lederman et al. (2000) and Matthews (1994).

> They moved from thinking science was stuck in a laboratory testing various liquids to seeing that science was something more creative (Appendix K).

> I found it easy to explore the NoS with these children as they were willing to discuss and had opinions (Appendix K).

Many of the elective students (79 percent) maintained that explicitly addressing NoS made students more aware of current scientific issues in society and 90 percent specifically stated that teaching about NoS explicitly gave students broader and more elaborate understandings of the nature of science.

> I think that students would be in a better position to understand and appreciate how scientifically advanced we are today by analysing the

> scientists of the past in a more comprehensive way. By taking philosophical, historical sociological and psychological factors into account we could get to know the 'whole' scientists and not just his / her work in isolation. It is very important to view science as dynamic rather than static, after all we are living in a changing world... (Appendix K).

While these findings appear to be encouraging there are a number of issues that need to be considered. Firstly, these pre-service teachers were required to plan and explicitly teach an aspect of NoS over the course of their final teaching practice. Whether these pre-service teachers would elect to plan and explicitly address aspects of NoS as practising teachers needs to be considered.

Secondly, based on their teaching practice experiences, these pre-service teachers maintained there were numerous benefits to be gained from explicitly teaching NoS. However, it is important to note here that the students' teaching practice reflections were graded and therefore their responses may have been more indicative of responses that would please the lecturer, rather than their actual experiences. Secondly, it is difficult to establish whether their pupils had actually gained from any of these benefits, as no formal assessment of the pupils' NoS conceptions was conducted.

The next section examines data that was collected from four beginning teachers, in their initial teaching year. Two of these teachers had taken the NoS elective course.

5.3 Phase Three: Beginning Teachers

The third phase of the study was school-based and four beginning teachers, who had graduated from the same college of education, took part in this phase. All four of these beginning teachers had taken the curriculum science course in their second year of college. Two of these beginning teachers had taken the NoS elective the previous year (test teachers) and two had taken a different elective course (control teachers). The sample comprised four primary classes, two third (eight - nine years old) and two fourth (nine - ten years old) classes. One test and one control teacher taught each class grouping (Table 5.1).

Table 5.1 Phase three: The classes taught by the beginning teachers

Test Teacher 1 (T1)	**Test Teacher 2 (T2)**	**Control Teacher 1 (C1)**	**Control Teacher 2 (C2)**
Third Class	Fourth Class	Third Class	Fourth Class

The four beginning teachers were asked to plan and teach science as was required by the Science Curriculum (DES, 1999a). In addition to this they were asked to complete a 'Reflective Journal' (Appendix H), which required that on five specified weeks over the course of the second term the teachers were asked to reflect on seven questions regarding their teaching of science for the particular week. The second term was chosen to allow the beginning teachers a 'settling in' period and indeed time to devise their lesson plans and schemes of work.

The purpose of these reflective journals was threefold:

- To establish any differences between the test and control group in terms of their planning of and methodologies utilised to teach science.
- To gain an insight into the aspects of NoS that were explicitly addressed and the extent to which they were addressed.
- To establish the extent to which the test teachers' NoS conceptions had changed and/or developed from the initial 'science is ' statement (phase one), to their final teaching practice (phase 2) and into their initial teaching year (phase 3).

The reflective diaries from the test and control teachers were analysed and compared. The findings revealed that there appeared to be considerable differences between the test and control teachers' reflections regarding teaching NoS as part of the science curriculum, perhaps not surprisingly as the test group had taken the NoS elective. However, there also appeared to be substantial differences between the test and control teachers' philosophies regarding teaching and learning in general. This was a particularly unexpected finding as teachers in both groups, with the exception of the third year elective, had taken the same education courses and had completed similar teaching practice placements over the course of their three-year degree. This section will therefore open with an exploration of the test and control teachers responses regarding teaching and learning of science and subsequently the extent to which these beginning teachers explicitly addressed NoS aspects in their teaching will be considered. An overview of how the test teachers' NoS conceptions have changed and developed over the course of the two-year study will be provided in the final section.

5.3.1 Beginning Teachers' Reflections on Teaching and Learning of Science

In this section a general overview of the findings from the test and control teachers' reflective journals (Appendix H) will be presented. The responses to the seven questions the teachers reflected on will be considered in turn.

Question 1: What topics did I work on?

All four teachers taught strand units (topics) that were taken from the Science Curriculum (DES, 1999a). Topics that were taught by the four teachers included electricity and magnetism, forces, sound, human life (healthy eating and teeth) environmental awareness and care, properties and characteristics of materials. The two teachers who had not taken the NoS elective course (control teachers) did not include any elements of NoS when answering this question. In answering question one, the teachers in the control group stated the strand and strand unit which they had covered in the particular week. They did not elaborate on which aspects of the topics they had taught nor did they refer to any of the science skills outlined in the Science Curriculum (DES, 1999a).

> 'Strand: Materials properties and characteristics of materials 3': Control teacher third class (C1) (Appendix H).

> 'Living Things: Human Life: Teeth': Control teacher fourth class (C2) (Appendix H).

The teachers in the test group (who had taken the NoS elective) were also utilising the Science Curriculum (GoI, 1999). However, their responses to the first question were considerably more detailed and unlike the control group, referred to the scientific concepts and skills outlined in the curriculum. They also included aspects of NoS they had addressed as an integral part of the particular strand unit for the particular week in question.

> 'Energy and Forces: Magnetism and Electricity. Explore and appreciate the influence that scientific and technological development has on societies through comparisons of past and present technology': Test teacher third class (T1) (Appendix H).

> 'Energy and Forces: Electricity. Science and Society. Philosophy of Science: what if there was no electricity today? How would it affect our lives and the way we live? Skills Development: General introduction and look at the nature of Science. Involved a lot of discussion, observation, questions and analysing... tentative nature of Science observation versus inference, body of reliable information, how we can observe/look at the same piece of evidence but yet come to different conclusions/inferences. ': (Test teacher fourth class (T2) (Appendix H).

The test teachers' responses were considerably more detailed than those of the control teachers and indicated that they had knowingly introduced their pupils to a more extensive range of scientific ideas and skills than their peers in the control group. The four teachers were following the Science Curriculum (DES, 1999) which emphasises the importance of the development of scientific concepts and skills throughout. The control teachers did not refer to any of the science skills when answering this question

It is important to acknowledge however, that the control teachers may not have felt it relevant to mention science skills, as the question referred to which 'topics' they had addressed (the control group did refer to science skills that were addressed in response to other questions). However, the fact that the test teachers referred to science skills, concepts and aspects of NoS when asked about 'topics addressed' suggests, that their inherent conceptions regarding the teaching of science, appear to be more in keeping with the Science Curriculum (DES, 1999a, page 5) and indeed the current literature (AAAS, 1990; Driver, 1983; Gega & Peters, 1998, Harlen, 1993;), which consider the development of scientific concepts and skills to be equally important.

Question 2: Which specific aspect(s) of scientific investigation were addressed?

The four teachers referred to various science skills outlined in the Science Curriculum (DES, 1999a). The control teachers' responses to question two were not as detailed as the test teachers' responses and tended to adhere entirely to the curriculum. One of the teachers in the control group (C1) used objectives taken directly from the curriculum documents that referred to a scientific investigation she had covered.

> Exploring how objects may be moved. Exploring how a moving object can be slowed down. Discovering the effect of friction on a moving object (C1) (Appendix H).

The second control teacher (C2) recounted activities the children had done in science class.

> The children looked at each other's teeth so as to work out how many teeth a child has and also the different types. The children also examined their own teeth using their finger (C2) (Appendix H).

The teachers in the test group also referred to scientific skills that were outlined in the curriculum documents. However, unlike the control teachers they elaborated on and gave specific examples of how their pupils had employed these skills while engaging with different scientific concepts.

> Predicting: will the bulb light? Analysing; sorting and classifying as conductors and insulators. Design: planning, making. Recording and communicating: record how they make their circuit. Use annotated drawings (T2) (Appendix H).

The fact that the teachers in the test group were more specific about the aspects of scientific inquiry that they had addressed and their provision of examples suggested that they appeared to be aware of which skills the activities and investigations addressed. Neither teacher in the control group provided examples, which could suggest their uncertainty regarding how and when their pupils were utilising the various science skills.

Constructivist theorists assert that when children are provided with opportunities to discuss and defend their ideas, these discussions help scaffold their ideas, which in turn lead to improved understanding. In a similar manner Pollard and Tann (1993) maintain that pupil discussion is particularly important as an essential component in the interchange of ideas and understandings and is therefore essential in a reflective teaching-learning process. It was evident from the test teachers' responses to question two that discussion formed an integral part of their science classes, something that was not evident in the control teachers' reflections. The responses illustrated that the teachers in the test group provided their pupils with numerous opportunities for reflection and discussion throughout the science classes.

> Discussion on the role or impact of scientists in modern society in terms of technical advancements. Briefly discussed Galileo's discoveries and how he might have worked: planning, making. 'Tricky Tracks' image was then used and discussed. Comparisons drawn to work of scientists (T1) (Appendix H).

> Linking Science and electricity to every day life. The positive role that electricity has played in our society and how we live: Questioning, predicting, hypothesising, analysing... life without electricity (T2) (Appendix H).

In the final week the teachers were asked to reflect on which science skills they believed their pupils had developed over the course of the study. The teachers in the control group listed a number of skills from the Science Curriculum that they believed their pupils had developed. However, they gave no examples of when and how their pupils had developed or applied the skills.

> I feel that the skills of observing, predicting, investigating and experimenting, analysing: (sorting/classifying) and recording have been best developed during the year so far. Each lesson in Science involves most if not all of these skills. (C1) (Appendix H).

> ...activity to predict. Investigation skills. Questioning and also explanatory skills. Recording skills. (C2) (Appendix H).

On the other hand the responses from the test teachers were considerably more detailed and reflective. They mentioned the skills they believed their pupils had developed and gave elaborate accounts of why they believed their pupils had developed these skills.

> A wide range of Science skills has been effectively developed over the course of the year, from questioning, analysing to recording and communicating. If I was to pick one it would be analysing. I firmly believe that the children now have a more structured approach to how they analyse. Methodologies which I have used through the incorporation of NoS in my class have greatly aided the development of Science skill I believe (T2) (Appendix H).

> Predicting: The children developed a great sense of predicting through their efforts to complete the whole picture using a small sample (T1) (Appendix H).

These responses suggest that the test teachers showed a better understanding of the different science skills and the detail of what each one entailed, than the control teachers did. The responses to question two also indicate that the test teachers displayed an awareness of when and how their pupils were applying and developing the different skills during science class, again something that was not evident from the control teachers' responses.

Question 3: How did the pupils respond? Please comment.

In addressing this question all four teachers referred to the children enjoying science and finding science interesting. Both teachers in the control group tended to recall activities and concepts they had taught during the various science classes and commented on how their pupils had enjoyed or had expressed interest in them.

> I showed the children a number of objects – sheet of paper, scrunched paper, a sponge ball, plastic ball, tennis ball, medium-sized sponge ball and a straw. In groups they were asked to design a fair test to find out which object falls the fastest and slowest. They predicted before testing. Groups worked very well together, having one person as the dropper, one timer and one recorder... They found the activity very enjoyable (T1) (Appendix H).

One teacher in the control group (C1) recalled elements the children could do well and elements they had difficulty doing. The majority of this teacher's (C1) responses to this question tended to provide a summary of what had been covered in each lesson. There were fewer comments relating to how the children had responded to the lesson.

> Children were given a picture of a construction site and were able to locate the materials found and also why certain materials were used for a specific purpose. Children were asked to sort various solids, liquids and gases into groups. They came up with various group names such as food, drinks, wet objects and hard objects. When I discussed the groups further they came up with solids and liquids but they did not use the term gas (C1) (Appendix H).

The second teacher in the control group (C2) recalled how her pupils had enjoyed science and found science lessons interesting. This teacher provided specific examples:

> The children found it very interesting and some boys – especially the 'sports enthusiasts' in the class – found it very exciting. They liked comparing their diets also to see who had the healthiest one (C2) (Appendix H).

In addition to referring to particular activities that their pupils had enjoyed and were enthusiastic about or scientific concepts their pupils had grasped, the test teachers also reflected on their pupils becoming more inquisitive and more aware of NoS.

> Immediately a lot of the pupils drew references to the work of scientists while designing their insulators.... They were enthusiastic about the content taught. Most of the children became rather inquisitive about the scientist and were enlightened I felt about how this scientist had a very normal background....By drawing comparisons of their work to scientists, I believe the children have gained a huge insight into the work of scientists (T1) (Appendix H).

The test teachers also reflected on how their pupils responded to various discussions that had occurred during the science classes, particularly in relation to aspects of the HoS and the contributions science (and technology) have made to society.

> The pupils responded well to this lesson. They were full of enthusiasm and excitement about electricity and the light bulb. A lot of the pupils were very inquisitive about why Edison was interested in electricity and light. The children seemed to be enlightened by the developments made by the light bulb through time (T1) (Appendix H).

> The children loved making the circuits and the whole hands-on approach. There was some excellent discussion amongst the group on how best to design and make a conductor/insulator test (T2) (Appendix H).

Social constructivist theories highlight the importance of social interaction and the role of language in children's learning. The test teachers' responses to this question again illustrate the emphasis the test teachers placed on discussion and the development of their pupils' thinking skills throughout the science lessons. This was unlike the teachers in the Galton and co-workers (1980) study who rarely provided their pupils with opportunities to reflect on open-ended problem-solving questions or tasks.

In a similar manner to the responses to question two, the test teachers' responses to the question regarding how their pupils responded, also illustrate that the test teachers appeared to be more aware of the children developing and applying science skills. Both test teachers provided ample specific examples of when their pupils had utilised their science skills. The examples provided indicate that not only did the test teachers provide their pupils with opportunities to engage in scientific inquiry, they were also aware of when various scientific skills were being utilised.

Question 4: What was my view of the lesson (strengths/ weaknesses?) Please comment

The responses to question four indicated that all four teachers were very positive about teaching science. Amongst the strengths discussed by all four teachers included their pupils enjoying science, being engaged in science lessons, group work and the development of science skills.

> They found it a fun activity.... The children found it very interesting and some boys – especially the 'sports enthusiasts' in the class – found it very exciting... (C2) (Appendix H).

> They responded very well. They enjoyed the fact that they quite often drew different but yet equally acceptable conclusions to the various investigations (T2) (Appendix H).

> Children thoroughly enjoyed these lessons as they were practically involved in predicting, observing, recording and evaluating (C1) (Appendix H).

Many of the test teachers' responses regarding the strengths of the lessons were more reflective and perceptive than the control teachers' responses. For example, in addition to considering organisational and management issues, the test teachers again in response to this question, reflected on how they had facilitated the development of their pupils' learning and thinking skills.

> Strengths: not giving much away and letting the children (do the talking). Using concept maps and brainstorming the class on their prior knowledge of electricity. It brought up some interesting misconceptions but also gave a good point from which to start (T2) (Appendix H).

> I thought that this lesson went well as the story of Thomas Edison really brought the concept to life. It attached humanity and reality I felt to the content. The children really engaged with this inventor and enjoyed listening to his story (T1) (Appendix H).

The test teachers' comments illustrate that in addition to reflecting on methodological and organisational strategies in a particular lesson, they had begun reflecting in broader terms on how they could foster the learning and development of thinking skills. The test teachers' reflections also indicated that they were employing constructivist approaches to learning in that they were finding out the children's ideas prior to introducing a new concept.

Another thing that is worth noting is that many of the test teachers' more philosophical reflections and examples provided, were related to aspects of NoS. Indeed many of the instances when the pupils in the test group were engaged in discussion and reflection were in relation to NoS.

> Due to the discussions on the NoS dealing with the scientists lives etc., I feel the children no longer view technological advancements made in the past as merely 'just appearing'. Instead they now view them as being developed and re-developed throughout time. They now attach a sense of humanity to Science rather than observing facts as isolated items. I believe the children now feel they too can be scientists and play an active role in shaping the world (T1)(Appendix H).

> The incorporation of NoS has helped to give a human side to Science, to make it more accessible and enjoyable to the children by linking it with every day life, showing the effects that society played on the lives of famous scientists, how these scientists lived lives that were very similar to ours... (T2) (Appendix H).

The control teachers' comments on the other hand were less reflective and tended to focus on strengths that revolved around successful methodologies in a particular lesson. When referring to strengths of lessons, their responses were often general with no provision of specific examples to highlight particular points.

> Children were actively involved in each lesson both visually and physically (C1) (Appendix H).

> I felt the children reacted very well to the 'hands-on' approach of examining their teeth (C2) (Appendix H).

Three out of four of the teachers referred to weaknesses in their science lessons. One of the teachers in the control group (C1) did not refer to any weaknesses. Weaknesses that were referred to included poor management and organisational skills and insufficient resources.

> The main weakness was that I didn't have enough of magnets, so each group had to take turns using them, which left some groups waiting (C2) (Appendix H).

> Weakness: When I originally had the children designing and making using the K'NEX packs, I did not get them to draw or make a plan of what they intended to make. This might have helped them to get used to the actual criteria of the K'NEX challenge itself. (T2) (Appendix H).

The issues these beginning teachers reflected on as weaknesses in their lessons were typical of many beginning teachers (Akerson et al., 2000; Fuller & Brown, 1975; Pollard & Tann, 1993)

Question 5: In what way(s) can I improve the way I work with the pupils?

In general the comments made by the control teachers to this question were related to organisational issues. For example allowing the children more time to finish their work, smaller groupings, having sufficient materials for experiments, planning for earlier finishers.

> Children could have been given more time to record their findings as some children did not get to complete the worksheet where they were asked to write why they think certain objects are made from plastic, glass or paper (C1) (Appendix H).

> By making sure I have enough materials to keep each group busy (or else to make the groups bigger so that I'd need less magnets (C2) (Appendix H).

These responses indicated that the control teachers had reflected on their science lessons and were capable of recognising aspects of various lessons that needed to be altered in the future. Their responses referred specifically to particular aspects of the science lessons, the majority of which related to organisational issues that could be improved in future lessons. Reflecting on organisational issues is something that appears to be prevalent amongst beginning teachers (Akerson et al., 2000; Fuller & Brown, 1975; Trumbull et al., 2006).

The test teachers also referred to (but to a lesser extent) how they might improve their organisational strategies in future lessons.

> I could have allowed the children more time to invent their ideas on what the image was about (T1) (Appendix H).

> Go through the different pieces in the K'NEX packs so that the children know what each piece is for and what it could be used for (T2) (Appendix H).

However, in addition to reflecting on organisational strategies, the test teachers also reflected on how they might improve or develop their teaching strategies,

> I thought that I could have allowed the children to do more 'hands-on' work when it came to drawing similarities and differences in both past and present kitchens, perhaps allowing the children to search for the images and maybe in groups designing an invention timeline throughout the ages, focusing on one invention… (T1) (Appendix H).

They also referred to how they might have improved on how they facilitated their pupils in taking a greater responsibility for their own learning.

> I thought that I could have allowed the children to explore this scientist on the Internet by themselves and discover items or details that they would have been interested in discovering... ....I should have allowed them to guess or discover how this problem applies to scientists and their findings, rather than explaining it to them. But I felt at the time I really had to guide them or direct them to think about the work of a scientist in having this problem.... (T1) (Appendix H).

> It would be nice to record some of the discussion that went on using a tape recorder as well as just through written work so that the children could have another source with which to relay how their opinions and learning has changed (T2) (Appendix H).

These responses are a further illustration of the test teachers' understanding and employment of constructivist approaches. Dewey (1933) maintained that eagerness to partake in continuous self- assessment and development was an essential quality of a reflective teacher. The test teachers' more detailed responses appeared to indicate that they were eager to assess their teaching. In addition to this the test teachers were observing, assessing and reviewing their practice, which according to Pollard and Tann (1993) are characteristics of competent reflective teachers.

Question 6: Using the experience gained, how would I approach my teaching of this topic / area in the future?

In response to this question the teachers in the control group again tended to refer to organisational issues that were related to particular lessons.

> Would have a metal spoon and a wooden spoon and I would put them on the radiator showing the children the effect of heat on these materials (C1) (Appendix H).

> Give children more time when investigating. Allow children to investigate everything first, before reading the text (C2) (Appendix H).

When reflecting on this question in the final week, one of the control teachers (C1) mentioned that she would do more design and make activities, try to integrate science with other curriculum areas, and make more use of concept maps.

> To engage in the designing and making process. I would also try to connect topics explored with other topics and across the curriculum. I think allowing children to make drawings shows their understanding of a particular topic as well as using semantic maps (C1) (Appendix H).

In response to this question, the test teachers reflected on facilitating their pupils' learning in science, rather than commenting on organisational and management skills. One of the test teachers reflected on how teaching about the history of science helped contextualise science for her pupils, and made different topics more interesting and tangible for the pupils.

> I really thought that the children benefited from exploring this scientist in this particular context, i.e. we were just after completing various experiments on sound. They could relate more to the scientist as a result. This has taught me to incorporate the scientist explored into the curriculum area being explored... In teaching electricity to the pupils, I found that discussing the inventor of the light bulb had an enormous effect on the content 'Electricity' for the pupils. The story of Thomas Edison really added a sense of humanity and brought I felt a great deal of reality to this area (T1) (Appendix H).

Constructivist theories of learning view students as active learners and constructors of understanding. Both test teachers commented on how they would try to enable their pupils to take more responsibility in their learning, something that neither teacher in the control group did.

> I will plan to ask more questions in my next lesson and get the children themselves to draw references or comparisons between the concept/idea taught and the work of a scientist (T1) (Appendix H).

> As much hands-on experience as possible. Allow the children to develop their own learning (T2) (Appendix H).

When responding to this question in the final week, both teachers in the test group were particularly positive about incorporating NoS as part of the Science Curriculum (DES, 1999a) and reflected in detail on how its incorporation benefited their pupils

> In general I thought that teaching NoS as part of the Science curriculum was beneficial in many ways. In areas such as 'Electricity' and 'Sound' I thought the inventors explored, have really brought the content in both areas to life. I would definitely incorporate this into my Science scheme. It brought out great enthusiasm among the children and I felt the children were rather enlightened by these inventors (T) (Appendix H).

The responses from the test teachers to this question were again indicative of more refined and comprehensive conceptions of progressive models of teaching science, of how children learn science and indeed more profound understandings of teaching and learning in general. Their reflections were more profound and indicative of more experienced teachers. (Akerson et al., 2000; Fuller & Brown, 1975; Pollard and Tann, 1993)

Question 7: What did the pupils experience/learn as a result of my work on this topic so far?

In response to this question, both control teachers referred exclusively to science concepts that they had taught during the lesson.

> They learned that every object can be classified/put into a group ... metal, glass, etc ... We discussed the use of metal and why some materials are/are not made from metal – focusing on the saucepan – children were able to deduce why a saucepan is made from metal and why the handle of a saucepan is not made from metal (C1) (Appendix H).

> The importance of a balanced diet. Why a certain amount of each food type is required. Understand the right amounts of each food group that should be taken each day, i.e. portions (C2) (Appendix H)

Both control teachers briefly referred to the children enjoying science and working in groups.

> They have experienced fun and enjoyment in discovering working in groups during Science lessons (C1) (Appendix H).

> That Science is a subject that can have a very 'hands-on' and 'fun' aspect to it. That 'teamwork' is often very important in solving questions/problems/experiments (C2) (Appendix H).

One of the control teachers (C2) also briefly referred to the children developing science skills over the course of the year:

> The value of recording predictions, methods and outcomes (C2) (Appendix H)

The test teachers also referred to science concepts that the children had learned. However, they also gave detailed accounts of how their pupils had developed more contemporary concepts of NoS and reflected on the different science skills the children had applied and developed and different methods of scientific inquiry the children had employed over the course of the study.

> The pupils learned that scientists have a particular motive for doing or discovering things. Also, that their work requires much planning and re-planning and that they do not always succeed in the beginning...Due to the discussions on the NoS dealing with the scientists lives etc., I feel the children no longer view technological advancements made in the past as merely 'just appearing'. Instead they now view them as being developed and re-developed throughout time. They now attach a sense of humanity to Science rather than observing facts as isolated items. I believe the children now feel they too can be scientists and play an active role in shaping the world (T1) (Appendix H).

> That observing and inferring are two different things. It also helped to humanise Science more in a way. They liked the fact that they were

> involved in questioning, analysing, observing and inferring just like scientists do in real life. They enjoyed the role of investigating – being part of a team that gathers the evidence, observes it, analyses it and makes predictions/inferences based on the evidence...The incorporation of NoS has helped to give a human side to Science, to make it more accessible and enjoyable to the children by linking it with every day life, showing the effects that society played on the lives of famous scientists, how these scientists lived lives that were very similar to ours (T2) (Appendix H).

The control teachers' responses to question one and five focused on the learning of science content rather than skills. These responses could be an indication that the control teachers prioritised the learning of scientific concepts over the development of scientific skills. This is a characteristic of behaviourist models of learning where teachers transferring knowledge in a whole class situation dominate teaching.

The test teachers' responses on the other hand indicated that they focused on the development of science concepts and skills as well as incorporating discussion and activities relating to aspects of NoS. Their responses appear to be more focused on 'child-centred' approaches to learning, where the objective of lessons is the development of independent self-activity and the teacher's role is one that presents pupils with ideas and materials that are meaningful and relevant. The test teachers' responses to question five again were considerably more detailed and reflective than those of the control teachers. They acknowledged the importance and benefits of discussion for helping the children to understand and consider their ideas and reflected on the effectiveness of hands-on inquiry in developing the children's skills and knowledge. Discussion is something both test teachers maintained make science more accessible and learning more enjoyable and relevant to pupils. The test teachers' responses to the fifth question again illustrate elaborate understandings of constructivist theories of learning and their ability to reflect on teaching and learning in a manner that is more in keeping with experienced teachers than beginning teachers.

Discussion

It was evident from the written responses in the teachers' journals that all of these beginning teachers were implementing the Science Curriculum (DES, 1999a) and were using hands-on approaches to science. The reflective journals illustrate that the four teachers were conscientious about their planning and that their pupils appeared to enjoy science in school and were enthusiastic about taking part.

The control teachers had not taken the NoS elective course the previous year nor did they specifically refer to any aspect of NoS in their responses. They did not plan or explicitly address NoS. Where aspects of NoS may have been addressed, these were done implicitly. For example the children were given numerous opportunities to conduct hands-on experiments where they utilised various scientific skills. The teachers in the control groups conducted some fair test investigations with their pupils and the children utilised science skills such as observing, predicting, measuring, recording and communicating. However, the teachers did not apparently ask the pupils to reflect on these skills nor relate them to how scientists use these skills during scientific inquiry.

The teachers in the test group had taken the NoS elective the previous year and in a similar manner to their peers in the control group, were implementing the Science Curriculum (DES, 1999a). In addition to the experiments and investigations regarding specific scientific concepts outlined in the curriculum, the test teachers utilised many additional activities that explicitly addressed various NoS issues. Both test teachers incorporated aspects from the history of science in their science lessons and discussion and reflection formed a central component of every science lesson.

In general the test teachers' written responses were more detailed and reflective than those of the control teachers. The test teachers' intrinsic conceptions regarding the teaching and learning of science appeared to be more in keeping with constructivist approaches to teaching and learning science outlined in the Science Curriculum (DES, 1999a). This evidenced itself in the way the test teachers tended to comment on the children developing scientific knowledge and skills and developing conceptions regarding NoS. The control teachers on the other hand tended to comment on their pupils acquiring conceptual knowledge, unless specifically asked about scientific skills. The control teachers' intrinsic conceptions regarding teaching and learning science appeared to be primarily concerned with the comprehension of scientific concepts, characteristic of behaviourist models of learning.

When specifically asked about science skills, all four teachers referred to science skills their pupils had employed during science class. The test teachers' responses however, indicated that they appeared to have a better understanding of scientific skills, in that when referring to the various skills that their pupils were applying and developing, they provided examples and reflected on how the skills were being developed. The control teachers did not provide examples nor did they elaborate on how their pupils had applied the science skills.

Both test and control groups adhered to the Curriculum Guidelines (DES, 1999b). However, in addition to the content outlined in the curriculum guidelines, the test group introduced a more extensive range of additional activities and ideas regarding science. The test teachers afforded their pupils numerous opportunities to discuss and reflect on these ideas. They displayed the confidence to allow their pupils to discuss various issues, and appeared to be unperturbed by the questions their pupils might raise, a confidence that is more common amongst experienced teachers than beginning ones (Fuller & Brown, 1975). The test teachers maintained discussion and reflection were important components in science class and both remarked on the importance of discussion in the development of their pupils' thinking skills. The control teachers on the other hand did not introduce additional material to that in the Curriculum and it is not evident from their responses that discussion formed a central part of their lessons.

The test teachers also illustrated the ability to reflect in more depth on their practice. In addition to commenting on the improvement of organisational and management issues, the test teachers, unlike the control teachers, also reflected on teaching and learning in general terms. More in-depth reflections regarding teaching and learning were not prevalent amongst the control teachers' responses.

The more in-depth and profound responses from the test group's reflective journals indicate that the beginning teachers who had taken the NoS elective course appeared to have employed more constructivist approaches to teaching science. They also appeared to be more confident and enthusiastic about teaching science, which was evident through more frequent use of group work and a more diverse range of ideas and activities than those outlined in the Curriculum. The test group also revealed a greater ability to reflect on their practice and a greater understanding of how children learn. In general the teachers in the test group displayed more proficient understandings of teaching and learning in science.

It has to be acknowledged however, that the researcher had delivered the NoS elective course to these teachers the previous year and so had developed a relationship with them. The teachers in the test group may therefore have wished to affirm the researcher's enthusiasm. However, while the teachers in the control group did not have the same relationships with the researcher they still knew her as a lecturer and were aware of the researcher's interest and propensity for science and equally may have been eager to seek the researcher's approval.

In addition to these beginning teachers' conceptions regarding teaching and learning, there were considerable differences regarding the extent to which the test and control teachers addressed aspects of NoS. The test teachers explicitly taught about different aspects of NoS which is something that the control teachers did not explicitly address. The next section explores the data obtained from the reflective journals and explores the aspects of NoS that were explicitly addressed. The various methodologies utilised are also explored.

5.4 Nature of Science in the Classroom

The data obtained from the teachers' reflective journals will be considered under the following five headings:

- Human endeavour
- Scientific Inquiry
- Science and Society
- History of science
- Science as a body of knowledge

5.4.1 Human Endeavour

The test teachers referred to science involving people, the subjective NoS and creativity and imagination. Table 5.2 provides a summary of which aspects the test teachers referred to and in which reflections.

Table 5.2 Aspects of science as a human endeavour explicitly addressed

Reflection Entry	Test 1	Test 2	Control 1	Control 2
1	Creativity Science involves people	Subjective NoS Science involves people		
2	Subjective NoS Science involves people	Not Mentioned		
3	Science involves people	Creativity Science involves people	Not Mentioned	Not Mentioned
4	Creativity	Not Mentioned		
5	Subjective Creativity and imagination	Creativity		

Both test teachers did the 'Tricky Tracks' activity (Lederman & Abd-El Khalick, 1998, p. 85-91) with their classes, discussing the differences between observations and inferences, highlighting the subjective NoS.

> Explore that scientific knowledge is... often based on subjective interpretations (T1) (Appendix H).

> Creativity and imagination utilised by scientists were addressed through designing and making activities where the children's designs were discussed and the process of designing related to scientists' work.

When referring to the subjective NoS or creativity and science, both teachers specifically referred to science involving people that is science as a human endeavour.

> They have learned that Science and scientists are not some mystical and mysterious concepts and people. The incorporation of NoS has helped to give a human side to Science, to make it more accessible and enjoyable to the children by linking it with every day life, showing the effects that society played on the lives of famous scientists, how these scientists lived lives that were very similar to ours. Also, that Science isn't just about making (T2) (Appendix H).

> Due to the discussions on the NoS dealing with the scientists lives etc., I feel the children no longer view technological advancements made in the past as merely 'just appearing'. Instead they now view them as being developed and re-developed throughout time. They now attach a sense of humanity to Science rather than observing facts as isolated items. I believe the children now feel they too can be scientists and play an active role in shaping the world (T1) (Appendix H).

The data indicate that the teachers in the test group displayed more elaborate conceptions of science as a human endeavour and explicitly taught about science as a human endeavour as part of the Science Curriculum.

5.4.2 Scientific Inquiry

Teachers from both the test and control groups referred to numerous process skills their pupils had applied and developed over the course of the second term. The term 'science skills' incorporates references to the 'working scientifically' skills outlined in the Curriculum Guidelines (DES, 1999a) that the beginning teachers referred to in their reflections.

> Analysing: sorting and classifying as conductors and insulators.. Recording and communicating: record how they make their circuit. Use annotated drawings... (T2) (Appendix H).

> Exploring and investigating falling objects (C1) (Appendix H).

As mentioned in the previous section, the test teachers elaborated on and gave examples of how and when the science skills were utilised whereas the control teachers tended to refer to the various skills without elaborating.

In addition to the 'science skills' the teachers in the test group made explicit references to 'NoS skills'. The term 'NoS' skills is used to describe those skills that the teachers explicitly addressed that enabled the children to develop more contemporary understandings of NoS. These 'NoS' skills included references to the differences between observations and inferences, how past experiences and knowledge can influence scientists examining evidence and explicit references to how scientists use creativity and imagination during scientific inquiry.

> General introduction and look at the nature of science. Involved a lot of discussion, observation, questions and analysing. Empirical – tentative nature of Science observation vs inference, body of reliable information, how we can observe/look at the same piece of evidence but yet come to different conclusions/inferences. Human endeavour – observations and inferences (T2) (Appendix H).

References to 'working as scientists', that is when the teachers explicitly equated the science skills the children were using with how scientists used skills in their work, were also included in scientific inquiry.

> Working as scientists to develop their designing and making skills and make comparisons of their work to that of past scientists (T1) (Appendix H).

Table 5.3 provides a summary of the different aspects of scientific inquiry the test teachers referred to in their reflections.

Table 5.3 Aspects of scientific inquiry addressed

Reflection Entry	**Test 1**	**Test 2**	**Control 2**	**Control 2**
Science Skills	√	√	√	√
NoS Skills	√	√	X	X
Working as Scientist	√	√	X	X

(√= Addressed X = Not addressed)

The table indicates that the test teachers had more elaborate conceptions of scientific inquiry in that they addressed and reflected on all three areas in this category. The control group on the other hand only referred to one of the three categories. As noted earlier, the test teachers' responses regarding scientific inquiry were more detailed and reflective than those of the control group.

5.4.3 Science and Society

The control teachers did not refer to science and society in their reflections. Both test teachers referred to teaching about the influences science and scientists have on society.

> Discussion on the role or impact of scientists in modern society in terms of technical advancements (T1) (Appendix H).

> Linking Science and electricity to every day life. The positive role that electricity has played in our society and how we live (T2) (Appendix H).

5.4.4 History of Science

Again the control teachers did not make any references to the history of science. The teachers in the test group made numerous references to the history of science in all four reflections. Both test teachers mentioned significant figures, landmarks and events in the history of science.

> ...discussed Galileo's discoveries and how he might have worked: planning, making... (T1) (Appendix H).

> Michael Faraday – that scientists experience failures as well as successes, downs as well as ups, how society and religion has a major role in how and what he came to discover and the discussion which followed (T2) (Appendix H).

5.4.5 Body of Knowledge

Teachers from the test and control group referred to the scientific concepts addressed in their reflections. As mentioned in section 5.3, the control teachers addressed concepts that were taken from the Science Curriculum and placed considerable emphasis on the learning of these scientific concepts in their reflections. In a similar manner, the test group referred to science concepts that were taken from the Curriculum however the application and development of scientific skills and indeed aspects of NoS were always referred to in conjunction with acquiring scientific knowledge.

5.4.6 Discussion

All four teachers were informed of the purpose of the research, to establish if their pupils' conceptions of NoS could be developed while implementing the Science Curriculum. Although the teachers in the control group had taken a year-long course in curriculum science in their second year of college, they had not taken the NoS elective. The second year curriculum science course did not explicitly address NoS issues, did not include methodologies for teaching about NoS, nor did it give the pre-service teachers the opportunity to discuss or reflect on their conceptions of NoS. The test group was given numerous opportunities for reflection during the third year NoS elective. The data obtained from the reflective journals revealed that the control teachers did not explicitly address any aspect of NoS in their teaching. In light of the extant literature on teachers' limited NoS conceptions, and due to the lack of explicit NoS instruction evident in the reflective journals, it is quite probable that the teachers in the control group did not hold elaborate explicit conceptions of NoS.

The teachers in the test group on the other hand were given time to reflect on and develop their NoS conceptions. They were also given methodologies for explicitly teaching about NoS as part of the science curriculum. Their reflective journals indicated that the test teachers appeared to have a good understanding of NoS and had explicitly addressed aspects of NoS throughout their science teaching and appeared to have maintained elaborate conceptions a year later.

In light of these findings the next section outlines the changes in the NoS conceptions held by the two beginning (test) teachers over the course of the study.

5.5 Mapping the Change in NoS Conceptions

As mentioned earlier the two beginning teachers in the test group had taken the NoS elective the previous year. This section traces the changes in their conceptions of NoS over the course of the three phases of the study.

5.5.1 Third Class Teacher (Pseudonym: Claire)

'Science is' Statement

In answering the initial 'what is science' question, Claire described science as

> a body of knowledge, which is put into practice through experimentation and analysis. It provokes wonder and allows us to question the world in which we live (Appendix L).

Claire's exit statement regarding what is science was notably more detailed and revealed considerably more contemporary conceptions of NoS:

> Science encompasses many things: It is a body of knowledge that is constantly changing (tentative) and is never really objective. (It) is a 'living ' subject that allows for differences of opinions and changes with context, age, and circumstance (cultural and social). It incorporates all scientific skills such as observing, inferences and predicting, which illustrates that the body of knowledge in science was derived from a 'process' of carrying out those skills. It has an origin, (it is) not abstract (Appendix L).

Nature of Science Questionnaire (NOSQ)

Claire's written responses to the NOSQ also revealed elaborate conceptions of NoS. She showed contemporary conceptions regarding the nature of scientific knowledge being reliable yet tentative and subject to change. She discussed how scientists are continuously testing and re-testing their experiments to ensure reliability and consistency (NOSQ 1, NOSQ 3, NOSQ 6) (Appendix L).

> I think that they are never certain.. they have based their 'theories' on whatever information they have attained... but these theories are subject to change. Elements of subjectivity also come into play as scientists interpret data based on their previous knowledge and experiences (Appendix L, NOSQ 1).

Claire was aware of science as a human endeavour and commented at length on the subjective nature of science where scientists view the same data but have different interpretations because of their experiences, (NOSQ 1,NOSQ 2, Appendix 20). She also referred to occasions when scientists could not handle data first hand (for examples dinosaurs) and therefore had to use their creativity (as well as available evidence) to draw conclusions (NOSQ 4).

Claire had a good understanding of scientific inquiry and discussed issues such as scientists making observations and recording data, scientists interpreting data, and testing and re-testing experiments. She referred to the fact that scientists cannot always handle their data first hand and therefore often had to 'recreate' circumstances (NOSQ 1, Appendix L).

> When scientists develop a theory, their subjectivity not only comes into play, but also the reliability of their results. Theories, I believe are made so that they can attempt to explain what is happening, but they are tentative and subject to change. Other scientists improve the present theory or prove it wrong altogether. (Appendix K)

Claire also showed elaborate understandings regarding how science and society are affected by one another. She commented on how various societies can influence scientific progress (NOSQ 3, NOSQ 5, NOSQ 6) and she drew on examples from the history of science to illustrate how society can affect scientific progress.

> A science attempts to deal with issues that affect our everyday lives, the society in which these theories are made influences the way the experiment is carried out as well as the acceptance of the final results... In Galileo's case, the Catholic church rejected his claim that the Earth revolved around the sun. I t went against the pre ailing view at the time. Thus his theory was not accepted in society...(NOSQ 5, Appendix L).

Claire's detailed and in-depth responses in the NOSQ revealed elaborate and contemporary conceptions of NoS.

Teaching Practice Reflections

During her final teaching practice Claire had a junior infant class (ages 4 - 5 years) and she specifically planned and taught a number of aspects of NoS as part of her science lessons. These included working as scientists in developing their designing and making skills (creativity); the tentative nature of scientific knowledge; the influences of science and technology on society; the history of science (Appendix K). Claire was very positive about explicitly addressing NoS as part of the science curriculum. She maintained that including teaching about aspects of NoS helped contextualise the scientific concept (sound) for the children making it less abstract and easier for them to learn. As she had junior infants, she used story to introduce different aspects of the history of science to the children. She gave the children time to discuss the history of science and how science has contributed to society (Appendix K). She also maintained the different science stories helped humanise science for the children.

Reflective Journals

In her initial teaching year Claire planned and explicitly addressed science as a human endeavour, scientific inquiry, the history of science, science and society and science as a body of knowledge to her third class. Her reflective journal indicated that she explicitly addressed at least one aspect of NoS in every science lesson (Appendix H). She utilised a number of methodologies and activities to help develop her pupils' NoS conceptions. These included story, discussion, a number of the Lederman and Abd-El-Khalick (1998) NoS activities, writing letters to scientists, conducting investigations and experiments, designing and making activities (Appendix H).

The reflective journal indicated that Claire was extremely positive about the benefits of explicitly addressing NoS as part of the science curriculum (DES, 1999a)

> The pupils responded well to this lesson (electricity). They were full of enthusiasm and excitement about electricity and the light bulb. A lot of the pupils were very inquisitive about why Edison was interested in electricity and light. The children seemed to be enlightened by the developments made by the light bulb through time...the story of Thomas Edison really brought the concept to life (Appendix H).

> The children learned that science has a place in society and how valuable inventors and inventions are. .. the children could see the significant impact that science has on the environment. This was clearly expressed in many of the letters they wrote to the inventor (Appendix H).

5.5.2 Fourth Class Teacher (T2) (Pseudonym: Jim)

'Science is' Statement

In answering the question 'what is science' at the beginning of phase one, Jim wrote:

> Science as a continuous study and investigation of everything in the world, and how they function and live (Appendix L).

Similar to Claire, Jim's response to the 'what is science' statement at the exit stage was considerably more elaborate and profound:

> Science is a dynamic and ever-changing body of knowledge. It is never exact and never will be as long as there is freedom of thought. Although we can observe the same events we may still infer different meanings/ explanations for what is happening, that is all to do with the tentative nature of science. Science incorporates everything in our world, indeed one might say it is a dynamic study of the nature of our word and beyond. It is influenced by many areas including culture, society, philosophy and ethics. Science and discovery within science involves a lot of creativity and always will, it is the creative side of us, our imagination that helps us discover, to invent, to explain and to embrace the world of science that is out there (Appendix L).

NOSQ

Jim's responses in the NOSQ questionnaire revealed contemporary NoS understandings. He viewed scientific knowledge as reliable, yet not absolute. In his responses to NOSQ 1 he maintained that scientists had a significant degree of certainty regarding the structure of the sun but would not be able to test their theories,

> I believe that scientists know that the sun is made up of .. and various properties about it. But they can never be certain to any significant degree of its structure. They will never be able to test their theories, they cannot take samples so most of what they know, although scientifically based is only waiting to be disproved (Appendix L).

He showed good understandings of scientific inquiry giving examples of how scientists observe data and use different technology to help their observations (NOSQ 2, Appendix K). Jim had a considerable amount to say regarding the tentative nature of scientific knowledge. He maintained that no matter how conclusive one set of scientists can be another set of scientists could disprove their results. He maintained that this was a good thing as it facilitates scientific development:

> This is no bad thing as it pushes scientist to go further, dig deeper, develop more concrete ... evidence so that hopefully eventually, the doubters and 'disapprovers' will eventually draw similar conclusions (NOSQ 2, Appendix L).

Jim illustrated a good understanding of the role of creativity and imagination in scientific inquiry, and again drew on an example from the history of science, to illustrate his point:

> I believe that all scientists use their creativity and imagination. I believe that they have to. It is hard to imagine Copernicus / Galileo and Newton ever conducting investigations and research about the stars without them having to use their imagination and creativity. They relied on their imagination to draw scenarios. I believe that it is a truly

> great scientist's creativity and imagination that sets them apart from others (NOSQ 4, Appendix L).

Contemporary understandings of how science and society are affected by one another were evident in Jim's response to NOSQ 5. One example he gave was how religion has influenced science. He discussed how science has disproved many religious beliefs and provided more scientific theories (evolution) in their place:

> Science has disproven so many aspects of religion from evolution and the creation of the world to the Turin shroud being scientifically dated to disprove that it was genuine. Although society and culture will always play a role in scientific study, I believe that it (society and culture) is having a less significant impact today in stalling or interrupting scientific freedom today as it once did not so long ago (Appendix L).

In answering NOSQ 6 Jim revealed that prior to taking the NoS elective he had not ever heard about NoS, but now sees NoS as something that has humanised science for him and added a more interesting dimension (NOSQ 6, Appendix L).

Teaching Practice Reflection

In a similar vein to Claire, Jim was extremely positive about teaching aspects of NoS as part of the science curriculum (DES, 1999a).

> I can honestly say that I loved teaching children about the nature of science during teaching practice. Not only was it fun but it also helped the children to become interested in my science scheme of work. Although I had the tentative NoS and the History of Science - Newton and gravity- as distinct parts of my scheme, I would like to think that I implemented an NoS methodology right behind my science teaching and right throughout my science scheme. I believe that NoS is such a positive teaching and learning resource for science that has to be implemented in the science curriculum. (Appendix L)

He maintained that the HoS made science more interesting for them and helped humanise science for the children, making it more enjoyable. The inclusion of elements of the HoS was something Jim claimed he would do throughout any science course he would teach:

> ... Delving into the History of science allows children to empathise with the scientists and the times they lived in, what their discoveries meant to the people of the time, how they had lived/ managed before these discoveries, how these discoveries effected/ changed their lives. I really believe that learning about the history and nature of science gives science a human side...(Appendix L).

Discussion was a central feature in Jim's lessons and he maintained that allowing the children time to discuss the different aspects of NoS gave them confidence to question things and not take them for granted (Appendix L). Jim also asserted that discussion would form a key part in his science lessons in the future:

> At times it was difficult to transfer contemporary NoS conceptions to the class through instructional practice. I walked myself into trouble on one occasion simply by using language that was slightly too complicated such as 'inferring' but I addressed this. I overcame any problems with regard to instructional practice by engaging the children in 'thinking time' like settings, very much drawing on contsructivist learning, engaging the children in discussion and debate about the tentative nature of science (Appendix L).

Drawing the children's attention to the creative aspects of scientific inquiry was something Jim believed helped the children to begin thinking for themselves and enables them to be responsible for their own learning (Appendix L).

In general Jim was very positive about the benefits of explicitly addressing NoS in science lessons in the primary classroom. In fact he claimed that in the future he would explicitly address aspects of NoS throughout his science schemes as he maintained that incorporating NoS as part of the science curriculum seemed to be a natural and logical thing to do (Appendix L).

Reflective Journal

Perhaps not surprisingly, Jim explicitly addressed numerous aspects of NoS over the course of the second term of his initial teaching year. He explicitly addressed elements from the history of science, science as a human endeavour, the nature of scientific inquiry, the tentative nature of scientific knowledge and how science and society affect one another. It was evident from the reflective journal that Jim addressed at least one aspect of NoS in every science lesson (Appendix H). He used various methodologies for addressing these: Discussion, story, hands-on group work, conducting investigations and experiments, designing and making artifacts, specific NoS activities, videos. In a similar manner to his final teaching practice, discussion formed a very important part in Jim's science lessons. Jim was very positive about explicitly addressing NoS as an integral part of his science lessons. In reflecting on 'Tricky tracks' (Lederman and Abd-El Khalick 1998, pp 85-91), Jim had the following to say:

> The children learned that observing and inferring are two different things. It also helped to humanise science in a way. They loved the fact that they were involved in questioning, analysing, observing and inferring just like scientists do in real life. They enjoyed the role of investigating - being part of a team that gathers the evidence, observes it, analyses it and makes predications/ inferences based on the evidence (Appendix H).

> The children have learned that science and scientists are not some mystical and mysterious concepts and people. The incorporation of NoS has helped to give a human side to science, to make it more accessible and enjoyable for the children by linking it with everyday life, showing the effects that society played on the lives of famous scientists, how these scientist lived lives that were very similar to ours (Appendix H).

5.5.3 Discussion

Claire and Jim's responses to the NOSQ, the exit 'science is ' statement, their teaching practice reflections and their reflective journal responses revealed that their conceptions of NoS had developed considerably over the course of the study. Both maintained that NoS was an important aspect of science and should be addressed explicitly throughout science lessons in the Irish Primary classroom. They addressed many aspects of NoS in their final teaching practice and in their initial teaching year. Claire and Jim utilised methodologies they had encountered during the NoS elective but they also devised numerous other ideas for explicitly addressing NoS as part of the Science Curriculum (DES, 1999a). Constructivist approaches to teaching science were employed. For example, Claire and Jim began each new topic by finding out the children's ideas. They then gave the children the opportunity to test their ideas by conducting investigations and experiments. They then assessed the change in the children's ideas. Claire and Jim utilised a number of methodologies to assess the change in the children's ideas. Examples of these include discussion, pictorial and written records and concept maps. It is worth noting that throughout their second year science methodology sessions, constructivist approaches were advocated. Such approaches highlighted the importance of finding out children's ideas, contextualising science for children, giving children opportunities to test their ideas and assessing the change in the children's scientific ideas. The student teachers were also shown numerous examples of formative and summative assessment. While all four teachers took this second year curriculum science course, the findings indicate that only the teachers in the test group utilised more innovative methodologies for teaching science. Discussion, group work and hands-on activities were common features of Claire and Jim's classrooms. Constructivist approaches to teaching science were more apparent amongst the test teachers, who engaged their pupils in more hands-on activities and afforded the pupils time for reflection during science class. All four teachers took similar pedagogical and methodology courses during their pre-service education and all four had similar teaching practice experiences. It appears therefore that the NoS elective resulted in the more innovative methods of teaching science that were apparent amongst the test teachers.

In summary it would appear that both Claire and Jim had developed more contemporary and elaborate conceptions of NoS over the course of the study. They both planned for and taught about different aspects of NoS in their final teaching practice and in their initial teaching year. In fact they explicitly addressed different aspects of NoS issues in the majority of their science lessons over the course of their final teaching practice and in their initial teaching year. Claire and Jim both maintained that explicitly addressing NoS in the primary classroom was important and worthwhile and maintained it helped humanise science for their pupils and therefore made science more interesting, enjoyable and therefore easier to learn.

This chapter has illustrated the development of pre-service and beginning teachers' conceptions of NoS and how these teachers planned and addressed aspects of NoS as part of the Science Curriculum (DES, 1999a). The findings suggest that the teachers' conceptions of NoS have developed considerably over the course of the study and that they were extremely positive about their experiences of explicitly addressing NoS as part of the Science Curriculum. In addition to this the findings indicate that the teachers who had taken the NoS elective course used more innovative and constructivist approaches to teaching science, approaches advocated in the science curriculum (DES, 1999a). The extent to which their pupils' conceptions of NoS have been developed will be considered in the next chapter.

6 PRIMARY CHILDREN'S CONCEPTIONS OF NoS

6.1 Overview of Chapter

This chapter outlines the data gathered from the 32 third and fourth class children (9 - 11 years), over the course of the school-based component (third phase) of the study. In addition to considerable differences between the test and control groups' responses regarding NoS, there were substantial differences in their responses in relation to their perceptions of school science. This chapter opens with an exploration of the responses made by the control and test group regarding science in school. The development of the children's conceptions of NoS over the course of the study will be considered in more depth in the subsequent section.

6.2 General Responses Regarding Science in School

The main focus of the initial and exit group interviews with the 32 third and fourth class children (ages 8 - 11) in the third phase was to establish their conceptions of NoS (Appendix G). Therefore with the exception of one question which specifically asked the children about what they liked and disliked about science in school the remaining questions posed during the interviews related to various aspects of NoS. When answering the questions in the exit interviews, the children in the test group referred to, drew examples from and discussed their experiences of science in school in considerably more detail and more frequently than their peers in the control group. There were noticeable differences between the control and the test group regarding the extent to which they discussed doing hands-on investigations in school, utilising creativity during science class, learning about the history of science and conducting, discussing and reflecting on activities they had done in school that were related to NoS (Table 6.1). This was not surprising as the evidence from the teachers' reflective journals corroborated this.

Table 6.1 Number of children who referred to school science in the exit group interviews

	Test (n= 16)	Control (n=16)
Discussions about hands-on science in school	16	3
Nature of Science (including history of science)	16	0

These differences will be considered under the following three headings:

- Enthusiasm and interest in science
- Hands-on activities in science
- Nature of science in the classroom

6.2.1 Enthusiasm and Interest in Science

Both groups asserted they enjoyed science in school when asked about this in the exit interviews. However, the children in the test group had considerably more to say regarding their school science experiences throughout the exit interview. With the exception of three brief references to school science at the beginning of the interview,

> I think of all the experiments we've done in school... (Control) (C) (Appendix M).

> I think science is a fun learning experiment and it's very educational.. it does lots of fun experiments and it teaches you a lot of good stuff (C) (Appendix M).

> I think of fun and learning more stuff... like when you... do magnets (C) (Appendix M).

the children in the control group only referred to science in school again when specifically asked whether or not they liked science in school.

On the other hand all of the children in the test group referred to science they had done in school throughout the interviews, whether or not they were specifically asked about it. When answering the various interview questions regarding NoS issues, the children in the test group drew on numerous examples from their experiences of school science to substantiate their arguments. For example, they talked at great length about experiments, and investigations that they had conducted in science class:

> ...to experiment with all stuff.. Well one time we put a tissue in a glass and we...put it in a bucket and put water in it and we put it down and the tissue didn't get wet because the air was pushing it , the water out of the glass, instead of up it. (T) (Appendix M)

> We had to make a switch for a circuit.. and me and C. and V. did a brilliant job. C. had this metal... and there was a metal bar, kind of like a right angle, and we had this swirly thingy, we swirled it up and we sello-taped all the wire onto the top of it, so when we turned it up to the top, the metal piece touched it, which lit the entire surface... so we (had to use our imagination) to make the switch (T) (Appendix M).

They referred to things they had designed and made in science class:

> We had to use our imagination in the K'NEX Challenge. You didn't actually know what pieces you had so you had to, come up with a design and you had to try and make your thing as close to your design as possible. An you had to have three sections for your, recycling material: plastics, glass and paper (T) (Appendix M).

> Once we had to design our own telephone when we were learning about Alexander Graham Bell. We had to make our plans and our designs and then we had to write how it works.... It was really fun and all our ideas came out different, none were the same...' (T1) (Appendix M)

A number of the children in the test group recalled NoS activities they had done in school:

> I have an example of figuring out things...teacher gave us a little tiny piece of a picture and you had to figure out what it ...(it was working like scientists because) scientists have to guess from the stuff (evidence) they have and we only had, they only have a small piece, and we only had a small piece and we had to guess what (the rest) (T) (Appendix M).

> Well I learned that even though someone tells you that like this is real they could've just faked it.... Like in the video they had ... I weigh one ton and he stood on to the weight scales and he said one ton and then he went on an ordinary weighing scales in a bathroom... in order to believe you need proof...so if you don't have proof it would be ... well science needs proof so you can actually learn from it' (T) (Appendix M).

Some of the children drew on examples from the history of science they had learned about in school to illustrate points they were making throughout the interview.

> 'Because when we are doing Science, I always get reminded of Ben Franklin, Thomas Edison and Alexander Graham Bell and Louis Pasteur and when we are doing Science we can do all exciting things' (T) (Appendix M).

> '... when we're doing Science, it's like when, when eh, Thomas Edison made the, light bulb and if he didn't make the light bulb it wouldn't be light anywhere in our homes or in the street' (T) (Appendix M).

One can see from the accounts presented above that that the children in the test group had considerably more to say about their experiences of school science than their counterparts in the control group. The test group's responses were more elaborate and detailed and revealed a higher level of enthusiasm for school science. They discussed their experiences of school science more frequently than the control group.

As outlined in chapter six, the data obtained from the teachers' reflective journals revealed that discussion formed an important component in the test group's science classes, particularly when discussing different NoS activities and issues. The more detailed responses provided by the test children in the exit interviews, could be an indication that the opportunities afforded to them for discussion and reflection in science class had been beneficial in developing their thinking and language skills. The teachers' reflective journals also indicated that the test teachers appeared to be more enthusiastic about teaching science, appeared to have provided their pupils with more opportunities for engaging in hands-on scientific inquiry and utilised a wider variety of methodologies for teaching science. The extent to which the test children talked about and reflected on their experiences of school science also suggests they appeared to be more positive and enthusiastic about science and that they had conducted more hands-on investigations over the course of the year than their peers in the control group.

At the end of the exit interviews the children in both groups were asked what they liked about science in school. Table 6.2 summarises the children's answers.

Table 6.2 What do you like about science in school? (Summary of responses in each category)

	Test Group (N= 16)	**Control Group (N = 16)**
Doing Investigations/ Hands-on	14	6
Informative	7	5
Interesting / Fun	8	9
Design and Make	4	1
Group Work	1	3
NoS	5	0

In general the children in both groups were positive about science in school and said it was something they enjoyed, found informative and interesting.

> I like doing science because I like figuring out what makes light and what makes things levitate and also what is a hoax (sic)and what isn't. I also like seeing what is a conductor and what is an insulator' (T) (Appendix M).

> 'I like doing science in school because it's fun and you learn a lot and all your questions are answered' (T) (Appendix M).

> I like doing science in school because it's fun doing all the experiments and I don't have to do all the subjects I don't like in school' (C) (Appendix M).

> Yes, because it's fun (C) (Appendix M).

Children from both groups regarded conducting experiments and the 'hands-on' aspects of school science as something they enjoyed doing in school, although a considerably higher number of the test group referred to this as an aspect of science they enjoyed (Table 7.9). Three of the children in the control group asserted that they didn't like science in school because it wasn't always fun, they didn't do enough experiments and that some of the topics they had done were not interesting.

> Yes I do like science in school… well sort of...not really… I don't find it that fun (C) (Appendix M).

> A bit…but we could be given different experiments maybe…we don't do so much experiments' (C) (Appendix M).

> …(the science we do in school) it's not the stuff I like…its boring stuff like magnets…(would prefer to) making fake rockets and other things…(C) (Appendix M).

The fact that only six of the control group referred to enjoying doing experiments and one of them saying they didn't do enough experiments, could indicate that the control group did not do as many hands-on experiments as the test group. The data from the questionnaires (Appendix M), and the teachers' journals, appeared to corroborate this finding in that the seven children who indicated they didn't like science in school in the exit questionnaires were from the control group. One reason given was a dislike for a particular topic:

> Sometimes, like when we were doing stuff with liquids and gases. But not with insects because it's very boring and you already know about them (Appendix M).

Another reason given was because they maintained they didn't do enough experiments themselves:

> I don't like it so much because we don't get to do all the experiments (C) (Appendix M).

In the exit interviews the children from both groups maintained they would like to do more hands-on investigations and experiments in science class, whereas writing was something of which the majority of students in both groups would like to do less.

6.2.2 Hands-on Science

Hands-on investigative work, where the children develop their science skills is a primary feature of the Science Curriculum (DES, 1999a) and is considered to be equally important as the development of their conceptual understanding:

> 'Practical investigation is central to scientific activity of all kinds... For most children, objects and events have to be experienced in reality before they can be the subject of thought and mental manipulation. First hand investigation is central to the way in which young children learn science. It equips them with the realisation that they can provide their own answers to problems and that they can learn from their interaction with things around them' (DES, 1999b, page 2).

Conducting investigations and hands-on experiments was something children in both groups enjoyed.

> I like to do science in school because I get to find out more about stuff and learn stuff I never knew (C) (Appendix M).

> I like doing science in school because it's fun and you learn a lot and all your questions are answered (T) (Appendix M).

Throughout the exit interviews, all of the children in the test group discussed and reflected on numerous hands- on investigations and experiments they had conducted in school over the course of the year. They utilised examples of hands-on investigations they had done in school science to illustrate their answers to each question posed during the interview. This was in comparison to the control group, who made only brief references to school science in response to the first question and only referred to school science again when specifically asked about things they liked in school science.

In addition to the higher frequency of referrals to hands- on activities in school science, the children in the test group gave considerably more detailed accounts of the investigations they had conducted in school, which included references to different science skills they had been utilising. The test children's descriptions of exploring materials, planning designs, making and evaluating their telephones and green machines were an example of responses that referred to applying 'designing and making' (DES, 1999a) skills:

> Once we had to design our own telephone when we were learning about Alexander Graham Bell. We had to make our plans and our designs and then we had to write how it works.... It was really fun and all our ideas came out different, none were the same... (T) (Appendix M).

The children's recollections of the investigations and experiments they had conducted in groups indicated that the children had been given the opportunity to apply and develop their investigating and experimentation skills.

> We had to make a switch for a circuit.. and me and C. and V.a brilliant job. C.had this metal... and there was a metal bar, kind of like a right angle, and we had this swirly thingy, we swirled it up and we sello-taped all the wire onto the top of it, so when we turned it up to the top, the metal piece touched it, which lit the entire surface... so we (had to use our imagination) to make the switch (T) (Appendix M).

They referred to materials they had used and procedures they had taken:

> I like doing science in school because sometimes you get to go outside and do experiments outside and then sometimes you can do it inside, and one time we got a mirror, and we got a flash-lamp and we shone it against the mirror and we seen if it came back and like somebody stood behind the mirror and then it shone on them (Appendix M).

In many cases the test children discussed the results and reflected on the significance of the outcomes, which often revealed an understanding of the various scientific concepts the investigations and experiments had addressed.

> ...to experiment with all stuff.. Well one time we put a tissue in a glass and we...put it in a bucket and put water in it and we put it down and the tissue didn't get wet because the air was pushing it, the water out of the glass, instead of up it (T) (Appendix M).

The detail with which the test children were able to recall the different investigations and the results obtained was an illustration of the children's well-developed reporting and communication skills:

> ...one day we were doing science and we had a race with butter, sauce and vinegar...to see which one was fastest (T) (Appendix M).

> ...at the count of three we poured them all, we poured all the ingredients down and the first one to get to the end you're just seeing which one is a better liquid...(it was a fair test because) we all got at the count of three, we all poured at exactly the same time) (T) (Appendix M).

When the control group discussed hands-on activities they had done in science class their responses were shorter, less detailed and less frequent.

> You learn different activities and you learn how to turn on a bulb or a battery and stuff like that...We learn how air can blow up a balloon...(C) (Appendix M).

The test group was more spontaneous in discussing investigations and experiments they had done in school and on numerous occasions throughout the exit interview enthusiastically drew on their school experiences. The fact that the test group made more references to hands-on science and that these references were more elaborate and detailed suggest that the test group was more enthusiastic about science in school and that they had done more hands-on activities in school than the control group. Another indication of this, as outlined above, is that in the exit interviews some of the children in the control group mentioned that they did not do enough experiments themselves in school science and would like to do more. In a similar manner, the teachers' reflective journals revealed that the test teachers more frequently referred to their pupils applying scientific skills, appeared to have provided their pupils with more opportunities to conduct hands-on activities and appeared to be more enthusiastic about teaching science. The test teachers also seemed to have offered their pupils greater opportunities for discussion, which may in turn have enhanced the pupils' abilities to discuss their experiments in the subsequent interviews

6.2.3 Nature of Science in the Classroom

The main focus of the interviews was to establish the children's conceptions of NoS and these conceptions will be considered at length later in the chapter. It is worth noting here, however, the extent to which the children in the test group referred to, drew examples from and discussed in detail, activities and occasions where they had addressed different tenets of NoS in school throughout the exit interviews. When drawing on their classroom experiences of NoS the children in the test group illustrated an ability to philosophise about various NoS issues, which enabled them to apply and develop their thinking skills.

For example, when asked whether they believed scientists used their creativity and imagination at work one child referred to the 'fossil activity' (Lederman and Abd-El Khalick, 1998, pp95-100), which they had done in science class. This activity aimed at developing conceptions regarding the subjective NoS, where scientists at times are required to use past experiences, knowledge and creativity to draw inferences and form hypotheses, when sufficient evidence is not available:

> I think scientists use both (creativity and imagination) because (in science) when we were using that little piece of paper we had to use our imaginations to think what it was but we had to create like what the other part of it was as well... I was kind of thinking about nature because it looked a lot like outside and trees or stones or something (T) (Appendix M).

This is an example of a child utilising an activity she had done in science class to illustrate her reflections regarding the subjective NoS. While the response does not portray an elaborate understanding of the subjective NoS and how scientists form hypotheses, it does suggest that the child is beginning to move towards more elaborate conceptions of science as a human endeavour. The response is also an illustration of the child utilising higher order thinking skills and her ability to equate her experiences of school science to the work of scientists.

When discussing questions relating to science as a human endeavour and whether society should influence scientific development a number of children again referred to aspects of the history of science they had learned about during science class to strengthen their arguments. Two children in the test group when discussing science as a human endeavour referred to the fact that Alexander Graham Bell's personal experiences could have influenced his invention of the phone:

> In their (Scientists) childhood, if something went wrong they'd try and make it better...Alexander Graham Bell made the phone (T) (Appendix M).

Other children drew on examples from the history of science they had learned about in school when discussing their beliefs as to why society should or should not influence scientific development:

> Scientists should be allowed to do it (invent things) on their own... like (Alexander Graham Bell) nobody told him to do the telephone, he just wanted to do it because of his parents...they were deaf...(T) (Appendix M).

These children's responses are again an illustration of the children employing thinking skills when considering philosophical issues surrounding science as a human endeavour.

The children in the test group on numerous occasions throughout the exit interview referred to their experiences of school science, when considering and discussing NoS issues. Their responses also indicated the impact that the various NoS activities appeared to have on their NoS conceptions and their ability to consider abstract ideas regarding NoS and relate them to their practical experiences in school. Driver and co-workers (1996) maintain that children's ideas regarding NoS are influenced by various factors in their immediate environment, from the media, from discussions with adult or parents, or from experiences encountered in school. The findings suggest that the test group's experiences of school science influenced their responses to the questions regarding NoS whereas the control group largely provided examples from experiences outside school to substantiate their answers.

The test group's responses regarding the subjective and creative aspects of science indicated that they were beginning to move towards more elaborate conceptions of this aspect of NoS. They drew on examples from their school experiences, when answering questions about NoS and their responses revealed more elaborate conceptions of NoS than those of the control group who almost exclusively drew on experiences outside the school environment when substantiating arguments regarding aspects of NoS. For example, in response to the question concerning whether scientists use their imaginations and creativity in their work, the control group almost exclusively referred to scientists using their imaginations and creativity in designing artifacts and substantiated their answers by referring to programmes they had seen on television or articles they had read:

> I think they do actually use their imagination and creativity because, em, they've made a lot of things. It's well, like the oven or the stove,

> like what, they'd have to use their imagination to put something on that or in that. So like they'd have to make a way for it to light...Cause I've been watching this thing called Myth Busters and inside it they have a little mechanical machine with a lighter stuck to it and it lights in the stove (C) (Appendix M).

In addition to referring to scientists using their creativity to invent things the children in the test group also referred to scientists using their imagination during scientific inquiry. Many of them referred to incidences where they had employed their creativity and imagination during science class.

> I think you use both because...when we were using that little piece of paper, we had to use our imaginations to think what it was but we had to create like, what the other part of it was as well. I was kind of thinking about nature because it looked a lot like outside and trees or stones, or something (T) (Appendix M).

> In the K'NEX Challenge Em, yeah, like you didn't actually know what pieces you had, so you had to, like, come up with a design and you had to, try and make your thing as close to your design as possible. And you had to have three sections for like your, cycling material; plastic, glass and paper...And, and when you do the conductors and insulators, you have to use your imagination, cause like if you do one thing and it'll go through it you have to see like, lets just say it was tin foil, then you know that, eh, it'll probably go through other metals, so you could try other metals and stuff (T) (Appendix M).

While the test group also drew on examples from the media when discussing NoS issues, they gave considerably more examples from their school experiences to illustrate and exemplify their ideas regarding NoS. The findings indicate that the test group also revealed more elaborate understandings of NoS at the end of the study.

Discussion

The data suggest that the children in the test group appeared to be more enthusiastic about school science than the control group and appeared to have conducted more experiments and investigations. The children in the test group were able to recall in detail numerous investigations they had conducted in school and their responses also indicated that they had been given numerous opportunities to apply and develop different scientific skills. As discussed in chapter five, the teachers in the test group who had taken the NoS elective appeared to have utilised a wider range of teaching methodologies, had provided their pupils with more opportunities for hands-on scientific inquiry and were more aware of incidences when their pupils were utilising science skills, than the control teachers. In the exit interviews, the test children recalled a greater number of investigations they had conducted in school and in doing so referred to various science skills they had employed. This was not so evident amongst the control pupils' responses.

Constructivist theories of learning view students as active learners, constructors of understanding, where they make sense of a new concept by trying to fit it into their own experiences. Social constructivism emphasises the importance of providing learners with opportunities to discuss and defend their ideas, maintaining that this helps children 'scaffold' one another's ideas. Language, therefore plays a vital role in learning as it is the means of thinking and understanding. In addition to advocating constructivist approaches, the Science Curriculum emphasises the importance language plays in facilitating children's learning in science:

> Through discussing their ideas and the results of their scientific investigations, children will develop their scientific understandings. Through language children name and classify things, express and modify ideas, formulate questions and hypotheses and report conclusions. In this way language contributes to the expansion of the children conceptual development... language is important too in helping children to access and to retrieve information and to record and communicate ideas. The extent, therefore, to which language is an integral part of the teaching and learning process should be a consistent concern in the planning and implementation of the curriculum in science (DES, 1999a, Page 10).

As discussed in chapter five, the teachers in the test group afforded their pupils more opportunities for discussion and reflection in science class. The responses from the children in the test group regarding school science in the exit interview were more elaborate, detailed and spontaneous than the control group's responses.

When discussing investigations they had done in school the depth and detail of the test group's responses regarding school science illustrated their ability to discuss and express their ideas, to question and hypothesise, to retrieve information and report conclusions. The test children appeared to have a better understanding of scientific inquiry, which was evident in the way they referred to and provided examples of scientific skills they had utilised and discussed during science class.

The responses the children in the test group provided when discussing various NoS issues in relation to school science illustrated their ability to consider, reflect and articulate thoughts regarding a range of philosophical ideas regarding NoS in-depth.

These profound responses illustrated the application and development of the test children's thinking skills. Further examples of the test group's ability to reflect on various philosophical issues regarding NoS will be provided in the following section.

To summarise, the data suggest that the children in the test group were given more opportunities than the control group, to engage in hands-on scientific inquiry and more opportunities to discuss and reflect on the various scientific activities and ideas they had encountered. The children in the test group were more enthusiastic about science in school and recalled more hands-on activities that they had conducted and in greater detail. The test group's more in-depth responses included more frequent references to science skills they had utilised and revealed a greater ability to reflect on and comprehend ideas regarding NoS.

6.3 Children's Conceptions of Nature of Science

In the previous section the extent to which the children referred to and drew on examples of school science in response to the interview questions was discussed. This section will consider the data in terms of the development of the children's conceptions of NoS.

6.3.1 Overview of Findings

The five categories that emerged from the analysis of the open-ended questions in section A of the questionnaires, regarding the children's conceptions of NoS, are presented in Table 6.3. The 'rules for inclusion' and examples of typical responses in each category are also illustrated on the table.

Table 6.3 Children's questionnaires: Open-ended question categories regarding NoS

Category and Abbreviation	**Rules for Inclusion**	**Typical Responses**
Human Endeavour (Human End.)	References to human issues around scientists' lives. Creativity of science, scientists making mistakes, scientists improving things	'Science is smart people doing research' 'I think they create things and invent things like hovercrafts, TVs, rockets and lots of different gadgets
Scientific Inquiry (Inquiry)	References to science skills and science and the empirical nature of science were included here.	'They mix and make new things'
Science and Society	General mentions of science improving the world we live in; the positive effects science has on society; references to diseases, cures and medicine; science and crime; technology	'Without science we wouldn't have cars, electricity, clocks'
Body of Knowledge (BoK)	Responses that related to science as; a body of knowledge that informs us and provides us with information about the world; specific references to physics, chemistry and biology were typical of the responses that were included in this category.	'Find out new ways to do things' 'Is about trees, mini-beasts and soil chemicals and things like that'
History of Science (HoS)	Specific mentions of scientists and the development of their ideas and inventions; comparisons made between science today and many years ago; references to Egyptians / Vikings	'They might find stuff out about the past' 'They examine old things and handle them with care'

The control and test groups' responses in the initial and exit questionnaires were compared, and the change for each group determined. Table 6.4. illustrates the number of responses given by the test and control group when their responses to the open-ended questions in their initial and exit questionnaires were compared.

Table 6.4 Number of responses made by the test and control group in each category in the initial and exit questionnaires

	Test (Initial) (N = 51)	Test (Exit) (N = 49)	Difference Between Test's Initial and Exit Responses	Control Initial (N = 53)	Control Exit (N = 51)	Difference Between Control's Initial and Exit Responses
BoK	156	226	*+ 70*	232	214	*- 18*
Skills	45	111	*+ 66*	89	99	*+ 10*
Science and Society	97	154	*+ 57*	111	75	*- 36*
HoS	13	53	*+ 40*	4	1	*- 3*
Human End.	24	41	*+ 23*	19	9	*- 20*

(Note: 1 mark was awarded for every time a reference was made to each category. If a child made more than one reference to a category this was recorded accordingly)

There were higher frequencies of positive responses from the test group in all categories of NoS in the exit questionnaires (Figure 6.1).

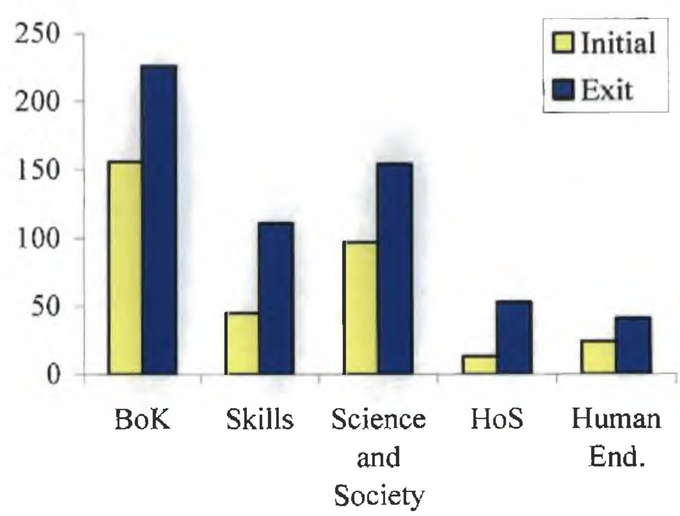

Figure 6.1 Comparison of test group's responses to the open-ended questions in the initial and exit questionnaire

The control group gave more responses in only one area (scientific skills) at the exit stage (Figure 6.2).

Table 6.4 Number of responses made by the test and control group in each category in the initial and exit questionnaires

	Test (Initial) (N = 51)	Test (Exit) (N = 49)	Difference Between Test's Initial and Exit Responses	Control Initial (N = 53)	Control Exit (N = 51)	Difference Between Control's Initial and Exit Responses
BoK	156	226	*+ 70*	232	214	*- 18*
Skills	45	111	*+ 66*	89	99	*+ 10*
Science and Society	97	154	*+ 57*	111	75	*- 36*
HoS	13	53	*+ 40*	4	1	*- 3*
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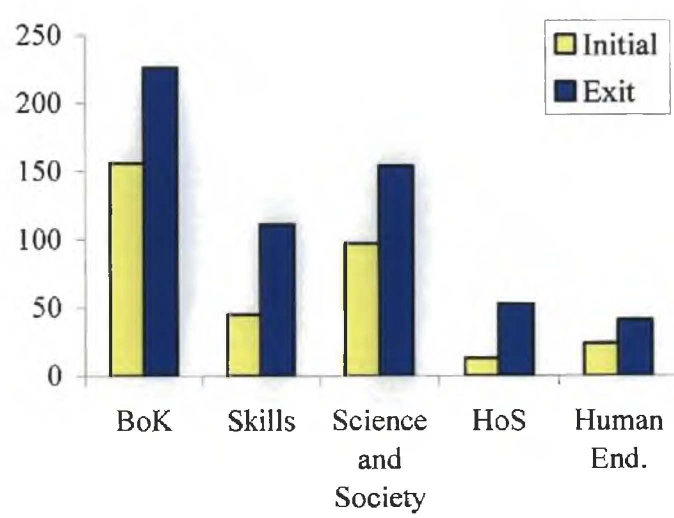

Figure 6.1 Comparison of test group's responses to the open-ended questions in the initial and exit questionnaire

The control group gave more responses in only one area (scientific skills) at the exit stage (Figure 6.2).

Table 6.5 Number of responses in each sub-category of science as a human endeavour: Open-ended questions on the questionnaire

	Test Initial (N = 51)	Test Exit (N = 49)	Control Initial (N = 53)	Control Exit (N = 51)
Science Involves People	0	5	5	3
Science is Subjective	0	2	0	0
Creativity and Imagination in Science	24	34	14	6

Table 6.6 Comparison of test and control groups' response relating to science as a human endeavour in the closed questions on the questionnaire

	Test Initial (%)	Test Exit (%)	Difference (%)	Control Initial (%)	Control Exit (%)	Difference (%)
Scientists use their imaginations when explaining things.	29	65	+ *36*	44	32	*-12*
Scientists use their imaginations when doing experiments.	57	78	+ *21*	53	53	*0*
Different scientists can have different answers to the same question.	82	100	+ *18*	75	88	+ *13*
Scientists use their imaginations when they invent things.	73	90	+ *17*	75	81	*+6*

Evidence from the exit interviews with children supported this finding (Table 6.7).

Table 6.7 Number of responses relating to science as a human endeavour in the exit interviews

Sub-categories	Test Group (N = 16)	Control Group (N = 16)
Subjective	5	0
Creativity: Thinking up inventions	5	3
Creativity: Devising and conducting experiments	6	1

The test group had a higher frequency of responses relating to science as a human endeavour in the exit interviews. In addition to this there were considerable differences between the depth of responses made by the test and control group in the exit interviews, in that the test group's responses were more detailed, diverse and reflective.

Subjective NoS

There was only one reference made to the subjective NoS in the initial interviews and a child in the control group made this:

> Em, yes, it can, because you know like the way Dinosaurs are extinct. Well scientists think that they, some scientists think that they died of an asteroid. Some think they died in a volcano, some think they died of poisoned plants and all. So that can change (C) (Appendix N).

It is difficult to establish from this response whether the child understood science as subjective or whether he was using this example to explain the tentative NoS

In comparison, five children from the test group referred to the subjective NoS in their exit interviews. Two of these children believed that scientists sometimes argue and therefore disagree with each other, illustrating an understanding of the subjective NoS.

> They always disagree most of the time... No, they should all agree, but like, they can't be always right..(T) (Appendix N)

> And, and, when, like, they can't, like Amber said, they can't be always right because they can't know everything, everything in the world (T) (Appendix N)

The third believed scientists were entitled to have their own opinion. But did not elaborate on her argument.

> ...(Scientists) are entitled to their own opinion (T) (Appendix N)

None of the children in the control group referred to the subjective NoS in the exit interviews.

Creativity and Imagination

In the initial and exit interviews, the children were asked whether they thought scientists used their imagination and creativity in their work. The children from both groups had a considerable amount to say in response to this question in both initial and exit interviews. To facilitate discussion, the children's responses to this question will be presented under the following two sub-categories. Scientists use their creativity and imagination when:

- Thinking up inventions
- Devising and conducting experiments

There were also numerous responses made regarding creativity being employed while designing and making artifacts and inventions. These will be discussed in section 6.5 (science and society).

Thinking up inventions

In the initial interviews only children from the control group discussed scientists using their creativity and imagination when thinking of inventions. Two children believed they did and one child believed they did not:

> Well, like em....The person who invented the light, he must have thought of something to make it not so dark in your house or in your basement (C) (Appendix N).

> Well I think they don't really (use their creativity and imagination) because if they are using creation they could get it from something was ages back like and then they use your own imagination to get stuff more to add onto it so it would be more powerful than the one that was from ages back (C) (Appendix N).

In the exit interviews five children from the test group and three children from the control group discussed how scientists use their creativity and imagination when coming up with an idea for an invention. All of the references were made in terms of technology. The children typically referred to how scientists' personal experiences may have led them to think of an idea in the first place:

> …like washing machines or something to wash our clothes out of instead of washing them by hand… I'm too tired of washing my clothes. I need a machine that can do it (C) (Appendix N).

> I think they use their imagination and creativity .. because in their childhood, if something went wrong they'd try and make it better (by coming up with an idea for invention) … like Alexander Graham Bell made the phone (T) (Appendix N).

The responses suggested that the children were developing some understanding of scientists being informed and how past experiences and knowledge often influence their work.

Devising and conducting experiments

Three children from the control group and two from the test made references to scientists using their imaginations when devising and conducting experiments in the initial interviews. Three of the children from the test group maintained they did and two children from the test group were unsure.

> I don't really think they use their imagination when they are doing their experiments because they use facts and imagination well sometimes can't be, sometimes when you use your imagination, sometimes thing might not be true (T2) (Appendix N).

In the exit interviews, only one child from the control group briefly referred to scientists using their imaginations 'in experiments'. On the other hand six from the test group discussed scientists using their creativity when conducting experiments:

> I think you do sometimes but not all the time. Like, when they're doing medicine and like, when they're just, their first time taking a go at, I think they use their imagination the second time, I think they'd learn stuff the first time so they wouldn't, they wouldn't, eh, like they just know things so they wouldn't try it again (T)(Appendix N).

At a glance the responses from the children in the test group in the exit interviews, could be interpreted as depicting 'cartoon' images of scientists (Solomon et al 1994). That is, perceiving scientists as not having any idea of the potential outcomes of their investigations and often ascribing a degree of danger and surprise to scientists' experiments. However, at a closer examination one can see a development in the test children's understandings regarding the nature of scientific inquiry where scientists are testing and re-testing to establish better understanding. While the test children maintained that scientists use their 'imaginations' their responses also revealed an understanding that scientists have some prior knowledge regarding a particular investigation, albeit not having knowledge of what exactly will happen. This suggests that the children in the test group were beginning to move away from the notion of what Solomon et al. (1992) refer to as 'serendipitous empiricism', (a belief in 'shot in the dark' type approaches to scientific inquiry where scientists do not know what might happen prior to an experiment) to more elaborate understandings of scientists having some knowledge of the expected outcomes.

Scientists using their imaginations and creativity when formulating hypotheses was an issue that was not raised during the initial interviews. One child from the test group did discuss this in the exit interviews.

> I think you use both because this morning when we were using that little piece of paper, we had to use our imaginations to think what it was but we had to create like, what the other part of it was as well. I was kind of thinking about nature because it looked a lot like outside and trees or stones, or something' (T1) (Appendix N).

Discussion

The findings from the open and closed questions and group interviews indicate that the test group had developed more elaborate conceptions of science as a human endeavour after the intervention. The subjective NoS and the influences of scientists' past experiences and knowledge on scientific inquiry were not referred to by the control group in their exit interviews and by contrast were aspects of science that were discussed at length by the test group. The teachers in the test group explicitly addressed science as a human endeavour on numerous occasions over the course of the study. On a number of occasions throughout the exit interviews the test group pupils drew on examples from school science when discussing science as a human endeavour.

The test group's responses regarding the role of creativity in thinking of an invention and in devising and conducting investigations were more reflective that the control group's responses. The test group's responses were also more detailed and diverse during discussions about the creativity employed by scientists when coming up with ideas for inventions as well as referring to how scientists' different personal experiences can influence their ideas and investigations. The findings obtained from the questionnaires corroborated the interview data revealing that the test group had considerably higher response rates than the control group regarding science as a human endeavour in the exit questionnaires (Table 6.4). Many of the responses, particularly from the test group revealed an increase in understanding of the notion of scientists testing and investigating things to develop a better understanding of phenomena. These will be discussed later in the chapter when considering the data in relation to science as a body of knowledge.

6.3.3 The Nature of Scientific Inquiry

The data obtained from the open-ended questions in the questionnaires indicated that the children in the test group had a considerably higher frequency of responses regarding scientific inquiry when their initial and exit questionnaire responses were compared (Table 6.8).

Table 6.8 Number of responses made by the test and control group regarding scientific inquiry in the initial and exit questionnaires

	Test Initial (N = 51)	Test Exit (N = 49)	Difference Between Test's Initial and Exit Responses	Control Initial (N = 53)	Control Exit (N = 51)	Difference Between Control's Initial and Exit Responses
Number of Responses	45	111	+ *66*	89	99	+ *10*
Percentage of Overall Responses	29%	71%	+ *42%*	47%	53%	+ *6%*

Both groups had more responses that related to scientific inquiry in the exit questionnaires, however the test group had a considerably higher frequency of responses (Table 6.8). When referring to the work of scientists at the exit stage, the children in the test group referred to a wider range of skills and processes utilised by scientists, than the control group:

> Eh, experiments and like, different chemicals mixed together to make another chemical and stuff like that (C) (Appendix N).

> When I think of Science, I think of, em, Science is beakers and pouring different chemicals into bottles and how, em, the world was formed (C) (Appendix N).

> I think of dinosaurs...I think of like clues and looking for like, the claws and like other dead dinosaurs that have been eaten and all (C) (Appendix N).

> I think science is finding out new things by what evidence you have (T) (Appendix N).

> science is finding explanations for how everything is made and doing experiments and answering questions that people would like to know (T) (Appendix N).

I think scientists experiment about things that happen in the world, and why they happen (T) (Appendix N).

Scientists find out things and tell us. Sometimes scientists are not right and they have to guess (hypothesis) from the evidence they get', 'scientists get things wrong sometimes (T) (Appendix N).

In the exit questionnaires the test pupils referred to scientific inquiry involving hypothesising, predicting and gathering evidence, which they did not refer to in their initial questionnaires and to which the control group never referred. The teachers in the test group had completed activities (Lederman & Abd-El Khalick, 1998) that addressed issues regarding scientists' predictions and gathering evidence and had given their pupils a number of opportunities to devise and conduct investigations that required them to utilise these skills. As mentioned earlier in this chapter all of the children in the test group referred to school science when discussing scientific inquiry as opposed to the control group who only made brief references to school science throughout the interview.

Three children from the control group and nine from the test referred to the nature of scientific inquiry in the exit interviews in relation to scientists conducting experiments and investigations in the exit interviews:

When I think of Science, I think of, em, Science is beakers and pouring different chemicals into bottles and how, em, the world was formed (C) (Appendix N).

I think, em, experiments and, labs and em, investigations...Em, maybe that em, they em, the scientists go and investigate stuff where people have, sighted U.F.O.s. (T) (Appendix N).

...Yeah they'd use evidence, like, bones, like, there might be some scales left and they have this kind of thing, you look at it and it comes up...Yeah, and then you look in it and you can see the scales up closer (T) (Appendix N).

Although the test group made a higher number of references to investigations and experiments conducted by scientists neither group elaborated to any great extent on the purpose of scientific experiments and investigations being about testing ideas or finding answers to questions. The children appeared to have limited conceptions regarding this aspect of scientific inquiry.

Discussion

The children in the test group had a considerably higher frequency of responses regarding scientific inquiry in the open-ended questions of the exit questionnaires than the control group. A number of children in the test group referred to hypothesising and examining evidence in their exit questionnaires, something the control group did not refer to. Many of the children referred to investigations and experiments in their exit interviews, however the majority of these responses were made with regard to school science. The responses regarding the general nature of scientific inquiry revealed that, the children in both groups still possessed limited conceptions regarding this aspect of nature of science.

6.3.4 Science and Society

There was a difference in the number of responses the children made regarding science and society in the open-ended questions at the initial and exit stages. The frequencies of responses indicating science improving the world increased by 28% and 26% respectively in the test and control group in the exit questionnaires (Table 6.9).

Table 6.9 Number of responses made by the test and control group regarding science improves world in the initial and exit questionnaires

	Test Initial (N = 51)	**Test Exit (N = 49)**	**Difference**	**Control Initial (N = 53)**	**Control Exit (N = 51)**	**Difference**
Number of Responses	43	75	*+35*	32	54	*+22*
Percentage of Overall Responses	36%	64%	*+28%*	37%	63%	*+26%*

Improving the world, the quality of life, advancing medicine and finding cures, improving the environment and solving crime were typical responses given by both groups in both questionnaires (Appendix N).

> ...it's helpful because...if the light bulb wasn't made you wouldn't be able to see and it's helpful because you would probably hurt yourself, by walking into walls. And if the, if the, lightning, thing that goes down the wall wasn't invented...the top of your house would probably get struck and then some people in your family could die (T) (Appendix N).

> Well I think of curing sicknesses like cancer. Without Science we wouldn't know about germs or anything...Germs can some, it doesn't always make you sick. Some germs aren't like that. Like there's actually a germ, I saw this in a book, there's actually germs that on your skin and it stops other germs from getting into you (C) (Appendix N).

The test group had a considerably higher response rate in the exit questionnaires regarding science and technology. The frequencies of responses indicating science and technology increased by 18 percent for the test group, whereas responses in the control group decreased by 58 percent in the exit questionnaires (Table 6.10).

Table 6.10 Number of responses made by the test and control group regarding science and technology in the initial and exit questionnaires

	Test Initial (N = 51)	**Test Exit (N = 49)**	**Difference**	**Control Initial (N = 53)**	**Control Exit (N = 51)**	**Difference**
Number of Responses	54	79	*+25*	79	21	*-58*
Percentage of Overall Responses	41%	59%	*+18%*	79%	21%	*-58%*

Typical responses in this category included references to electricity and electrical appliances, light, computer technology and programmes, improved models of transport (Appendix N).

Two of the fourteen items in Section B of the questionnaires referred to science and society (Appendix F). The results of this analysis showed that the test group had a higher frequency of responses in the exit questionnaire regarding society influencing scientific development (Table 6.11).

Table 6.11 Comparison of Test and Control Groups' Responses Relating to Science and Society in the Closed Questions on the Questionnaire

	Test Initial (%)	**Test Exit** (%)	**Difference** (%)	**Control Initial** (%)	**Control Exit** (%)	**Difference** (%)
Scientists should not invent things that might harm people	10 (unsure)	19 (unsure)	*+9*	9 (unsure)	8 (unsure)	*-1*
People in society should always tell scientists what to investigate	29 (unsure)	40 (unsure)	*+11*	19 (unsure)	29 (unsure)	*10*

The data from the interviews support these findings in that the test group had a higher number of responses regarding science and society in the exit interviews (Table 6.12).

Table 6.12 Number of pupils who discussed science and society in the group interviews.

Sub-categories	**Agree (Yes) Disagree (No)**	**Test Initial** (N = 16)	**Test Exit** (N = 16)	**Control Initial** (N = 16)	**Control Exit** (N = 16)
Science improves the world / is helpful.	Yes	11	10	12	10
	No	7	6	10	5
Technology is helpful.	Yes	8	11	8	10
	No	5	8	7	10
Society should influence science.	Yes	3	2	2	3
	No	10	9	0	0
	Depends	4	10	8	8
Total Number of Responses Regarding Science and Society		48	56	47	46

During the interviews the children were asked a number of questions regarding science and society (Appendix G). The children from both groups had similar responses to these questions. A brief overview of their conceptions regarding science and society will be provided under the following three headings:

- Science improves the world
- Technology is helpful
- Society should influence scientific development

Science Improves the World

The children in both test and control groups had much to say regarding science and society. Typical responses from both groups included the usefulness of science in terms of the knowledge it has provided us about space, nutrition and health, medicine, the environment and in preventing crime (Appendix N). Their responses were similar in the initial and exit questionnaires.

When talking about the harmful effects of science the children in both groups typically referred to how working in a science environment can be detrimental in terms of chemicals exploding and damaging health:

> Science can be bad for you if you spend too long in the lab.... Because the radiation and it might be kind of dark in there... It (dark) can hurt your eyes (T) (Appendix N).

> 'Well, if they're trying out things that explode maybe there'll be a big kaboom and people might die (T) (Appendix N).

One child seemed to portray Solomon and co-workers' (1994) 'vivisectionist image' of scientists when talking about how animals get hurt when scientists are testing them in a lab:

> Yes, it (science) can be harmful but not all the time. It can be harmful to animals cos they do test things. .... Yeah it's been banned but some people still do it (T) (Appendix N).

These descriptions of the potential detrimental aspects of science clearly portray serendipitous empiricist understandings of scientific inquiry (Solomon et al., 1992), where the scientists are unsure of potential outcomes of their investigations. Similar to their counterparts in other studies (Aikenhead et al., 1987; Carey et al., 1989; Driver et al 1996), one could assume from these responses that the children in both groups portrayed 'techno-science' (Aikenhead et al., 1987) and 'technologist' images (Solomon et al 1994) of scientific inquiry. That is in general they maintained that the purpose of scientific work was providing solutions to technical problems, inventing cures and appliances, rather than providing powerful explanations.

In a similar manner to Aikenhead et al. (1987) the children in the test and control group appeared to hold 'techno- science' views of science. That is their responses indicated that they did not distinguish between different aspects of scientific inquiry and tended to treat science and technology as the same entity aimed at improving the world. Many of the children in both groups discussed issues relating to science and society exclusively in terms of technological development and science's role in solving problems and therefore appeared to have limited conceptions regarding the relationship between science and society.

Technology is Helpful

The children in both test and control groups had similar things to say about the helpfulness of scientific inventions and technology in both interviews. However, both groups tended to have more to say in the exit interviews (Table 6.5). In general the children talked about how scientific inventions help us in our everyday lives and help improve our quality of life. Typical things that were discussed included electricity and electrical appliances, computers and the internet, specific references to inventions and technology in space (Appendix N).

> Computers and technology and stuff like that... About people if they went into space, actually, they wouldn't be able to go to space, because they wouldn't have the technology (T) (Appendix N).

> I think Science is important because where we are now we wouldn't have gotten there if Science hadn't invented all the stuff that we

> need...and...technology has improved the life of a lot of people and without computers or anything we'd probably be stuck for answers and all that, 'cause you can go on the internet and get answers (C) (Appendix N).

In the both interviews children from both groups discussed the potential dangers of scientific inventions. The potential dangers of electricity, pollution, bombs, guns, make-up, spending too long on computers were amongst the things the children referred to:

> I think Science can be actually dangerous, especially to the scientists, because they were mixing like, chemicals that you, most times, see on TV. They could be, like, spilling it and then it could blow up in their face (T) (Appendix N).

> Yeah, it is. It helps us but it pollutes as well...It makes our lives easier but then we like we paying the price 'cause it pollutes (C) (Appendix N).

The children's interview responses suggest that the students perceived the role of science as improving and developing the world we live in. Similar to the students in the Aikenhead et al. (1987) survey, the children in this study did not distinguish between different aspects of scientific inquiry and tended to refer to science and technology as having one purpose, that of improving the world. Aikenhead et al. (1987) referred to this as 'techno-science', where societal issues regarding science were related to technology and the role of science was to solve these technological problems. The primary children in Driver et al. (1996) study also believed the purpose of scientific work was the provision of solutions to technical problems rather than providing powerful explanations.

Society Should Influence Scientific Development

Children from both groups adopted democratic models of decision making with regard to scientific and technological societal issues, maintaining that since all citizens are affected by the decision, everyone should have a say. Some children believed society should have some influence on scientific development. Areas in which it was considered acceptable for society to have some say included issues that related to improving life, preventing scientists from causing destruction and informing society about things of which they are uncertain:

> It should be balanced like, if scientists have an idea, they should ask permission to research it, but if, the em, Government ask the scientists to research something, they should have their own, em, part in it. Like, say, 'Well, that could be dangerous, so we'll have a check and we might say no (T) (Appendix N).

> I think laboratories should have a special room for suggestions... Yeah but they shouldn't do whatever they want. They should discuss the idea first (C) (Appendix N).

Others contended that there should be mutual consensus between the scientific community and society regarding whether or not something is funded or researched. These children believed that scientists should not go ahead and research anything they wanted; rather they should consult with society regarding its needs. One child maintained that scientists should not be allowed to research whatever they wanted in case it was harmful to society and that society at times should intervene to ensure that scientists' proposed inventions are not potentially harmful to society.

> I don't think scientists should just do whatever they want. They should have a big meeting. 'Cause if they went ahead with something, like a weapon and it backfired, it could blow up their country rather than the other country that they want to blow up. (C) (Appendix N).

In a similar manner to the young children in Driver et als' (1996) study, neither the control or test group seemed to be aware of how society influences and prioritises various scientific research projects, and did not elaborate on how society as a whole makes decisions. Many of the children's views regarding the role of society in science are similar to Ryan's study (1987) in that some maintained scientists worked to satisfy their own curiosity while others maintained scientists worked in order to improve the world in which we live. Their responses suggest they had limited conceptions of NoS in that they did not appear to be aware of how society and science are influenced and affected by one another.

To summarise, the data obtained from the exit interviews revealed similar findings to that of the initial interviews that is children from both groups believed the purpose of science was about improving the world. Many of the children did not distinguish between science and technology when discussing social issues and viewed scientists as being honest. Some of the children claimed that science and technology were responsible for a number of social problems like pollution. Others maintained that science was not responsible for many social problems rather it was people abusing science and technology that were to blame. In general the children still perceived science as a means of improving the world, inventing new cures and devices rather than developing explanations about the world. The main difference between the test and the control group's responses regarding science and society was in relation to the increase in the number of times they referred to science and society in their exit questionnaires and interviews. The test group had a higher frequency of responses regarding science and society in both exit questionnaires and interviews. In a similar manner to scientific inquiry and science as a human endeavour the test group had more to say regarding science and society at the exit stage than the initial stages

6.3.5 Science as a Body of Knowledge

The data obtained from the questionnaires indicated that both groups appeared to have developed better understandings regarding science as a body of knowledge (Table 6.13) and, science as explaining phenomena (Table 6.14). Evidence from the interviews with children supported these findings. However, in the exit interviews, more children from the test group referred to science as explaining knowledge and the tentative NoS (Table 6.15) indicating more elaborate conceptions regarding the nature of scientific knowledge.

Table 6.13 Number of responses made by the test and control group regarding science as a body of knowledge in the initial and exit questionnaires

	Test Initial (N = 51)	Test Exit (N = 49)	Difference	Control Initial (N = 53)	Control Exit (N = 49)	Difference
Number of Responses	153	200	+ *47*	223	201	- *22*
Percentage of Overall Responses	43%	57%	+ *14%*	64%	47%	- *17%*

Table 6.14 Number of responses made by the test and control group regarding science explaining phenomena in the initial and exit questionnaires

	Test Initial (N = 51)	Test Exit (N = 49)	Difference	Control Initial (N = 53)	Control Exit (N = 51)	Difference
Number of Responses	3	26	+ *23*	9	13	+ *6*
Percentage of Overall Responses	10%	90%	+ *80%*	41%	59%	+ *18%*

Table 6.15 Number of students who discussed science as a body of knowledge in the initial and exit interviews

Sub-categories	Test Initial (n=16)	Test Exit (n=16)	Control Initial (n=16)	Control Exit (n=16)
BoK	3	3	5	4
Explain	2	4	0	3
Tentative NoS	10	14	9	9

The data obtained from the questionnaires and interviews will be considered under the following three headings

- Body of knowledge
- Explaining phenomena
- Tentative nature of scientific knowledge

Body of Knowledge

In the initial questionnaires, almost half, 45 percent, of the total number of responses given by students in all eight categories were made in relation to science providing us with facts (Appendix N). In the questionnaires, where pupils made more than one reference to science as a body of knowledge, these were recorded. The pupils made 376 references to science consisting of a body of knowledge with the test group making 153, of these responses (Table 6.12).

It is obvious from the quantity of responses regarding science as a body of knowledge in the initial questionnaires, that the over-riding conceptions of NoS held by the children at the beginning of the study related to science as a body of factual knowledge. Such responses are an indication of the children holding 'traditional' NoS conceptions, where they believed science to provide absolute and definite information and knowledge about the world. There were also more responses made in the 'facts' category in the exit questionnaire than any other. However the pupils made considerably more responses in all of the other categories at the exit stage, indicating more elaborate NoS conceptions.

The frequencies of responses indicating science as a body of knowledge increased by fourteen percent (Table 6.12) amongst the test group. At a first glance this may appear to indicate a move towards more traditional conceptions of science amongst the test group. However, there are two important factors that need to be considered. Firstly, the test group had a considerably higher frequency of responses regarding the explanatory nature of scientific knowledge in the exit questionnaires, which is an indication of more elaborate conceptions of NoS. Secondly the test group had considerably more to say regarding science in general (had higher frequencies of responses in all categories) in the exit questionnaires. So while the higher frequency of responses in the BoK category may appear to indicate a move towards more traditional or simplistic conceptions of science, amongst the test group, when the above factors are taken into consideration, the higher frequency of responses is more likely to indicate more elaborate conceptions of NoS. Another reason for this higher frequency of responses in this category may also be that NoS helped them to increase their conceptual knowledge.

In the initial interviews the children in both test and control groups generally talked about science as providing information about the world, (including environment) space (planets, the solar system) and dinosaurs (Appendix N).

> When I think of Science, I think of different types of chemicals and I think about space and different types of things like that... discover more things about planets..' (C) (Appendix N).

One child in the control group mentioned three different disciplines.

> I think that different scientists have different jobs – biologists study living things – chemists study chemicals and astronomers study space – that's what different scientists do? (C) (Appendix N).

One can see from these responses, that these children's understanding of scientific knowledge was one of providing information and facts about the world and space. In a similar manner to their counterparts in the UK (Driver et al., 1996) none of the children elaborated on science's role in providing explanations about various phenomena in their initial interviews revealing somewhat limited conceptions regarding the nature of scientific knowledge. Science's role in providing 'facts' and 'information' about Space in particular seemed to be seen as a significant feature of scientific knowledge. Some of the children referred to the 'facts' of chemistry, biology and physics. These responses illustrate the limited views held by the children pertaining to the nature of scientific knowledge, exclusively viewing scientific knowledge as making observations about the world and providing information. In the exit interviews a higher number of children made responses regarding science explaining phenomena and the tentative nature of scientific knowledge.

Explaining Phenomena

In the initial questionnaire the 'explain the world' category was only referred to 12 times and the control group made nine of these responses (Table 6.14). In the exit questionnaire, there were more responses, from both groups in this category indicating that the children were showing signs of developing more contemporary views regarding the role of scientific knowledge in providing explanations about the world (Appendix N). However, the frequency of responses from the test group in this category in the exit questionnaires was considerably higher than that of the control group (Table 6.14).

The data from the closed questions revealed a similar trend (Table 6.16 and 6.17).

Table 6.16 Comparison of test group's response relating to science as a body of knowledge in the closed questions on the questionnaire

	Test Initial (%)	Test Exit (%)	Difference (%)
Science answers questions about the world.	96 agree	94 agree	-2
When scientists give explanations they are always true.	63 disagree	96 disagree	+ 33
When scientists discover something it doesn't change.	22 disagree	53 disagree	+ 31

Table 6.17 Comparison of control group's response relating to science as a body of knowledge in the closed questions on the questionnaire

	Control Initial (%)	Control Exit (%)	Difference (%)
Science answers questions about the world.	87 agree	88 agree	+ 1
When scientists give explanations they are always true.	75 disagree	78 disagree	+ 3
When scientists discover something it doesn't change.	43 disagree	59 disagree	+ 16

This increase in response rate from both groups suggests that the pupils in both groups were beginning to move away from an understanding of scientific knowledge as solely providing factual information about the world. Their responses suggested that they were beginning to move towards an understanding of scientific knowledge also providing explanations about phenomena. The test group illustrated more acceptance of scientific knowledge explaining phenomena in the open and closed questions (Tables 6.13, 6.14, 6.16 and 6.17).

In the exit interviews the reflections from both groups regarding science as explaining phenomena were detailed and contemplative:

> Yes, I think it's very important because if we didn't know about the earth we would still be thinking that the world is, em, like a circle...like spherical and we would still be thinking that everything goes around the earth and we wouldn't know about gravity...(C) (Appendix N).

> I think science is about finding out new things about the world... They discover things and then they find out what they have to do with them and then they tell someone and someone might tell it to a school...and then everyone gets to figure out and they get to learn more about it (T) (Appendix N).

These references illustrate more in-depth ideas about scientific knowledge. In addition to accepting that science comprises facts (body of knowledge), the responses appear to indicate that the children were beginning to see the importance of scientific facts in providing explanations for different phenomena. For example, gravity (Body of knowledge) explains why things fall to the ground (explaining phenomena) (Appendix N).

Driver et al. (1996) found that many of the students in their study perceived science to be about the provision of solutions to technical problems rather than providing powerful explanations. The accounts of scientific knowledge outlined above suggest that the children in the both groups, particularly the test group, in this study appeared to have begun to move towards understandings of science as providing powerful explanations. That is not to say that they do not also perceive science as being about solving technical problems, but it does seem to indicate that the children are beginning to move towards more elaborate understandings of the role of scientific knowledge.

Mc Comas (1998) asserted that as children's NoS conceptions develop, they should become more aware of scientific knowledge and appreciate its contributions to the world. The children's responses regarding scientific knowledge in the exit interviews clearly illustrate the children's appreciation of scientific knowledge and are a good illustration of the children's understanding of science as providing information about a the world.

Tentative Nature of Science

There were only three references to the tentative nature of scientific knowledge in the open-ended questions in the questionnaire and the test group in the exit questionnaires made these.

> It can be tested as many times... (T2) (Appendix N).

In the questionnaires two of the closed questions referred to the tentative nature of scientific knowledge. The results of this analysis showed a similar trend to that observed for the open-ended questions in that, children in both groups showed more acceptance of the tentative nature of science at the exit stage (Tables 6.15 and 6.16).

The children in both groups had a considerable amount to say regarding the tentative NoS during the initial and exit interviews.

In the initial interviews children from groups referred to the development of scientific knowledge from a 'flat' world to a 'round' one:

> Yes (science knowledge can change) like when Christopher Columbus discovered America... and you know they all thought the world is flat and they stick with that ... for a couple of years.... and then scientists found out that it was round and then it changed. (C) (Appendix N)

One child from the control group had the following to say about the tentative nature of scientific knowledge:

> Yeah it has – an example some scientist guy who I've forgotten the name thought that everything was made out of fire, water, earth and air – and although later he would prove that everything was made out of atoms (C) (Appendix N).

This particular child was very articulate and his contributions in the interviews were detailed and elaborate. This level of detail regarding the tentative NoS was not typical of the responses in either group.

Three children from the control group referred to the tentative nature of science in terms of falsification in the initial interviews. They talked about science being tentative because of the possibility that more evidence could arise that would prove existing knowledge to be inaccurate.

> Yes, I think it (scientific knowledge) can change because like say if they thought a say like all the dogs were extinct, they actually might be wrong because there still might be a dog… And they could like find it and it would change. (C) (Appendix N)

> Well, see the way Dodos are extinct. Well there could be another Dodo somewhere in a foreign country or something that they don't know about and they find it, so it could change (C) (Appendix N).

The third child commented on the empirical nature of science and the way scientists replicate investigations to confirm or falsify an existing body of knowledge when referring to the tentative nature of science:

> Well yes sometimes. One scientist could make this really complicated equation and he puts in the answer and another scientist proves him wrong by doing the equation again and getting it right so really it can change until you get it exactly right and you perfect your invention or whatever you are doing sort of and that's it. (C2) (Appendix N).

This child revealed a more profound understanding of the developmental NoS.

In the exit interviews, there were more responses regarding the tentative NoS from the test than control group (Table 6.14). In the exit interviews many of the responses regarding the tentative NoS were made in relation to the tentative nature of scientific knowledge and the developmental nature of technology. Information about the Earth, Space and Nutrition, were characteristic of the examples given regarding the tentative nature of scientific knowledge.

> I'd say, when Fiona was saying about all the planets, I heard just about a few months ago that they (scientists) discovered a new planet (C) (Appendix N).

> (Gravity) They thought it was just, a world where everything was sticking to the ground like glue... They thought like, there was no gravity, they thought gravity didn't even exist (T) (Appendix N).

> Yeah it's like when the things are changing, like, the cars like, they used to be the old Fords and Morris Minors, and now they're all like, new cars like, Hondas and Subarus (T1) (Appendix N).

One child in the control group gave an example from the HoS to elaborate on the tentative NoS and he used an example of Columbus:

> It's like when Christopher Coloumbus thought that he'd go over and he'd find a new way to go to India to get spices and stuff. But when he went over he found America. He thought it was India but it wasn't, he found a whole new place (C) (Appendix N).

On the other hand there were seven references made to the HoS in relation to the tentative NoS amongst the children in the test group in the exit interviews. These children drew on examples from the history of science they had learned about in school:

> because when Galileo said that the world was round, and, and, everybody didn't believe him cause they thought that the world was flat and then they, they, trapped, they locked him in his house, so ... cause they all said that it was flat and then when he said they, they found out, and, em, they sort of did, cause they did experiments to see (T) (Appendix N).

The test teachers had incorporated elements from the history of science in their science classes. The children's responses in the exit interviews suggest that the aspects of HoS they had learned about in school contributed to their understanding of the tentative nature of scientific knowledge. The extent to which the history of science assisted the development of the children's understanding of NoS will be considered in more detail later in the chapter.

Mc Comas et al. (1998) assert that if students view science as a process of improving our understanding of the world, the tentative NoS would be viewed as a positive trait. I think it is apparent from the test groups that the children have some comprehension of science's role in improving our understanding of our world. In addition to this their responses indicate that the children in both groups, particularly the test group, viewed the tentative NoS as a positive thing. Mc Comas et al, (1998) also maintained that if students were aware of the developmental NoS, science would become more interesting for them to learn. The influence of HoS in helping pupils to arrive at an understanding of the tentative NoS was evident by the numerous citations regarding the history of science amongst the test group.

6.3.6 History of Science

The data obtained from the open-ended questions indicated that the children from the test group developed considerably more elaborate conceptions of the history of science than those developed by their peers in the control group (Table 6.18).

Table 6.18 Number of responses made by the test and control group regarding history of science in the initial and exit questionnaires

	Test Initial (N = 51)	Test Exit (N = 49)	Difference	Control Initial (N = 53)	Control Exit (N = 51)	Difference
Number of Responses	13	33	+ *20*	4	1	+ *3*
Percentage of Overall Responses	25%	75%	+ *50%*	75%	25%	- *50%*

Table 6.18 illustrates that the test group had a higher frequency of responses regarding the history of science (HoS) at the exit stage.

The interview data also revealed that considerably more children in the test group referred to aspects of the history of science in their exit interviews, particularly in relation to significant figures and events in the history of science and society and the history of science (Table 6.19).

Table 6.19 Group interviews: History of science

Sub-categories	Test Initial (N=16)	Test Exit (N=16)	Control Initial (N=16)	Control Exit (N=16)
Significant figures and events	6	9	2	0
Society and the history of science	0	3	2	2

Significant Historical Figures and Events

In the initial interviews, children from both groups made brief references to important figures in the history of science.

> the first thing that comes into my head is probably Albert Einstein...(C) (Appendix N).

> I think of inventors (T) (Appendix N).

Two children in the control group made references to significant figures in the history of science in the exit interviews. The first was a vague references to a scientist whom 'no one believed at the start'. This child couldn't remember the scientist's name or what he invented. The second was a general reference to science and scientists' contributions over the last number of years:

> Well I think of the like, the scientists that kind of risked their lives for the better of mankind and all that.... You know, all the things that we'd found out of the last, well, fifty years and that and how we made the microchip, we've made it to the moon and we've unlocked many of the secrets of the universe, loads of physics and all that (C2) (Appendix N).

The test group on the other hand had a considerable amount to say regarding the significant figures and events in the history of science in their exit interviews. They talked in detail about scientists' lives particularly referring to the human and personal aspects of their lives. They discussed famous scientists that they had learned about in school.

> ...Alexander Graham Bell, he invented the phone because his Mam and Dad were deaf...he was so interested in sound and he wanted people to be able to hear each other...before he made, like, talking one, he used beeps like (T) (Appendix N).

They also incorporated many different tenets of NoS when reflecting on the history of science. These included human endeavour, creativity, technology used to aid scientific observations, influence of society, tentative and developmental NoS.

> ...the reason they probably thought the world was flat, they might have...walked a long way or something and realised it wouldn't turn or something like and thought it was all just flat (Observation, investigation)...he invented the telescope (technology used to aid observations/ empirical NoS)...Well you could just see...look at the clouds and see how they went down (observation, ,evidence, empirical NoS)...he might have looked at them and say the clouds were down and then went (Drawing conclusions...Empirical NoS) (T) (Appendix N).

The teachers in the test group used elements from the HoS throughout their science teaching. In many incidences accounts of scientists' lives were given and various social factors that may have contributed to or inhibited their work were provided (Appendix H). The data obtained from the children appeared to indicate that the children remembered detailed accounts from the history of science and were able to consider these accounts and equate them with different aspects of NoS.

Society and the History of Science

In the initial interview, one child from the control group mentioned how people accept electricity as normal today but would have found it very unusual many years ago.

someone finds out electricity and they think it's amazing and all but maybe years and years ago, like in cavemen time, they could've invented all really weird things... but they just couldn't do anything like that (invent electricity) , or maybe they could. But, em today em, like, we know electricity is normal to us (C1) (Appendix N).

The test group children made no comments regarding how science and society are affected by one another in the initial interviews.

A number of children in the test group remarked on society and the history of science in their exit interviews. Two of the children commented on how society has had an influence over scientific development in the past. The first child talked about Galileo and how society at the time did not believe what he had to say:

...because when Galileo said that the world was round, and, and, everybody didn't believe him cause they thought that the world was flat and then they, they, trapped, they locked him in his house, so ... cause they all said that it was flat and then when he said they, they found out, and, em, they sort of did, cause they did experiments to see' (T) (Appendix N).

One child talked about how religion has different explanations of reincarnation than science:

Just the thing about the food chain, that all comes em, down to, em, the, the Buddhas, because, they, think that...Yeah, if they say, if they were a good animal or a good person they would be reincarnated with a higher form of like (T) (Appendix N).

Another child talked about how society was disagreeing with Faraday about his theories on electricity:

He was trying to prove that you can make electricity from magnets, but, em, people, were trying to say no you can't. Magnets, em, magnets can em, get rid of em, electricity not the other way around (T) (Appendix N).

These references illustrate a development in the children's understanding of how society has influenced scientific development in the past.

Discussion

When the children from the test group referred to landmarks and figures in the HoS in their exit interviews, all of them were related to aspects of the HoS that they had learned about in school over the course of the year. The control group on the other hand drew from sources other than school science. The test group's responses regarding the HoS were considerably more frequent and elaborate than those of the control group during the exit interviews.

While both groups made references to scientists and their significant inventions and the importance of these inventions to society, the test group also drew on examples from the history of science to exemplify arguments about the NoS.

In a similar manner to the Solomon et al. (1994) study, the use of historical aspects by the test teachers within the school science curriculum appeared to have contributed significantly to the development of the pupils' conceptions of NoS. In Solomon et al. (1994), this evidenced itself in that many of the pupils began to understand the purpose of scientific work as 'explaining phenomena' rather than 'discovery' of facts by chance.

In this study the impact of the HoS aspects that were incorporated in the science lessons was apparent by the numerous detailed recollections from the test group and the extent to which the test group ustilised elements from the HoS to exemplify arguments regarding different aspects of NoS. The extent to which the teachers explicitly linked these historical accounts to aspects of NoS cannot be established from the teachers' notes and therefore the extent to which the HoS affected the development of more contemporary NoS conceptions is difficult to ascertain. However, it appears that the inclusion of HoS has helped humanise science for the children in the test group and is something that they appear to find interesting and memorable.

6.4 General Discussion

During their science classes the children in the test group conducted activities and discussed and reflected on various issues that were explicitly related to different aspects of NoS. The results appear to indicate that the children in the test group developed considerably more elaborate and contemporary conceptions of NoS than their peers in the control. The control group had not been exposed to the activities that explicitly addressed NoS issues nor had they been given the opportunity to reflect on and discuss NoS issues. The findings also revealed that there were considerable differences between the test and control group's experiences and perceptions of school science, their language and thinking skills and their conceptions of NoS.

In recent years there has been significant progression in the development and revision of science curricula all over the world. The emphasis in curriculum documents has moved away from teaching science as a body of knowledge towards a view of science as a human endeavour, emphasising the importance of the various processes and procedures employed in scientific inquiry. The Irish primary science curriculum also emphasises the importance of hands-on approaches to science on the application and development of pupils' science skills and on developing more positive attitudes towards science (DES, 1999a). As discussed in chapter five, the data obtained from the teachers suggests that the test teachers were more enthusiastic and confident about teaching science, employed a greater variety of approaches and afforded their pupils more opportunities to discuss and defend their ideas. The data also revealed that the children in the test group discussed their experiences of school science more frequently than the control group at the exit stage. In addition to this the test group's accounts of school science were considerably more detailed revealing a higher level of enthusiasm and interest in school science. The test group's responses also suggest that they had conducted more hands-on investigations over the course of the year and had been given more opportunities to apply and develop their scientific skills. It would therefore appear that the children in the test group who had received explicit instruction in NoS, achieved some of the aims of the science curriculum to a higher degree.

As mentioned before, social constructivist theories of learning emphasise the importance language plays in facilitating learning. The findings of this study appear to indicate that the children in the test group were given more time to discuss and reflect on various issues during science classes. The test children's responses at the exit stage indicated that their language and thinking skills had developed to a greater extent than the control group. Many of the test group's responses regarding different issues were more in-depth and profound than the responses they had given at the initial stages. This was not the case for the control group, who at times had lower frequency of responses regarding different issues at the exit stage

In chapter two contemporary conceptions of NoS that were deemed appropriate for primary children to hold were outlined. It was suggested that primary school children should have some understanding of the reliability of scientific knowledge and the processes used to derive this knowledge. That primary children be aware of science as a human endeavour incorporating creativity, imagination and subjectivity was another feature outlined. Some knowledge of the relationship between science and society was also cited as a component of aspects of contemporary NoS conceptions of which primary school children might be aware.

The data obtained from the questionnaires and interviews revealed that the children in the test group developed more elaborate conceptions of NoS than that of their peers in the control group. The test group's more frequent and in-depth responses relating to the subjectivity and creativity that is involved in science illustrated an increase in their understanding regarding science as a human endeavour. Their higher frequency of responses regarding scientific inquiry at the exit stage and their references to a higher number of scientific processes and skills that scientists employed during scientific inquiry were also an indication of more contemporary NoS conceptions. There were also considerable differences amongst the test and control group's responses regarding scientific inquiry in that the test group utilised numerous examples from their school science experiences to illustrate points they were making about scientific inquiry. At the exit stage the test group also revealed more elaborate conceptions regarding the nature of scientific knowledge. They referred to science explaining phenomena and the tentative nature of scientific knowledge more frequently and in more detail than the control group. While both groups revealed similar conceptions regarding science and society at the exit stage the test group had a higher frequency of responses regarding science and society. In a similar manner the test group had considerably more frequent and in-depth accounts regarding significant figures and events in the history of science and how society has been affected by science in the past. This indicated more elaborate conceptions of the history of science than the control group.

While it is not suggested that the test group's earlier more 'simplistic' views of NoS have disappeared altogether, it is suggested that there were considerable changes towards more contemporary NoS conceptions amongst the pupils in the test group. Their responses regarding NoS issues were more frequent and detailed at the exit stage and they cited numerous examples from school science when discussing NoS and HoS issues. The control group had not explicitly addressed NoS issues, nor had their teachers incorporated aspects of HoS into the science class. The pupils made fewer responses regarding NoS and HoS issues in the exit questionnaire and did not utilise examples from school to illustrate points they had made. The test group's responses were more detailed and reflective than the control group's responses in relation to NoS and HoS issues. The test group had been given numerous opportunities to discuss these issues during their science classes.

It appears from the findings, therefore, that utilising explicit approaches in addressing various NoS issues in the Irish Primary class appears to have had considerable benefits to the children's learning. In addition to developing more elaborate NoS conceptions, the explicit approaches to NoS have resulted in increased children's interest and enjoyment of school science and an increase in the employment and development of children's science skills. Other benefits of explicit approaches to teaching about NoS apparent in the findings are language development and an increase in the children's ability to formulate and provide arguments for discussion. Opportunities afforded to the test children when explicitly addressing NoS issues have facilitated the employment and development of their reflective and thinking skills. The findings of this study suggest that the inclusion of explicit approaches in teaching about NoS as part of the Science Curriculum (DES, 1999a) benefits children in their science education and also teachers in achieving many of the curriculum aims and objectives.

7 CONTENT ANALYSIS

7.1 Introduction

In chapter two, the literature relating to teachers' conceptions of NoS, methods of developing these conceptions and methodologies for translating NoS conceptions into classroom practice was reviewed. Literature pertaining to primary and post-primary school pupils' NoS conceptions and various interventions on the development of these conceptions was also explored. The importance of prospective and practising primary and post-primary teachers and their pupils holding contemporary conceptions was deliberated on. Literature concerning issues relating to the inclusion of NoS in curriculum documents and assessment tools was also considered.

The first three phases of this study revealed that explicitly teaching NoS was effective in developing contemporary NoS conceptions amongst Irish pre-service teachers. The findings also revealed that teaching NoS explicitly resulted in beginning teachers using more reflective constructivist approaches to teaching science and increased their confidence and interest in teaching science. This study indicated that those primary children who were taught about NoS explicitly as part of their science class were given more opportunities to employ scientific skills. In addition to this these pupils were more interested and enthusiastic about doing science in school and gave more in-depth reflections regarding their experiences of school science than their peers who had not received explicit instruction in NoS. The literature suggests that amongst the factors for successful implementation of NoS is its explicit inclusion amongst the aims and objectives in curriculum documents (Bell et al., 1995; Hipkins et al., 2005; Lederman, 1998). The final phase of the study therefore conducted a preliminary content analysis of seven international primary science curriculum documents and two international assessment documents, in a bid to establish the extent to which each document prioritises NoS understanding. The findings of this analysis are pertinent in light of the forthcoming primary science curriculum review in Ireland.

7.2 Curriculum Reform

In recent years, reform efforts in various countries have focused on enabling students to develop sound conceptions of NoS and scientific inquiry. (American Association for the Advancement of Science [AAAS], 1990, 1993; Appleton, 2003; Hipkins et al., 2005; Klopfer, 1969; National Research Council [NRC], 1996; National Science Teachers Association [NSTA], 1982). The emphasis in curriculum documents has moved away from teaching science as a body of knowledge toward a view of science as a human endeavour, emphasising the importance of the various processes and procedures employed in scientific inquiry. Strong emphasis has been placed on a hands-on approach to science and on children enjoying science. Providing scientifically literate students, who are capable of utilising scientific knowledge to make informed decisions in society, is also advocated (Australian Science, technology and engineering council (ASTEC); 1997; DES, 1999; Ministry of Education Wellington, New Zealand, 1993; California Department of Education, 2004).

Seven international science curriculum documents were examined to ascertain the extent to which the development of NoS conceptions is addressed in each. The reasons for their selection were outlined in chapter three (section 3.4.1, phase four).

The seven curriculum documents that were analysed were:

- The Primary Science Curriculum (DES, 1999a, 1999b)
- The World Around Us (Northern Ireland Council for the Curriculum, Examinations and Assessment (CCEA 2007)
- The National Curriculum for England and Wales, key stages 1 - 4, (Department of Education and Employment, 2000)
- Environmental Studies: Society, Science and Technology, 5-14 National Guidelines, (Scottish Executive, 2000)

- New Zealand: Curriculum Framework, (Ministry of Education Wellington, New Zealand, 1993)
- Queensland: Science Curriculum Development Handbook, (Queensland Department of Education, 1996)
- Science Framework for California Public Schools, (California Department of Education, 2004)

Before a content analysis, which establishes the extent to which these seven curriculum documents emphasise the development of NoS conceptions and the extent to which NoS understanding is assessed in the seven countries is outlined, a brief overview of primary science in the seven countries is provided.

7.2.1 Ireland

In the 1971 primary curriculum, Social and Environmental Studies became a compulsory subject. Elementary science was a component of this programme for fifth and sixth classes. Unfortunately the science element was overlooked in most schools (I.N.T.O, 1992). In 1999 the Revised Primary Curriculum and Curriculum Guidelines (DES, 1999a, 1999b) were published, and science was included as a compulsory subject in its own right. This science curriculum aimed at improving the level of achievement in science and science related activities among Irish primary school children.

7.2.2 Northern Ireland

In 1990 a statutory curriculum was introduced in Northern Ireland. The science curriculum contained fifteen attainment targets (ATS), one of which included the Nature-of- Science (NoS). The entire curriculum was reviewed in 1992 and the original 15 ATS were reduced to five. The first attainment target (AT1) 'exploring and investigating in science' included aspects of NoS, however learning about the 'nature-of-science' was not as explicitly stated as it had been in the 1990 version.

The curriculum was reviewed again in 1996. This review resulted in a significant reduction in the scientific knowledge content and included technology with science. The science curriculum was re-organised into two attainment targets (AT),

- AT1 'Exploration and investigation in science and technology - Skills'
- AT2 - 'Knowledge and Understanding of Science and Technology - Concepts'
- (CCEA, 1996).

A new curriculum 'The World Around Us' was introduced in Northern Ireland in 2006, which integrates Geography, History, Science and Technology. The aim of this integrated curriculum is that the children should be given opportunities to explore their environment and to investigate a range of ways in order to make sense of their world (past and present). The skills to be developed in The 'World Around Us' include, communication skills, thinking skills, being able to manage information, problem solving skills, being creative, working with others and self management. The curriculum guidelines suggest that the development of these skills should be integrated.

7.2.3 England and Wales

The Beyond 2000: Science Education for the Future report, conducted by Millar and Osborne (1998), was influential in England and Wales. This report concluded that the National Science Curriculum for England and Wales failed to meet the needs of modern day society and did not anticipate the needs of the future. The authors reported that:

> The changing curricular position of science has not been accompanied by corresponding change in the content of the science curriculum ...This has remained fundamentally unaltered and is, essentially, a diluted from of the 1960s GCE curriculum (p4, 1994).

The report gives ten recommendations amongst which was suggested that greater attention should be given to the social processes utilised in the generation, testing and validating of scientific claims, the employment of a wider array of teaching methodologies and learning approaches which should include case studies of historical and current issues.

The current science curriculum is mandatory in primary schools in England and Wales, and the 'programmes of study' must be adhered to. The Education Act (1996), section 353b, defines a programme of study as the 'matters, skills and processes' that should be taught to pupils of different abilities and maturities during the key stage. Knowledge, skills and understanding in each 'programme of study' identify four areas of science that pupils study, which are taught through contexts. Science is one of the core subjects. While a subject in its own right, it is recommended that science be integrated with other subjects throughout the curriculum.

7.2.4 Scotland

The Scottish Consultative Committee on the Curriculum (SCCC) established a review committee in response to the growing awareness of the necessity for a more elaborate public understanding of science and a more scientifically literate society. A significant consideration of this review was to attend to the more extensive questions regarding "the nature of science and the science component of the curriculum" (SCCC, 1996, p4). This review defined scientific literacy / capability as comprising five aspects, scientific curiosity, scientific competence, scientific understanding, scientific creativity and scientific sensitivity.

NoS conceptions, or inadequate conceptions, were amongst the key issues that emerged from a review of 'Effective Teaching in Science', conducted by Harlen (1999) on behalf of the Scottish Office Education Department and 'Improving Achievement in Science in Primary and Secondary Schools' (HMIE, 2005). The reports indicated that teachers tended to largely deliver the science curriculum emphasising science as a body of 'facts' and processes, rarely referring to the tentative, developmental, human, cultural or historical factors that influence scientific inquiry and interpretations of science. Teacher intervention and guidance were deemed essential in conjunction with the aforementioned activities, so that pupils' attention could be drawn to the relevant aspects of NoS (HMIE, 2005).

The '5-14 National Guidelines for Environmental Studies' (Scottish Executive 1994) were first published in 1994 but an extensive review began in 1998 in an attempt to clarify and simplify these guidelines. In this revision, information technology and health education were taken out of the 'Environmental Studies programme' as they were considered to be important subjects in their own right. Separate guidelines were devised for these. In the revised curriculum guidelines, environmental studies consist of social (history and geography) science and technology. The revised science curriculum is essentially the same as the 1994 curriculum, with some slight changes.

The Scottish curriculum '5-14 National Guidelines' is currently under review. In 2004 the Scottish Executive published details of an extensive reform of the educational system in 'Ambitious, Excellent Schools'. This reform includes a new curriculum in schools.

7.2.5 New Zealand

Prior to the 1990s the primary curriculum in New Zealand was presented through numerous syllabi and curriculum guidelines, which spanned the years 1961 – 1986. In 1991 a total revision of the primary curriculum began. This initiative was called the 'The New Zealand Curriculum Framework', which was published in 1993. Science is one of seven essential learning areas. A curriculum is not prescribed, however, the government has outlined its expectations in the 'New Zealand Curriculum Framework' and 'National Curriculum Statements. These documents define the learning principles and achievement aims and objectives for the seven key learning areas, which are obligatory in all New Zealand schools.

The seven essential learning areas are compulsory from years 1 to 10 (age 5-15 years) but are optional after year 10. The new science curriculum was published in 1993 and has been compulsory since 1995. In 2002 a further review of the

Curriculum Framework was undertaken. The Ministry of Education published the draft New Zealand curriculum in July 2006, and sought feedback on this by the end of November 2006. The national curriculum was finalised and available at the end of 2007. Schools were provided time to implement it.

7.2.6 Queensland (Australia)

Science, as opposed to 'nature study' has been part of the curriculum in Australian primary schools for over forty years. However, Australian studies have revealed that many primary teachers are not teaching science. (Australian Science, Technology and Engineering Council, 1997; Department of employment education and training, (DEET), 1989; Goodrum et al., 2001). Reform efforts in Australia attempted to address these concerns by introducing more scientific content in pre-service courses (DEET 1989) however there is little evidence indicating that this has led to an improvement (Skamp 1989, 1997).

On a more positive note Appleton (2003) highlighted some studies, which revealed that when scientific content had been introduced in a less traditional manner, some success in addressing the concerns had been realised (Jane, Martin, & Tyler, 1991; Walsh & Lynch, 1985). Other studies reported success when focus had been put on pupils' 'alternative frameworks', through the employment of constructivist methodologies (Clark 2001, Hardly Bearlin, & Hirkwood, 1990; Napper & Crawford 1990,) Australia comprises 8 states and territories, each of which has constitutional responsibility for school education. Since 1994, all states and territories have been implementing different versions of a national curriculum, aimed at promoting scientific literacy (Rennie et al., 2001). In 1991 the Australian Education Council (AEC, now MECETYA) began to develop national statements and profiles for eight broad key learning areas, including science.

In Queensland, the Queensland School Curriculum Council (QSCC) was responsible for developing the Curriculum Development Handbook and the Curriculum Framework. The Queensland science curriculum was developed in 1996, and after a trial period implemented in 1999. In 2002 the Queensland Studies Authority (QSA) was formed in an effort (among other things) to streamline statutory arrangements of the state's curriculum. The QSA also assumed responsibility for curriculum revision. They review the syllabi every three to six years. These syllabi generally remain current for around five years.

7.2.7 California (USA)

Two educational documents that have been very influential in science education policy and practice in the US were 'Benchmarks for Science Literacy' (Benchmarks) (1993) and 'National Science Education Standards' (Standards) (1996). The majority of the 50 states has used these documents in the revision of their science education frameworks and curricula. Both documents portray the multi-faceted and complex nature of scientific inquiry, which provides reliable and stable knowledge about our world. This knowledge is portrayed as tentative and becomes progressively more accurate as new information about the natural world continues to unfold. (Good & Shymansky, 2001).

In the US, every state has autonomy over education. Many states have state assessment programmes or take national assessments like the National Assessment of Educational Progress (NAEP). In 1998 the state of California adopted the Science Framework for California Public Schools (SFCPS). A revised edition of this framework (2004) in addition to instructional material and guidance for elementary, middle and high schools includes evaluation criteria for grades K – grade 8 (ages 5 - 13 years). The science framework aims at instructing pupils in science and preparing a scientifically literate workforce (Curriculum Developmental and Supplemental Materials Commission, 2004).

7.3 NoS in the Seven Curriculum Documents

The extent to which NoS is included in these seven curriculum documents various considerably. Some of the documents specifically refer to NoS, providing detailed accounts of its characteristics while other documents outline rationales and methodologies behind their science curriculum without defining or referring to NoS at any stage. The New Zealand and Queensland documents for example, devote an entire unit to the development of NoS conceptions while the emphasis placed on the development of NoS conceptions various greatly in the remaining five documents.

Answers to the following questions were sought while examining the curriculum documents.

- Is a description of NoS provided in the introduction? What tenets of NoS are specifically mentioned in this description?
- Is the development of NoS conceptions specifically mentioned as a general aim?
- Is there a strand/unit/section specifically dedicated to the development of NoS? Are there objectives that explicitly address learning about NoS within this strand?
- Are there objectives that implicitly address different tenets of NoS within strands / sections / unit? If yes, which tenets are addressed?

The responses to these questions will now be considered in turn.

7.3.1 Is a Description of NoS Provided in the Introduction? What Tenets of NoS are Specifically Mentioned in this Description?

Out of the seven documents selected for analysis, The Northern Ireland Curriculum is the only one that does not provide a description of NoS in the introduction. Instead it provides an overview of how children learn utilising their senses and experiences.

> Children are naturally curious and often ask profound questions about themselves and the nature of the world around them ... before starting school they will have had opportunities to explore their world around them in their home, pre-school setting and the local area...(CCEA, 2007, p.37).

All remaining six documents provide a description of NoS in the introduction.

> Science involves people investigating the living, physical material and technological components of the environment and making sense of

them in logical and creative ways. Using systematic and creative investigations, scientists produce a constantly evolving body of knowledge and make an important contribution to the decisions, which are shaping our world and the world of future generations....Science and technology are major influences in many aspects of our daily lives (Ministry of Education Wellington, New Zealand, 1993, p. 1).

... The study of science as a 'way of knowing' and a 'way of doing';...Scientific knowledge is a set of explanations, made by communities of scientists, which attempts to account for phenomena and experiences. At times these explanations may seem to conflict with everyday understandings, but they are seen as viable in the light of current evidence and scientific argument. These explanations are tentative and continue to be modified. Scientists are very much a part of the world, which they study. Their observations and inferences are influenced by their prior experience and understandings, the social groups to which they belong and their status within these groups. Like scientists of the past and present, students understand and appreciate that current scientific knowledge has been built up over time and has been organised into disciplines and fields... (Department of Education, 1996, p.1).

Science is concerned with the development of knowledge and understanding of the biological and physical aspects of the world... science involves testing, changing or confirming ideas about how things are and how they work. Scientific theories are used to explain observed phenomena or to predict events. These ideas and theories are subject to review and change and will be modified as new evidence comes to hand. Science is a human endeavour that depends on the creativity and imagination of people as they reflect critically to make sense of their experience... (DES, 1999a, p.2).

Science is limited by its tools- observable facts and testable hypothesis...discussions of scientific fact, hypotheses or theory related to the origins of the universe, the earth and life (the how) are appropriate to the science curriculum...A scientific fact is an understanding based on confirmable observations and is subject to test and rejection. A scientific hypothesis is an attempt to frame a question as a testable proposition. A scientific theory is a logical construct based on facts and hypotheses that organises and explains a range of natural phenomena. Scientific theories are subject to testing, modification and refutation as new evidence and new ideas emerge. Because scientific theories have predictive capabilities they essentially guide further investigation...(California Department of Education, 1994, p.ix).

> Science does not tell us everything that we want to know about life, or all we need to know. But it does provide us with the most robust information about the way the universe works that has so far become available to us.... Scientific method is about developing and evaluation explanations through experimental evidence and modeling. This is a spur to critical and creative thought. Through science, pupils understand how major scientific ideas contribute to technological change - impacting on industry, business and medicine and improving quality of life. They learn to discuss science-based issues that may affect their own lives, the direction of society and the future of the world. (DES, 2000, p.15).

> ... environmental studies bring together the main ways in which pupils learn about the world. It involves learning about the social and physical conditions that influence or have influenced the lives of individuals and communities.... Acquiring, interpreting and using evidence and information about the world they live in is part of a sequence of discovery and rediscovery for every generation...pupils will be able to take better-informed decisions and to act in ways that are sensitive to environmental issues and consistent with the idea of sustainable development ... (Scottish Executive, 2000, p.3).

Table 7.1 outlines the aspects of NoS that are mentioned in some or all of these accounts and table 7.2 provides an overview of the aspects of NoS that were referred to in the introduction in each of the curriculum documents.

Table 7.1 Aspects of NoS and descriptions of categories

Aspects of NoS & Abbreviation	Description of Category
Body of Knowledge (BOK)	References to science as a body of knowledge that informs us and provides us with information about the world. Science as providing explanations about phenomena.
Tentative and Developmental (Tent.)	References to the tentative and developmental nature of scientific knowledge
Scientific Inquiry (Inquiry)	References to various scientific processes and skills and scientific inquiry
Human Endeavour (Human End.)	References to science as a human endeavour.
Creativity and Imagination (Creative)	Creativity and imagination employed in scientific inquiry
Science and Society (Society)	Science and technological inventions and advances. Science and computers. Science as improving quality of life.
Philosophy and Science (Phil.)	References to reflection and thinking skills in relation to science.
Scientific Literacy	Developing understanding of science concepts and skills to facilitate participation in society, being informed citizens.
History of Science (HOS)	References to landmarks and figures in the history of science.

Table 7.2 General account of NoS given in the introduction of the curriculum documents

	BoK	Tent.	Inquiry	Hum. End.	Creative	Society	Phil.	HoS
Ireland	√	√	√	√	√	√	√	√
CAL (California)	√	√	√	√	√	√	√	√
NZ (New Zealand)	√	√	√	√	√	√		√
QL (Queens-land)	√	√	√	√		√	√	√
Scotland	√	√	√	√		√	√	√
England & Wales	√		√		√	√	√	√

Table 7.2 illustrates that science as a body of knowledge, scientific inquiry, science and society and the history of science were mentioned in the introduction of all six documents. The philosophy of science was not referred to in the New Zealand account. Queensland and Scotland did not mention the creative aspect of science and the England and Wales document did not allude to science as a human endeavour or the tentative NoS.

In general the portrayals of NoS provided in the introduction of six out of the seven curriculum documents are in keeping with contemporary accounts of NoS, providing elaborate and modern descriptions of science.

7.3.2 Is the Development of NoS Understandings Specifically Mentioned as a General Aim?

The Queensland and New Zealand curricula are the only two documents that include aims that specifically refer to NoS understanding. For example, two of the 'key learning area outcomes' in the Queensland Curriculum Framework are that students will:

- understand and appreciate the evolutionary nature of scientific knowledge;
- understand the nature of science as a human endeavour, its history, its relationship with other human endeavours and its contribution to society" (p.8).

Amongst the general aims of science education in the New Zealand Framework is:

> the development of students' understanding of the evolving nature of science and technology (p. 9)

However, all the documents (with the exception of California and Northern Ireland), include aims that address different aspects of NoS understanding amongst their general aims of science education. Table 7.3 outlines the aspects of NoS addressed in the general 'aims / outcomes' sections of the curriculum documents.

Table 7.3 Different aspects of NoS that the general aims in the curriculum documents addressed

	BOK	Tent.	Inquiry	Hum. End.	Creative	Society	Phil.	HOS
Ireland	√		√		√	√	√	
CAL								
NZ	√		√	√		√		√
QL	√	√	√	√		√	√	√
England & Wales	√		√		√	√	√	√
Scotland	√		√			√		
N. Ire								

These aims are not explicitly linked with the development of NoS understanding, but rather they implicitly address NoS issues. For example, the Republic of Ireland document acknowledges the importance of creativity in science. One of the general aims of science education outlined in the Republic of Ireland Curriculum is:

> to encourage the child to explore, develop and apply scientific ideas and concepts through designing and making activities (p. 11).

However, this aim does not explicitly link designing and making with the development of creative aspects of NoS.

One of the general aims in the Queensland curriculum refers to science as a body of knowledge that explains phenomena:

> (that students will) understand that scientific knowledge has been organised by the scientific community into disciplines based on recognisable patterns in the phenomena studied (p. 8).

Science as a human endeavour is referred to in the general aims of science education in the New Zealand curriculum:

> developing students understanding of the different ways people influence, and are influenced by science and technology(p. 9.).

Again these aims are not explicitly linked to the development of NoS understandings. When figures 7.2 and 7.3 are compared, there are considerably more references to the different aspects of NoS in the descriptions of NoS provided in the introduction of the curriculum documents in each country, than are provided amongst the general aims of science education. While the documents provide contemporary and elaborate descriptions of NoS, the general aims do not appear to prioritise the development of NoS conceptions to the same extent. The Northern Ireland and California documents do not mention any aspect of NoS amongst their curriculum aims, Scotland only refers to three aspects, and Ireland and New Zealand refer to only four aspects. Six and seven aspects of NoS were referred to respectively in the England and Wales and Queensland curriculum aims.

7.3.3 Is there a Strand/Unit/Section Specifically Dedicated to the Development of NoS? Are there Objectives that Explicitly Address Learning about NoS within this Strand?

The Queensland and New Zealand curriculum documents both contain strands dedicated to learning about NoS and objectives that explicitly address tenets of NoS. One of the five strands of the 'key learning areas' in the Queensland curriculum is 'science and society'.

The key concepts in this strand are:

- 'Historical and cultural factors influence the nature and direction of science which, in turn, affects the development of society;
- Science as a 'way of knowing' is shaped by the ways that humans construct their understandings;
- Decisions about the ways that science is applied have short-and long-term implications for the environment, communities and individuals.

(p. 12, Queensland Department of Education, 1996)

At each level in primary school (Foundation to level 6) there are a number of core learning outcomes within this strand that are aimed at developing pupils' NoS conceptions (Table 7.4). Many different aspects of NoS are addressed from foundation stage to level 6, an overview of which is provided in Table 7.5.

Table 7.4 Examples of core learning outcomes in the science and society strand of the Queensland School Curriculum

Aspect of NoS	Example of Core Learning Outcomes
Science and Society	That students will understand some of the ways that science is applied in their daily lives (F, 1 - 6)
	Understand that everyone is affected by science and its applications
	Students are developing an awareness of the tools scientists use and the impact of the applications of science in society
	Students prepare presentations to inform others about some ethical implications of certain applications of science
Tentative	Understand that scientific ideas have changed and will continue to change as new evidence is collected
PoS	Children discuss their own thinking about natural phenomena
Empirical	Children make generalisations from observations made during an investigation
	Identify some ways scientists think and work
	Children recognise the need for quantitative data when describing natural phenomena
	Students refine investigations after evaluating variations and inconsistencies in experimental findings
HoS	Students relate some of the ways that people of various historical and cultural backgrounds construct and communicate their understandings of the same natural phenomena
	Contributions to the development of scientific ideas made by people from different cultural and historical backgrounds
Tentative	Consider how and why scientific ideas have changed over time
Human End.	Students examine and evaluate situations where their observations or conclusions are influenced by previous experience
Technology	Students create timelines showing how the science of tools and equipment has changed over time
	Students are developing an awareness of the tools scientists use...

Table 7.5 Aspects of NoS addressed in Queensland School Curriculum

Level	BoK	Tent.	Empirical	Hum. End.	Creat.	Soc.	Phil.	HoS	Tech.
Foundation						√			
Level 1	√		√			√	√		
Level 2	√		√	√		√	√	√	√
Level 3	√		√	√		√	√	√	√
Level 4	√	√	√	√		√	√	√	√
Level 5	√	√	√	√		√	√	√	
Level 6	√	√	√	√		√	√	√	√

There are six strands on the New Zealand Framework. One of the two integrating strands is ' Making sense of the NoS and its relationship to technology'. The achievement aims within this strand are that the students will use their developing scientific knowledge, skills and attitudes to:

- Critically evaluate ideas and processes related to science and become aware that scientific understanding is developed by people, whose ideas change over time;
- Explore the relationships between science and technology by investigating the application of science to technology and the impact of technology on science;
- Gain an understanding of personal, community and global implications of the application of science and technology.

(p. 24, Ministry of Education, Wellington, New Zealand, 1993).

An example of the achievement aims in the making sense of the NoS and its relationship to technology strand in the New Zealand Curriculum Framework is provided in table 7.6 and an overview of the aspects of NoS that are addressed at each level is provided in table 7.7.

Table 7.6 Examples of achievement aims in the making sense of the NoS and its relationship to technology strand in the New Zealand Curriculum Framework

Aspect of NoS	Example of Achievement Aim
Science and Society	Investigate the impact of some well-known technological innovation or scientific discovery and/or the local environment
	Investigate how knowledge of science and technology is used by people in their everyday lives
Tentative	Write a historical case study of people's developing ideas in a selected area of scientific knowledge
	Critically evaluate ideas and process related to science and become aware that scientific understanding is developed by people, whose ideas change over time
Technology	Explore and suggest what simple items of technology do
	Investigate examples of simple technological devises and link these with some scientific ideas
	Explore the relationships between science and technology by investigation the application of technology and the impact of technology on science
BoK	Critically evaluate ideas and process related to science and become aware that scientific understanding is developed by people, whose ideas change over time
	Use their knowledge of a scientific idea to identify and describe examples of technology in an applied way
Scientific Inquiry	Recognise when simple investigations can be classified as a 'fair test' and make decisions about the worth of results
PoS	Share and compare their emerging science ideas
HoS	Write a historical case study of people's developing ideas in a selected area of scientific knowledge

Table 7.7 Aspects of NoS addressed in New Zealand Curriculum Framework

Level	BoK	Tent.	Empirical	Hum. End.	Creat.	Soc.	Phil.	HoS	Tech.
Level 1							√		√
Level 2	√		√			√		√	√
Level 3			√			√		√	√
Level 4			√			√		√	√
Level 5	√	√	√			√	√	√	√
Level 6	√	√	√			√	√	√	√
Level 7	√	√	√			√	√	√	√

Tables 7.4, 7.5, 7.6 and 7.7 show that the 'Science and Society' strand in the Queensland science curriculum and the 'Making sense of the NoS and its relationship

to technology' strand in the New Zealand Framework explicitly address numerous aspects of NoS at all levels. The aspects of NoS to be addressed in classrooms that are suggested in these two documents portray contemporary and elaborate conceptions of NoS. If these 'achievement aims' and 'learning outcomes' were achieved, it is likely that contemporary conceptions of NoS would ensue.

None of the other five documents contain strands or units that explicitly address learning about tenets of NoS.

7.3.4 Are there Objectives that Implicitly Address Different Tenets of NoS within Strands? If so, What Tenets are Addressed?

The objectives in every strand in all seven documents were examined to ascertain whether they (implicitly) referred to aspects of NoS. All seven documents contained objectives that referred to numerous tenets of NoS within various strands and units but did not explicitly state that they were related to the development of NoS conceptions. Table 7.8 illustrates the tenets of NoS that were implicitly addressed in the various documents and table 7.9 provides examples of the objectives relating to each tenet.

Table 7.8 Summary of the tenets of NoS implicitly addressed in various strands in the curriculum documents

	BoK	Empirical	Tent.	Hum. End.	Creat.	Soc.	Techn.	PoS	HoS
IRE	√	√			√	√	√	√	√
CAL	√	√		√	√	√	√		√
NZ	√	√	√	√	√	√	√	√	√
QL	√	√	√	√	√	√	√	√	√
ENG	√	√			√	√	√	√	√
SCO	√	√			√	√	√	√	
NI	√	√			√	√	√	√	

Table 7.9 Objectives relating to the tenets of NoS in curriculum documents

Tenet Addressed	Sample Objective
BoK	To develop knowledge and understanding of scientific and technological concepts through the explorations of human, natural and physical aspects of the environment (Irish Curriculum, p 11)
Empirical	Pupils should be taught that it is important to collect evidence by making observations and measurements when trying to answer a question (England and Wales curriculum, p 16)
Tentative	That students will understand and appreciate the evolutionary nature of scientific knowledge (Queensland Curriculum, p 8)
Human End.	Students will use their developing scientific knowledge, skills and attitudes to critically evaluate ideas and processes related to science and become aware that scientific understanding is developed by people, whose ideas change over time (New Zealand Curriculum, p.24)
Creative	To encourage the child to explore, develop and apply scientific ideas and concepts through designing and making activities, (Irish Curriculum, p 11)
Society	That pupils should be taught the knowledge, skills and understanding through looking at the part science has played in the development of many useful things (England and Wales Curriculum, p20)
Technology	Students will use their developing scientific knowledge, skills and attitudes to explore the relationships between science and technology by investigating the application of science to technology and the impact of technology on science (New Zealand Curriculum, p24)
History	That students know people once thought that earth, wind, fire and water were the basic elements that made up all matter… (California Curriculum)

7.3.5 Discussion

The analyses of the seven documents indicates that there appears to be a strong consensus regarding how science should be taught in primary schools and the different characteristics of NoS that should be communicated to pupils while teaching science. The various descriptions of NoS and references to the history, philosophy and sociology of science provided in all documents, illustrate a portrayal of similar philosophies and conceptions of NoS.

What does differ from document to document however, is the accounts of NoS provided and the extent to which teaching about NoS and the development of contemporary NoS conceptions is emphasised or explicit. Whereas all seven documents include aims and objectives that address NoS in an implicit manner, only two of the documents (Queensland and New Zealand) explicitly mention the development of NoS conceptions amongst the aims and objectives. The Queensland

and New Zealand curriculum documents place significant emphasis on NoS, devoting an entire 'strand' to the development of NoS conceptions. The Irish, English and Welsh, Scottish and Californian documents provide a description of NoS in the introduction but do not include aims or objectives that explicitly address the development of NoS conceptions. Although NoS is only explicitly mentioned in the aims and objectives of two of the documents, (Queensland and New Zealand) there are objectives that implicitly relate to NoS in all seven documents.

Research has indicated that if contemporary conceptions of NoS are to be developed, explicit methodologies and approaches should be employed (Akerson et al 2000, Akindehin, 1988, Carey & Stauss, 1968, 1970, Craven et al, 2002, Khishfe (Abd-El-Khalock, 2002 Lederman & Abd-El-Khalick, 2000, Lederman, 1998, Loving, 1998). Pupils may not necessarily 'catch' contemporary conceptions of NoS by 'doing hands-on science' so their attention needs to be specifically directed towards the different tenets of NoS during scientific inquiry. Pupils need to be given time to reflect, discuss and question the different aspects of NoS and how they relate to various scientific concepts and processes that are encountered in school to facilitate the development of their NoS understandings (Tao, 2003; Lederman, 1998; Lederman & Abd-El-Khalick, 2000).

In the seven curriculum documents reviewed, it is mandatory for teachers in these countries to teach science and therefore teachers' lessons are more than likely planned around the curriculum guidelines. It would appear that if strands and objectives that explicitly address the development of NoS conceptions were included in curriculum documents, teachers would be more likely to plan and teach lessons around NoS. If these objectives are not explicit, NoS may be overlooked in planning.

However, research in New Zealand and Australia has shown that even when NoS strands and objectives are explicitly mentioned in curriculum documents, this does not automatically mean that they will be addressed in science classes and the 'actual' curricula being taught are quite different from the 'intended' curriculum. (Rennie, Goodrum, & Hackling, 2001; Hipkins, 2005; Loveless and Barker, 2000; Mc Gee et al., 2003). Research has indicated some factors that appear to be inhibiting successful implementation of NoS. These include, lack of a clear definition or description of what the NoS actually entails (Wellington, 1998; MC Gee et al., 2003); lack of specificity regarding the intended NoS content outlined in the curriculum documents (Hipkins et al., 2005); lack of resources, inadequate preparation time, teachers' lack of science subject knowledge and time limitations in what they considered an overloaded curriculum (Rennie et al., 2001). Despite the recent developments in science education and curriculum development in New Zealand, there still appears to be a lack of teacher's conceptual and pedagogical knowledge of NoS that are impeding the development of NoS conceptions in New Zealand. Pre-service and in-service courses aimed at developing teachers' personal philosophies and pedagogical knowledge of NoS are required to improve the extent to which teachers explicitly address NoS as an integral component in primary science (Bell et al., 1995; Hipkins et al., 2005).

The findings of the New Zealand research literature appear to imply that even though the development of NoS conceptions is one of two integrating strands, this strand in general is not being implemented fully. The science content knowledge appears to be dominating science teaching and often its importance is highlighted by the assessment procedures (Hipkins et al., 2005). Interestingly, the assessment tools that are used in New Zealand, National Assessment Education Monitoring Project (NAEP) or the National Certificate in Educational Achievement, do not include any questions that explicitly assess NoS Conceptions. Therefore another factor that could be contributing to whether NoS is being explicitly addressed in science classes could be related to whether it is assessed. The extent to which NoS is assessed in various assessment tools is therefore considered in the next section.

7.4 Assessment Tools

As shown the extent to which NoS is included in different primary science curriculum documents varies greatly from one country to another. The same seven countries were used again to establish the extent to which NoS is assessed at primary level in these countries. Northern Ireland was the only country out of the seven that had formal state exam in science at primary level. In Northern Ireland the children take statutory 'transfer tests' at the age of eleven. Science is one of the subjects that is tested. While the tests mostly assess scientific knowledge, the following aspects of scientific inquiry are addressed in these transfer tests:

Children are given opportunities to

- Recognise a fair test;
- Suggest ideas which can be investigated and make predictions;
- Suggest how to carry out a fair test.

Children are given opportunities to:

- Present findings using appropriate methods;
- Use results to draw conclusions or make comparisons.

As only one of the seven countries / states had a formal state examination in science at primary level, it was decided to examine international assessment tools to seek the extent to which they assessed NoS. This analysis also permitted a comparison to be drawn between the extent to which NoS was explicitly addressed in the various curriculum documents and the level of achievement, of each country, in the NoS related aspects on the international assessment tools. It is acknowledged however, that it is unlikely that these international assessment tests would have driven the teachers in the respective countries to teach NoS as there is no status or school specificity attached to these.

7.4.1 International Assessment Tools

In this section two major international assessment tools were explored to establish the extent to which they addressed NoS conceptions. In the first instance the International Assessment of Educational Progress 1992 (IAEP) will be considered. This will be followed by an analysis of the Trends in International Mathematics and Science Study (TIMSS) 2003. These two documents were selected as they were amongst the few international tools that assessed science amongst primary aged children.

International Assessment of Educational Progress (IAEP)

One of the main focuses of IAEP (International Association for the Evaluation of Educational Progress) studies has been the advancement of science and mathematics. For the past 40 years IAEP has been assessing student achievement and gathering information to help support student learning in mathematics and science.

All twenty participating countries in the second International Assessment of Educational Progress (IAEP) (1992), wished to identify what was possible for their 9 and 13-year old children to be able to do in mathematics and science. Science was assessed in 19 of the 20 participating countries. The second IAEP tests focused on common elements in the curriculums of all the countries. A representative sample of 3,300 students from 110 schools at each age was selected. Half of the 3,300 students were assessed in mathematics and half in science. With regard to science, four main areas were assessed at 9 and 13; life sciences, physical sciences, earth and space and the nature of science. Table 7.10 illustrates the number of questions ascribed to each of these topics at each age group. All questions were in a multiple-choice format.

Table 7.10 Number of questions on each topic addressed in IAEP 1992

	Life Sciences	Physical Sciences	Earth and Space Sciences	Nature of Science	Total
9-year-olds	23	17	10	8	58
-year-olds	19	23	9	11	64

IAEP outlined the NoS content area as an ' overarching topic area that encompasses the fundamentals of scientific literacy' (IAEP 1992, p.35). The questions relating to NoS were related to scientific inquiry and aimed at assessing the pupils' ability to interpret data, formulate hypotheses and to deduce results from experiments described in the test. Questions relating to the scientific inquiry aspect of NoS comprised 14 percent of the overall assessment tool. Out of the seven countries discussed in section 7.1, four took part in IAEP 1992; USA, Ireland, England and Scotland. The USA and Scotland scored higher than the European average in the NoS category, England scored about the European average and Ireland scored lower than the European average in the NoS category. It is worth noting that when the second IAEP study was conducted science was not a compulsory subject in primary schools in the Republic of Ireland at the time.

TIMSS

TIMSS (Trends in International Mathematics and Science Study) 2003 developed two frameworks, which outlined important content for students to have learned in science and mathematics. There were two main organising frameworks in relation to science content to be learned by students: a content dimension and a cognitive dimension. The content dimension comprised four areas: life science, chemistry, physics, earth science and environmental science. The cognitive dimension delineated the various behaviours students were expected to utilise when handling scientific content knowledge and comprised three domains: factual knowledge, conceptual understanding and reasoning and analysis.

An additional assessment strand, scientific inquiry, was also included and was 'treated as an over arching dimension that includes knowledge, skills and abilities assessed by items or tasks set in different content relate contexts that cover a range of cognitive demands' (Martin, Mullis, Gonzalez and Chrostowski, 2003, p 69). The items and tasks that were developed to assess conceptions and aptitudes relating to scientific inquiry were linked to the content and cognitive domains. Items and tasks that assessed areas that were directly related to scientific inquiry were also included.

The Assessment Frameworks and Specifications for TIMSS 2003 state that the aim of scientific inquiry is the provision of explanations of scientific phenomena that enable us to comprehend the fundamental principles that govern the natural world. The students in fourth and eighth grades (ages 9 and 13) were not expected to test fundamental theories, however, it was expected that they could ask scientific questions that could be investigated. Scientific inquiry at fourth grade (primary school age 9 years) should involve the children in posing testable questions based on their observations from the natural world. The students (ages 9 and 13) were expected to be able to plan and conduct investigations, gather evidence and draw conclusions based on their observations and understanding of scientific concepts. They were also expected to be illustrate an understanding of 'fair testing'

The students' conceptions and aptitudes relating to scientific inquiry were mainly assessed through tasks where the children were obliged to apply their science knowledge and skills in practical contexts. The assessment of scientific inquiry included items that required the children:

> to demonstrate knowledge of the tools, methods, and procedure necessary to do science, to apply this knowledge to engage in scientific investigations and to use scientific understanding to propose explanations based on evidence ...(p69).

The students were also expected to:

> possess some general knowledge of the nature of science and scientific inquiry, including the fact that scientific knowledge is subject to change, the importance of using different types of scientific investigations in verifying/ testing scientific knowledge, the use of basic 'scientific methods' and the communication of results (p69).

TIMSS outlined four benchmarks that described what fourth (and eighth) grade students would typically know and do at these levels. The four benchmarks were: the advanced international benchmark (AIB), the high international benchmark (HIB), the intermediate international benchmark (IIB) and the low international benchmark (LIB). While none of these benchmarks referred explicitly to children holding contemporary understandings of NoS, they all referred to the children developing a number of scientific inquiry skills. For example, students reaching the Advanced International Benchmark (AIB) demonstrated initial scientific inquiry knowledge and skills. These students would illustrate their ability to:

> apply their knowledge and understanding of science in beginning scientific inquiry.... describe the results of an investigation, draw conclusion from the results, and infer the purpose of an experiment from a table of data (p. 89).

Students reaching the High International Benchmark (HIB) were those who showed an ability to:

> apply knowledge and understanding to explain everyday phenomena...provide brief descriptions and explanations of some everyday phenomena and compare, contrast and draw conclusions (p93).

Those who reached the Intermediate International Benchmark (IIB) illustrated an ability to:

> apply factual knowledge to practical situations...interpret pictorial diagrams and combine information and draw conclusions (p.97).

As can be seen from the above descriptions, the children who reached the AIB demonstrated a more in-depth and elaborate understanding of scientific inquiry, in that they were expected to show an understanding of a wider range of scientific inquiry skills.

Two of the seven countries whose curriculum were analysed earlier in the section, did not take part in TIMSS 2003 (Ireland and Northern Ireland). Table 7.11 illustrates the percentages of students in the remaining five countries that reached the various TIMSS 2003 International Benchmarks of science achievement

Table 7.11 Trends in percentages of grade 4 (9-year-old) students reaching TIMSS 2003 International Benchmarks of Science Achievement

Country	Advanced International Benchmark (AIB)	High International Benchmark (HIB)	Intermediate International Benchmark (IIB)	Low International Benchmark (LIB)
England	15%	47%	79%	94%
USA	13%	45%	78%	94%
Australia	9%	38%	74%	92%
New Zealand	9%	38%	73%	91%
International Average	7%	30%	63%	82%
Scotland	5%	27%	66%	90%

While England, USA, Australia and New Zealand were all above the international average in AIB and HIB, the percentages of students in these countries reaching the AIB were relatively low. These results indicate that a high majority of students in the fourth grade in these countries did not exhibit elaborate understandings of scientific inquiry.

TIMSS 2003 also ascertained the emphasis placed on different approaches and methodologies utilised to deliver the 'intended curriculum', in the different countries

Table 7.12 illustrates that England, Scotland, Australia and New Zealand placed strong emphasis on conducting experiments or investigations and the USA placed very little emphasis on this. Australia, New Zealand and the USA placed some emphasis on designing and planning investigations while England and Scotland put a lot of emphasis into this. The USA and New Zealand curricula placed a lot of emphasis on writing explanations about what was observed and why it happened and Australia, Scotland and England placed some emphasis on this.

1= A lot of emphasis   2= Some emphasis

3= Very little emphasis   4= No emphasis

Table 7.12 Emphasis on approaches and processes in the intended science curriculum

Country	Knowing Basic Science Facts	Under-stand Science Concepts	Writing Explan-ations about What was Observed and Why it Happened	Designing and Planning Experi-ments	Conduct Experi-ments or Investing-ation	Inte-grate Science with Other Subjects
Australia	2	1	2	2	1	3
England	1	1	2	1	1	2
New Zealand	2	2	1	2	1	1
Scotland	1	1	2	1	1	2
USA	1	1	1	2	3	3

As outlined earlier, all of the curriculum documents emphasised the importance of the children engaging in scientific inquiry. To establish the extent to which this goal was being emphasised in different countries the children and teachers were asked about whether they did a number of activities in science. These are outlined in Table 7.13

Table 7.13 Percentage of students who reported doing the activity once or twice a month or more

Country	Watch the Teacher do Science Experi-ment	Design or Plan a Science Experiment	Work in Small Groups on Experiments and Investing-ations	Write Explan-ations about What was Observed and Why it Happened	Relate What is Being Learned in Science in to Our Daily Lives
Australia	59%	44%	48%	60%	64%
England	78%	73%	79%	83%	84%
New Zealand	55%	46%	47%	62%	65%
Scotland	60%	47%	50%	61%	65%
USA	63%	42%	53%	65%	73%
International Average	69%	50%	50%	57%	69%

The majority of pupils in the fourth grade asserted that they watched their teachers doing experiments and writing or giving explanations in science once or twice a month or more. Demonstrating experiments to their pupils was something 23 percent of the teachers reported doing. Over half of the pupils reported working in small groups to conduct experiments or investigations and 50 percent reported planning designing and conducting an experiment or investigation

Discussion

In IAEP 1992, three out of the four countries explored, scored at or above the European average and Ireland scored below the European average in the NoS category. Questions relating to NoS formed 14 percent of the total number of questions in IAEP 1992. However, these questions tended to assess students' ability to engage in scientific inquiry, aimed at assessing their 'scientific literacy' rather than explicitly addressing what they understood about different aspects and tenets of NoS.

In a similar manner, TIMSS 2003 did not explicitly address NoS understanding, however aspects of the nature of scientific inquiry were indirectly assessed. For example, those reaching the HIB were expected to demonstrate their ability to describe results, draw conclusions and make inferences. A very low percentage of the students in these countries reached the AIB benchmark (figure 7.12), which required the development of more elaborate scientific inquiry skills.

This was despite a high percentage of students reporting on participating in scientific inquiry and hands-on experiments.

Having explored the extent to which NoS is emphasised in international curriculum documents and assessment tools, some of the challenges facing the development of primary children's conceptions of NoS will now be considered.

7.5 Challenges to Teaching NoS in School Curricula

While the importance of contemporary NoS conceptions has been highlighted in research, there still appears to be a continuous pattern of non-uptake of this aspect of science in school curricula (Bell et al., 1995; Hipkins et al., 2005; Rennie et al., 2001). Despite the various revisions that have been made to primary science curricula internationally, many of them appear to have failed in achieving some of their aims. For example, the shift in emphasis to scientific processes from scientific knowledge does not appear to have had significant effect in increasing the number of students taking additional science courses. (Yager, 1982; Yager & Bonstetter, 1984; Task Force of Physical Sciences, 2002). Research has also indicated that revised curricula have not been successful in enabling students to develop more elaborate conceptions of NoS (Bybee et al., 1980; Yager and Yager, 1985; Hipkins et al., 2005; Rennie et al., 2001).

The literature has put forward a number of factors that appear to be contributing to the lack of successful implementation of NoS. Amongst these factors include a lack of a clear definition of what NoS entails (Wellington, 1998; Mc Gee et al., 2003) and a lack of specificity regarding the intended NoS content outlined in the curriculum documents (Hipkins et al., 2005). The research also suggests that NoS objectives be included as 'objective' rather than 'affective' objectives in curriculum documents (Lederman, 1998) and that assessment tests explicitly address NoS, so teachers will recognise NoS as an 'important' area that will be assessed (Gilbert 2003, White, 2003).

The content analyses conducted during the final phase of this study indicated that for the most part NoS was not explicitly defined or addressed in curriculum documents nor was it assessed in international assessment tools. In light of the research therefore, it is highly likely that primary teachers in these countries are not explicitly teaching NoS to their pupils as teachers may be more inclined to teach what is explicitly addressed in curriculum documents.

Rennie et al. (2001) maintained that teachers' lack of science subject knowledge and time limitations in what they considered an overloaded curriculum were factors that contributed to the lack of uptake of NoS in science curricula. Others asserted that lack of pedagogical and conceptual knowledge of NoS were responsible (Bell et al., 1995; Baker, 1999; Lederman, 1998, 2000; Shulman, 1986). It appears therefore that pre-service and practising teachers could benefit from courses that would provide them with conceptual and pedagogical knowledge of NoS.

In light of a review of the New Zealand science curriculum, Hipkins et al. (2005) maintain that long-term sustained classroom research is needed that investigates, how students' learning is progressing and what beliefs teachers hold regarding the nature and characteristics of science and the purpose of science education. They also suggest that strategies for teaching about NoS are required and assessment of the impact of pedagogies on students' perceptions and beliefs about science and on the engagement and achievement of all students should be conducted.

The current study explored the effectiveness of explicit methodologies in developing pre-service and beginning teachers' conceptual and pedagogical knowledge of NoS and also considered the effectiveness of teaching NoS explicitly on the development of primary children's NoS conceptions. A further aim of the current study was to establish whether explicitly teaching NoS affected teachers' approaches to or perceptions of teaching science and whether explicit approaches affected children's reflections of school science. The findings of this study are therefore informative and particularly pertinent within the Irish context in light of the forthcoming curriculum science review.

8 GENERAL DISCUSSION AND CONCLUSIONS

8.1 Chapter Overview

In this final chapter the aims of the study are reiterated and a summary of the findings presented. The findings are then considered to contextualise them within the research literature. Limitations of the study are outlined and implications considered. The chapter closes with a number of recommendations and concluding comments.

8.2 NoS Conceptions for the Irish Primary Teacher

This study revealed that teachers who had taken a year-long NoS elective course, explicitly addressed NoS in their teaching of science, utilised more hands-on, child centred, reflective constructivist approaches to teaching science and were more confident in teaching science in primary school in their beginning teaching year than students who had not taken the elective. The findings also revealed that primary pupils who were taught about NoS through explicit means employed more scientific skills, conducted more hands-on science in school and were more reflective, enthusiastic and interested in science than pupils who did not learn about NoS through explicit means. It appears therefore that explicitly addressing NoS as part of the Science Curriculum (DES, 1999a) benefits teachers and pupils alike.

In order to teach about NoS, primary teachers need to understand that NoS is concerned with philosophical, sociological and historical questions regarding how science operates. Irish primary teachers in Ireland are not experts in science, history, philosophy or sociology and therefore do not need an in-depth knowledge regarding the history, philosophy or sociology of science. Rather Irish primary teachers require some understanding of how various philosophical, historical and sociological issues apply to and potentially impact on science teaching and learning. They need sufficient knowledge of NoS in order to portray science to their pupils as accurately as possible.

Such knowledge of NoS comprises an understanding of science as a body of reliable knowledge that provides information about the world and explains different occurrences. It is accepting that scientific knowledge is reliable as it has been obtained by scientists, who are proficient in the subject matter of science and who have knowledge and experience in the employment of various scientific processes that are accepted throughout the scientific community. Contemporary conceptions maintain that there is not one 'scientific method' that comprises a fixed set of steps and procedures that all scientists follow. Those who hold contemporary conceptions of NoS accept that scientific knowledge is testable and developmental and therefore subject to change. That science is a human endeavour involving subjectivity, creativity and imagination in determining scientific knowledge is central to contemporary conceptions, as is knowledge regarding the figures and landmarks in the history of science. Those who have contemporary conceptions of NoS are knowledgeable about science and society and how they have been affected and influenced by one another in the past and in contemporary society. In addition to contemporary NoS conceptions primary teachers also require knowledge of basic scientific concepts and procedures in order to teach science in primary schools.

8.3 Aims of the Study

The aims of this study were to explore and develop Irish pre-service teachers' conceptions of NoS and establish the extent to which their pupils developed more contemporary NoS conceptions, when taught about NoS through explicit means. These aims were addressed in three phases. The study also considered the effects of explicitly teaching NoS on beginning teachers' approaches to and perceptions of teaching science and on their pupils' reflections of school science. The extent to which international curriculum documents and assessment tools explicitly addressed NoS was also established. These were addressed in four phases. The first phase explored the conceptions of Irish pre-service primary teachers' conceptions of NoS and assessed the effectiveness of explicit approaches in developing these conceptions. A yearlong course in NoS was devised and delivered to a group of nineteen third year B.Ed students. Over the course of the year various explicit approaches and methodologies were utilised to develop these teachers' conceptual and pedagogical knowledge regarding NoS.

The second phase of the study determined the extent to which these pre-service teachers planned and taught aspects of NoS during their final teaching practice. The pre-service teachers' experiences and perceptions of explicitly teaching NoS as part of the science curriculum were sought through written reflections.

Whether these pre-service teachers maintained their contemporary NoS conceptions and the extent to which they explicitly addressed NoS in their initial teaching year were considered in the third phase of the study. This phase also explored the effects explicitly teaching NoS had on the beginning teachers' approaches to and perceptions of teaching science. During the third phase an exploration of the development of two classes of third and fourth children's conceptions of NoS was also conducted. Two of these classes were taught by beginning teachers who had taken the NoS elective the previous year and two of the classes were taught by beginning teachers who had taken non-science elective courses the previous year. This comparative study aimed at assessing the effects of explicitly teaching NoS on the development of the primary children's NoS conceptions and on the way these children reflected on their science lessons.

The literature indicates that explicit inclusion of NoS amongst the aims and objectives in curriculum documents is a factor that permits successful implementation of NoS (Bell et al., 1995; Hipkins et al., 2005; Lederman, 1998). The literature also asserts that if assessment tests explicitly address NoS, then teachers would recognise NoS as an 'important' area to be assessed (Gilbert, 2003, White, 2003). The final phase of the study therefore conducted a preliminary content analysis of seven international primary science curriculum documents and two international assessment documents, to establish the extent to which each document prioritises NoS understanding.

8.4 Summary of Findings: Overview

This study set out to develop pre-service teachers' conceptions of NoS through explicit means and to investigate the effectiveness of their translation into practice. The findings of the study revealed that explicit methods were effective in developing pre-service teachers' conceptions and that when beginning teachers possessed conceptual and pedagogical knowledge of NoS, they were successful in developing their pupils' NoS conceptions. The research also revealed a number of other unexpected findings relating to beginning teachers' teaching and reflective skills and their interest and confidence in teaching science. There were also unanticipated findings regarding primary children's application and development of science skills and their increased interest and enthusiasm for school science.

Before the findings illustrating the effectiveness of explicit approaches to NoS are discussed, the findings regarding the beginning teachers' teaching and reflective skills and their pupils' increased interest and enthusiasm for school science will be considered.

8.5 Findings Regarding Teaching and Learning Science

8.5.1 Discussion and Reflection in the Science Class

Constructivist theorists (Ausubel, Piaget, Vygotsky) assert that when children are provided with opportunities to discuss and defend their ideas among themselves, these discussions help scaffold their ideas that in turn lead to improved understanding. In a similar manner Pollard and Tann (1993) maintain that pupil discussion is an essential component in the interchange of ideas and understandings and is therefore essential in a reflective teaching-learning process.

The teaching practice reflections gathered during the second phase of this study indicated that all nineteen of the NoS elective students allowed time for discussion and reflection in their science classes during their final teaching practice. Discussion and reflection formed an integral part of learning about NoS issues. Question and answer sessions, story, circle time and pictures and photos were utlised to instigate discussion (Chapter five). The NoS elective students illustrated confidence in allowing their pupils to reflect on and discuss scientific issues, something that many practising teachers are often reluctant to do for fear they will not be able to answer the pupils' questions (Fuller & Brown, 1975; Trumbull, Scarmo & Bonney, 2006). The NoS elective students' written reflections indicate that they maintained that explicit reflective approaches to teaching about NoS helped develop their pupils' philosophies regarding NoS as well as enabling them to apply and develop their thinking skills (Chapter five, figure 5.1 and Appendix K).

The primary science curriculum (DES, 1999a) outlines the importance language plays in helping children develop their scientific understanding and asserts that teachers should include discussion and reflection when implementing the science curriculum.

> Through discussing their ideas and the results of their scientific investigations, children will develop their scientific understandings. Through language children name and classify things, express and modify ideas, formulate questions and hypotheses and report conclusions. In this way language contributes to the expansion of the children conceptual development... language is important too in helping children to access and to retrieve information and to record and communicate ideas...(DES, 1999a, Page 10).

Social constructivist theories highlight the importance of social interaction and the role of language in children's learning (Pollard and Tann 1993; Vygotsky, 1978). During the third phase of the study the reflective journals illustrated that the teachers in the test group provided their pupils with numerous opportunities for reflection and discussion throughout the science classes. The test teachers reflected on how their pupils responded to various discussions that had occurred during their science classes, particularly in relation to aspects of NoS. The importance they placed on discussion and the development of pupils' thinking skills during science class was also evident in the test teachers' written reflections and was not apparent amongst the control teachers' reflections (Chapter five and Appendix H).

8.5.2 Teaching Skills: Hands-on Science

The pre-service teachers, who had taken the NoS elective, employed various explicit approaches when addressing NoS issues in their final teaching practice. However, they also provided their pupils with numerous opportunities to engage in scientific inquiry. Making circuits, conducting investigations on absorbency and investigating how sound travels were examples of the hands-on activities the children were given opportunities to engage in (Chapter five and Appendix K). The fact that the NoS elective students' pupils were making circuits, carrying out investigations, designing and making artefacts indicates that the NoS elective students were implementing the science curriculum during teaching practice. All of the NoS elective students used a variety of innovative hands-on methodologies to find out, develop and assess their pupils' scientific concept knowledge and their understandings of NoS (Chapter five and Appendix K). Many of the methodologies and ideas that they utilised were similar to the ones they had experienced over the course of the elective. It would appear that the NoS elective facilitated these pre-service students in devising and implementing more innovative science classes, which explicitly addressed NoS aspects as part of a hands-on approach to implementing the science curriculum.

However, the NoS elective students had also taken a compulsory science methods course the previous year, and this may have had an impact on their teaching strategies. A further study that would compare NoS elective students' and non-NoS elective students' teaching of science over the course of their final TP would establish the extent to which the NoS elective course might influence pre-service teachers' preparation and teaching of science.

During the third phase of the study the teachers in the test and control group were implementing the Science Curriculum (DES, 1999a) for third and fourth classes and therefore were teaching similar topics (Chapter five and Appendix H). However, the test teachers' intrinsic conceptions regarding the teaching and learning of science appeared to be more in keeping with methodologies underlying the Science Curriculum (DES, 1999a) in that the test teachers tended to refer to their pupils developing scientific knowledge and skills and attitudes towards science. The control teachers on the other hand primarily tended to comment on the acquisition of conceptual knowledge, more characteristic of behaviourist models of learning. When specifically asked about science skills, teachers from both groups mentioned science skills their pupils had utilised during science class. However, the test teachers demonstrated a better understanding of scientific skills, which evidenced itself in the provision of numerous examples of when these skills were applied and developed. The control teachers did not provide examples of when their pupils utilised science skills.

Although the children in the control group were given opportunities to engage in hands-on inquiry, their teachers tended to use teacher demonstration more frequently than the teachers in the test group. On the other hand the test teachers tended to use less teacher demonstration and afforded their pupils more opportunities to engage in hands-on group activities (Chapter five and six and Appendix H).

The test teachers illustrated a greater understanding of constructivist approaches to learning outlined in the Science Curriculum (DES, 1999a, page 7) in that they instigated every new science topic by finding out the children's ideas. They used concept maps, concept cartoons, question and answer sessions and think and draw activities to find out what the children knew about a particular topic (Appendix H). They contextualised the science topics and provided the children with opportunities to test their ideas (Chapter five and Appendix G).

The importance of finding out the children's ideas and hands-on group work were issues that were addressed and their importance highlighted in the compulsory second year curriculum science course, that both test and control teachers had taken. These issues were also revisited during the third year NoS elective in relation to the development of NoS conceptions.

Symington (1980) asserts that when pre-service teachers lack confidence in teaching science they tend to employ methodologies that enable them to retain control over the flow of knowledge. Symington also maintains that often these strategies are not in keeping with curricula that emphasise the importance of more hands-on approaches to science. The reflective journals indicated that the test teachers appeared to have incorporated more innovative, hands-on group orientated approaches in teaching science than the control teachers (Appendix G). While both test and control groups adhered to the Curriculum Guidelines (DES, 1999b), the test group introduced a more extensive range of additional activities and ideas regarding science. It could be argued that the test group selected the 'NoS elective' and therefore had an interest in science to begin with. While this may be true, teachers from both test and control groups had similar teaching experiences and had taken the same methodology courses over the course of their three year degree. The test teachers also appeared to be more confident and enthusiastic about teaching science than the control group. This was evident through their more frequent use of group work and a more diverse range of ideas and activities than those outlined in the Curriculum (Chapter five and Appendix G).

8.5.3 Reflective Practitioner

In the second phase of the study the pre-service teachers' written reflections on teaching practice revealed their ability to reflect in an in-depth and perceptive way. In addition to reflecting on organisational issues, which is typical of novice teachers' reflections (Fuller & Brown 1975; Pollard & Tann, 1993), they reflected on pedagogical issues demonstrating reflection skills that were more indicative of experienced teachers (Chapter five).

In the third phase of the study the test teachers' written reflections regarding teaching science were more in-depth, elaborate and showed a greater ability to reflect on their practice than the teachers in the control group. For example, when answering questions regarding how pupils responded to science lessons the teachers in the control group tended to write about what they had taught during the lessons. On the other hand the teachers in the test group tended to reflect on how the children responded to various lessons. Typical references included the children's enthusiasm, the children becoming more inquisitive, the development of various skills or how the children enjoyed particular aspects of the lessons (Chapter five, section 5.3.1, questions two, three, four, five and six & Appendix H).

Teachers in both groups referred to organisational and management issues in their written reflections. However, in addition to these, the test teachers also commented in broader terms on how they could foster the learning and development of their pupils' thinking skills, something on which the control teachers did not comment (Chapter five and Appendix H). Constructivist theories of learning view students as active learners and constructors of understanding. The test teachers reflected on how in the future they could facilitate their pupils in taking more responsibility for their learning, something to which neither teacher in the control group referred.

8.5.4 Children's Perceptions of School Science

The findings were also informative regarding the children's perceptions and experiences of school science. There was a considerable difference in the extent to which the children in the test and control group referred to school science throughout the exit interviews. The children in the test group were eager to discuss school science and were spontaneous in their discussions throughout the exit interviews. The children in the test group's responses regarding school science in the exit interview were more elaborate, detailed and spontaneous than the control group's responses. The children in the control group tended to discuss school science, only when they were specifically questioned about it (Chapter six, Table 6.1).

The results also indicated that the children in the test group were more enthusiastic about school science and appeared to have conducted more hands-on group experiments and investigations than the control group (Chapter six and Appendix M). When discussing investigations they had done in school the depth and detail of the test group's responses regarding school science illustrated their ability to discuss and express their ideas, to question and hypothesise, to retrieve information and report conclusions. The test children appeared to have developed a better understanding of scientific inquiry, which was evident in the way they referred to and provided examples of scientific skills they had applied and discussed during science class (Chapter six and Appendix M).

In general these findings seem to indicate that the teachers in the test group displayed more proficient understandings of teaching and learning and appeared to have employed more child centred, hands-on, reflective approaches to teaching science. The test teachers revealed a greater ability to reflect on their practice, a greater understanding of how children learn and were more confident and enthusiastic about teaching science. It would also appear that their pupils, who were given more opportunities to engage in hands-on scientific inquiry and reflect on and discuss scientific inquiry and ideas, were more enthusiastic and interested in school science than their peers in the control group.

8.6 Findings Regarding the Development of NoS Conceptions and their Translation into Practice

8.6.1 Phase One: Developing Pre-service Teachers' Conceptions of NoS

At the beginning of this study the pre-service teachers held largely 'traditional' conceptions of NoS, conceptions that were similar to their counterparts in other countries (Abell and Smith, 1992; Murcia & Schibeci, 1999). However, at the exit stage their responses to the 'science is ' statement, the written reflections and the Nature of Science Questionnaire (NOSQ) revealed considerably more elaborate conceptions of NoS. This was particularly the case for their responses regarding science as a human endeavour, scientific inquiry, the history of science and science and society (Chapter four and Appendix J).

After delivering this NoS elective course and seeing how these pre-service teachers' NoS conceptions developed, it became apparent that they had begun to realise that they do not need to know the 'right' answer to 'do' science. Their experiences and understanding of science as something that is constantly changing could have been a factor in making them more confident teachers of science. For example, the Long-range experiment (LRE) reflections indicated that the pre-service teachers appeared to have more confidence in their ability to devise, conduct and evaluate scientific investigations. When reflecting on the LRE the elective students indicated that when something had gone wrong with the experiments or when a hypothesis had been rejected that they were not disheartened by the experience. Rather they had accepted these experiences as part of the nature of scientific inquiry (Chapter four & Appendix J). Such experiences could build teachers' confidence about teaching science, in that they would come to realise that they do not need to know every fact about science to conduct an investigation and that it is often in the process of conducting an investigation where the answer to a question is found.

Many primary teachers are not confident in teaching science, as they perceive that they do not have sufficient background knowledge (Driver, 1983; Harlen, 1993). Despite not being experts in science, the LRE reflections indicated that the elective students were not disheartened when a problem arose while conducting their experiments or if their results were deemed invalid due to unfair testing (Chapter four and Appendix J). The students were confident in discussing hypotheses that were rejected realising that the rejection of hypotheses is as important as the acceptance of hypotheses (Chapter four and Appendix J). The reflections also revealed that the elective teachers were confident and positive about conducting LREs in their future classrooms.

Science is one of the subjects currently under review in the second phase of the Primary Curriculum review, being conducted by the National Council for Curriculum and Assessment (NCCA) in Ireland. In this second phase the NCCA sought to find out principals', teachers' parents and children's experiences with the primary Science Curriculum (DES, 1999a). The first report of this second phase reported on teachers', principals' and parents' experiences with the science curriculum. Findings from this interim report revealed that one of the most challenging things for teachers in implementing the science curriculum was the hands-on and co-operative learning advocated in the science curriculum (NCCA, 2007).

The findings of the current study suggest that if practising teachers were given the opportunity to reflect on and discuss aspects of NoS and experience the tentative and developmental NoS (realising that even scientists in the past had insufficient knowledge) teachers would feel more confident about teaching hands-on science in the classroom. The study also appears to indicate that pre-service and in-service courses that would explicitly address issues regarding NoS, the history of science, and that would provide teachers with the opportunity to devise and conduct investigations could be beneficial to teachers. Such courses could help teachers realise that they don't have to know all the right answers in order to facilitate their pupils in conducting scientific investigations. It appears from the findings that in addition to developing more elaborate NoS conceptions, courses that explicitly addressed teachers' conceptual and pedagogical NoS knowledge also help build their confidence as science teachers. This confidence resulted in them utilising more hands-on investigative work in the primary classroom, something that is strongly advocated in the primary Science Curriculum (DES, 1999a).

Providing Opportunities for Reflection

Contemporary understandings of NoS include knowledge of the history, philosophy and sociology of science (McComas et al 1998, Matthews 1994, Lederman 1998, 1999, 2000). Primary teachers are not experts in philosophy, history or sociology and therefore it is 'unrealistic' to expect primary teachers to become expert philosophers, historians or sociologists of science (Matthews, 1994). The history of science has considerable effects on the philosophy of science in that it shifts the emphasis from justifying scientific knowledge to the discovery and development of science and the reasoning employed by scientists in the development of scientific knowledge. It is for these reasons that Matthews (1994), Mc Comas (1998) and Solomon (2002) maintain that historical, philosophical and sociological components should be integrated in science education. With regard to philosophy of science, Matthews suggests that, rather than emphasising the various profound philosophical arguments regarding NoS, primary teachers be given opportunities to reflect on various NoS issues which, he maintains will empower them to develop their own NoS conceptions (Matthews, 1994, 1998; Mc Comas et al., 1998).

In the NoS elective course the pre-service teachers were given numerous opportunities to discuss and reflect on various historical, philosophical and sociological issues regarding science. For example, a number of workshops involved the students doing some of Lederman and Abd-El Khalick's (1998) activities regarding NoS (Appendix I). Discussion and reflection on these activities and how they related to various aspects of NoS was an integral part of each workshop. The elective students also discussed a number of significant figures and landmarks in the history of science. Ignaz Semmelweiss and the influences society at the time had on his discovery of Puerperal fever (childbed fever) was one of the figures in the history of science the students reflected on (Appendix I). While discussing various figures and events in the history of science, the students also reflected on the developmental

NoS and how society and scientists influence scientific development. As part of their history of science presentations the elective students considered the various influences society had on scientific development over the history of science (Chapter 4, section 4.5 & Appendix C & J). Another example of where the elective students were given the opportunity to reflect on issues regarding NoS was in their discussions regarding whether 'umbrella-ology' was a science (Boersema, 1998, p. 256-257, 265) or when they discussed 'critical incidences' (Nott and Wellington, 1998, p. 297 -302).

The detailed and in-depth responses in the elective students' science statements, NOSQ questionnaires and written reflections suggest that not only were these 'non-experts in science' capable of reflecting on various philosophical, historical and sociological issues, but such experiences appeared to facilitate the development of more contemporary NoS conceptions. For example the responses made by the pre-service teachers to the 'Science is' question at the initial and exit stages were compared. In addtion to two new categories that emerged at the exit stage, their written responses were more elaborate and detailed when referring to science as a human endeavour, scientific inquiry, science and society and science as a body of knowledge (Chapter four, Table 4.1 and Appendix B). The various opportunities afforded to the pre-service teachers to reflect on and discuss various NoS issues over the course of the elective appear to have contributed to improved reflection and thinking skills that were apparent in the elective students' written reflections and exit questionnaires.

Culture of 'NoS Science Classroom'

Over the course of the NoS elective, the pre-service teachers illustrated a willingness to make their work public (to their peers) rather than keeping it private between the instructor and student and they also valued peer review. These pre-service teachers appeared to accept the subjectivity of science and the value of multiple perspectives. For example, the data obtained from the LRE reflections indicated that when conducting and reporting investigations the elective students were accountable for testing their explanations and co-operated in groups to solve various problems encountered. Unlike the US pre-service primary teachers in the Spector and Strong

(1994) study, the NoS elective students' classroom 'culture' did not appear to 'clash' with the culture of science.

However, one factor that may be significant in this apparent difference between the US students and the Irish students is the fact that the Irish students had chosen to take the NoS elective course and the US students in the Spector and Stron study were obliged to take the course. A further study that would examine the 'culture' existing amongst pre-service teachers who were obliged to take a NoS course could establish whether the 'culture' of this group of undergraduate B.Ed students would 'clash' with the culture of science when the participants had not chosen to take the subject. Such a study could also establish whether the methodologies employed in the elective course simulated a classroom culture that was more in keeping with the culture of science. This classroom culture would encourage questioning, investigating, group work, creativity, and reflection and would recognise the subjective and developmental nature of knowledge.

Interest and Enjoyment

In addition to the development of more contemporary conceptions of NoS amongst the pre-service teachers, the LRE and HoS reflections and NOSQ also revealed an enthusiasm for and interest in science as well as positive attitudes towards explicitly addressing NoS aspects in future science lessons. For example the students were positive about their experiences of conducting the LRE:

> I certainly got a better insight into how my previous knowledge, experience and influences can influence an experiment e.g. when making a hypothesis, all of these things came into play (Appendix J).

In a similar manner in relation to the HoS reflections, the pre-service teachers were enthusiastic about incorporating HoS as part of the science lesson and maintained there were numerous benefits for its inclusion.

> I personally have no interest in physics as I prefer biology, but I found myself wanting to know more about Einstein's theories because I was interested in his life...It may not be very beneficial scientifically, to

> find out that Einstein formed a group of friends at college where they philosophised about life, but it shows that he was an ordinary person interacting with nature and trying hard to understand it. I am now able to put a face to the name and am aware of his contribution to science (Appendix J).

> I believe that history of science...helps children discover the background and process approach of what science is highlighting... they (scientists) are both replicating and developing scientific work...through observing ,inferring and concluding...(Appendix J).

> It is also important as the children learn how the scientists collected their data, made observations did experiments to come up with their theories. Children can relate to the scientists as they too carry out these procedures in class (Appendix J).

In a similar manner to the pre-service teachers who had taken the NoS elective, contemporary conceptions of NoS could potentially increase practising teachers' interest and enthusiasm towards science, which may in turn give them more confidence in teaching science. However, caution must be exercised here as the NoS elective was designed and delivered by the researcher who had a particular interest in and knowledge of NoS, which could have been efficacious in influencing the NoS elective students' interest. Additional courses in NoS therefore need to be devised and delivered in order to establish whether it is purely the conceptual and pedagogical knowledge of NoS or whether the delivery of the course influences teachers' interest in and enthusiasm towards teaching science.

Argument for Explicit Instruction

The literature has indicated that explicit approaches are more effective than implicit approaches in developing teachers' conceptions of NoS (Akerson et al., 2000; Carey and Strauss, 1989; Craven et al., 2002; Kiimball, 1968; Klopfer & Cooley 1963; Lederman, 1998; Loving, 1998). Pomeroy's (1993) study compared scientists, post-primary and primary teachers' beliefs about NoS. The results of her study revealed that the scientists and post-primary teachers in the study revealed more traditional views of science than the primary teachers, who agreed with significantly fewer of the traditional statements. Pomeroy maintains that one reason for the primary teachers' more contemporary conceptions could have been because they had just taken in-service courses that had addressed constructivist approaches to teaching primary science. These in-service courses were in contrast to the more traditional science programmes, experienced by the science teachers and scientists that tended to be heavy in science content and have little room for philosophy and reflection.

A study conducted by Murphy, Kilfeather and Murphy (2007), with 148 under graduate second year B.Ed students, in the Republic of Ireland, revealed that engaging in hands-on approaches to science, addressing NoS issues implicitly, helped them develop slightly more elaborate NoS conceptions. The findings of Murphy et al. (2007) are in keeping with Pomeroy's (1993) assumptions, in that the 'hands-on element ' and lack of emphasis on heavy science content of primary science courses appeared to facilitate the development of more contemporary NoS conceptions to some extent. However Murphy et al. (2007) also concluded that considerably more elaborate conceptions of NoS were developed when explicit approaches to teaching about NoS were used in conjunction with 'hands-on' science courses.

The findings of the present study indicate that courses in primary science that emphasise the importance of reflective hands-on approaches to teaching science and that emphasise explicit instruction in NoS appear to facilitate the development of more elaborate conceptions of NoS amongst pre-service primary teachers.

8.6.2 Phase Two: NoS and Pedagogy

Explicitly Teaching Different Tenets of NoS

A number of findings emerged from the second phase of the study. Firstly, the pre-service teachers who had taken the NoS elective planned and explicitly addressed a number of aspects of NoS over the course of their final teaching practice. The various aspects addressed and their reflections on the methodologies employed revealed that these pre-service teachers' new-found contemporary conceptions appeared to have been transferred into their classroom practice (Chapter five, section 5.2 & Appendix K). In phase one, science as a human endeavour, scientific inquiry, the history of science and science and society were aspects of NoS, in which the elective students illustrated more elaborate understandings. The pre-service teachers planned and explicitly addressed these aspects of NoS over the course of their final teaching practice.

This research continuously features two assumptions: That a teacher's NoS understanding affects his / her pupils' conceptions and that a teacher's behaviour and the classroom environment are influenced by the teacher's conceptions of NoS. Many authors accept these assumptions (Ballenilla, 1992; Brickhouse, 1990; Cahapuz 1994; Gallaghers, 1991) and many are hesitant in accepting them (Akerson & Abd-El-Khalick, 2003; Brickhouse, 1989; Duschl & Wright, 1989; Lederman & Zeilder, 1987; Zeilder & Lederman, 1989). Brickhouse (1990) maintains that teachers' conceptions about NoS influence their explicit lessons about NoS. Gallagher (1991) found that teachers who held 'traditional' views of NoS tended to emphasise the transmission of knowledge and memorisation of facts in their science classes. Cahapuz (1995) and Ballenilla (1992) also found similar connections between teacher 'inadequate' NoS conceptions and 'traditional' classroom practices.

On the other hand, there are studies that have found no direct influence between teachers' NoS conceptions and classroom practice. For example, Duschl & Wright's (1989) study revealed that while the teachers held contemporary NoS conceptions the teachers did not address NoS issues in a comprehensive way. Lederman (2000) acknowledges that there seems to be no significant relationship between teachers' NoS conceptions and their science teaching.

The findings of phase two in the present study seem to contradict Duschl & Wright (1989) and Lederman (2000). In the first phase, the pre-service teachers developed more elaborate understandings of science as a human endeavour, scientific inquiry, science and society, science as a body of knowledge and the history of science. These were also the aspects of NoS that they addressed over the course of their final teaching practice in phase two (Chapter 6, section 6.2, paragraph three & Appendix K). What is worth noting, however, is that the NoS elective students had experienced NoS explicitly over the course of their workshops and had developed conceptual and pedagogical knowledge in NoS. If the students in the Duschl & Wright (1989) and Lederman (2000) study had received explicit instruction in NoS, they may have been more inclined to explicitly address NoS in their practice. Bell et al (2000) maintain that addressing NoS tenets explicitly in undergraduate courses has a positive effect on students explicitly addressing NoS in practice. The findings in phase two of this study appear to confirm the findings of Bell et al. (2000).

NoS and the Irish Primary Science Curriculum

Some of the pre-service teachers expressed initial concerns regarding how they could explicitly address NoS as part of the Science Curriculum (Appendix K). This was particularly the case for those who were teaching the younger classes. However, without exception the teaching practice reflections indicated that all of the elective students were extremely positive about explicitly incorporating NoS as part of the science curriculum. They discussed many advantages of explicitly addressing NoS as part of the primary Science Curriculum (DES, 1999a), many of which were in keeping with findings in the research literature (Chapter 6, section 6.2, table 6.1). For example explicitly addressing NoS as a means of helping students to become aware of science as a human endeavour was something that Lederman (2000), Matthews (1994), Mc Comas (1998) asserted. A very high percentage (84%) of the elective students referred to this in their teaching practice reflections. NoS making science more interesting and therefore enabling pupils to learn scientific concepts and skills with greater ease was mentioned by all of the elective students in their responses, and affirms the work of Abd-El-Khalick's (2005), Huann-shyang et al. (2002) and Matthews (1994). The elective students maintained that explicit reflective approaches to teaching about NoS helped in developing pupils' personal philosophies about science and their thinking skills, benefits that were also outlined in Abd-El-Khalick (2005), Lederman (2000) and Matthews (1994). These pre-service teachers cited numerous benefits for children in explicitly teaching NoS. However it is difficult to establish whether their pupils had actually gained from any of their student teachers' 'perceived' benefits, as no formal assessment of the pupils' NoS conceptions was conducted. Additional research that would assess primary pupils' NoS conceptions as a result of receiving explicit instruction in NoS is required to establish whether these pre-service teachers opinions regarding the effectiveness of explicit approaches were accurate.

The findings also appear to indicate that NoS can be incorporated as an integral part of the science curriculum. Not only that, but these student teachers also maintained that its inclusion makes science more interesting for children, makes science concepts and skills easier for them to learn and develops their personal philosophies about science and their thinking skills. The broad aims of the Science Curriculum (DES, 1999a) are the development of children's conceptual and procedural knowledge. In addition the curriculum aims at developing children's thinking skills and enabling children to acquire positive attitudes towards science. The findings from phase two of the study indicate that explicitly including NoS as an integral part of the science curriculum could facilitate the achievement of these aims. Practising teachers however, may not be as convinced of the benefits of explicitly incorporating NoS as an integral part of the curriculum. In-service courses aimed at developing teachers' conceptual and pedagogical knowledge of NoS could address teachers' concerns and raise awareness of the benefits of explicitly teaching about NoS as part of the science curriculum.

While the findings from phase two are encouraging, a number of questions were raised.

1. To what extent would the NoS elective students maintain their elaborate NoS conceptions a year later?

2. Would the NoS elective students choose to incorporate NoS as an integral part of their science lessons as practising teachers, when not required do so?

3. To what extent did the NoS elective, as opposed to the second year 'curriculum science' course, influence the incorporation of innovative, hands-on, reflective approaches to implementing the Science Curriculum and explicitly addressing NoS?

4. Did the children develop contemporary conceptions of NoS as a result of explicit approaches to NoS?

The questions that were raised in phase two were addressed in phase three.

8.6.3 NoS and Pedagogy: Phase Three (Beginning Teachers' Data)

The previous sections indicated that those aspects of NoS that the pre-service teachers had developed more elaborate understandings of in their written reflections and questionnaires, were the aspects they explicitly addressed on teaching practice. However, the teaching practice placements occurred immediately after the pre-service teachers had taken the elective course. Their contemporary NoS conceptions would have been very current, and many of the issues and methodologies discussed and encountered over the course of the elective were still 'fresh' on the students' minds. The question as to the extent to which these pre-service teachers would maintain their contemporary conceptions of NoS a year after intervention was raised. Secondly the pre-service teachers were required to explicitly plan and teach aspects of NoS during their teaching practice. Whether they would elect to explicitly incorporate NoS in their science lessons in the future was also questioned. Phase three involved four beginning teachers and their classes in their initial teaching year. Two of these beginning teachers had taken the NoS elective (test) while the other two had not (control).

Explicitly Teaching about NoS

The findings from this phase revealed that although they were not required to do so, the teachers in the test group explicitly planned and taught about different aspects of NoS in all of their science classes in their initial teaching year. The aspects of NoS that the test teachers explicitly addressed were science as a human endeavour, the nature of scientific inquiry, the history of science and to a lesser extent science and society. The main aspects of science as a human endeavour that the test teachers explicitly addressed in their beginning year were science involving people, the subjective NoS and creativity and imagination. Both test teachers used a number of activities from the NoS elective that explicitly addressed the differences between observations and inferences, highlighting the subjective NoS in their initial teaching year. The activities both teachers used included 'Tricky Tracks', 'The Fossil Activity', 'The Cube activity' (Lederman and Abd-El Khalick, 1998), case studies from the history of science, and discussion of the video 'Bill Nye Science Guy' (Appendix I). Creativity and imagination utilised by scientists were addressed through various designing and making activities. For example the children in the test group designed and made a telephone, a 'green machine' in the K'NEX challenge and an electric 'light house'. The children's designs were discussed, as were the processes of designing and making in relation to scientists' work.

In their reflective journals the teachers in the test group reflected on how their pupils developed 'NoS skills'. These 'NoS' skills included references to the children discussing and reflecting on the importance of scientists' observations and examining evidence, how past experiences and knowledge can influence scientists examining evidence, explicit references to how scientists use creativity and imagination during scientific inquiry (Appendix H). References to 'working as scientists', that is when the teachers explicitly equated the science skills the children were using with how scientists use these skills in their work, were also included.

The teachers in the test group also referred to numerous occasions where they addressed aspects of the history of science. Both test teachers mentioned teaching about significant figures, landmarks and events in the history of science and one of them referred to how the pupils in her class compared their work to the work of scientists. The teachers in the control group did not explicitly address any aspect of NoS in spite of having taken the second year curriculum science course (Appendix H).

These findings address a number of the issues raised in phase two. Firstly, the findings indicate that the beginning teachers in the test group maintained their contemporary conceptions of NoS a year after the intervention. The aspects of NoS about which they revealed elaborate understandings of in their final teaching practice were the aspects they addressed in their initial teaching year. These were science as a human endeavour, scientific inquiry, science as a body of knowledge, the history of science, and science and society (Appendix H).

Secondly, these teachers elected to incorporate NoS explicitly as part of the science curriculum, when they were not obliged to do so. It has to be acknowledged that the fact that they were taking part in this study could have influenced their decision to incorporate NoS as part of their teaching. However, their responses in their journals were extremely positive and they cited numerous advantages of incorporating NoS as part of their science teaching (Appendix H). The findings revealed that the teachers in the test group explicitly taught about NoS in their initial teaching year. However, a follow-up study that would explore the extent to which these teachers explicitly address NoS a number of years into their service would be informative in establishing whether or not they continue to do so.

In addition to implementing the science curriculum using a variety of hands-on activities, the reflective journals revealed that the test teachers also explicitly addressed NoS issues (Appendix H). They used methodologies and activities that they had encountered during the NoS elective, as mentioned above and utilised and developed a number of activities and approaches of their own. For example, they devised their own vignettes regarding the history of science, they asked the children to write a letter to a scientist, afforded the children time to discuss the influences that science and technology have had on society, used posters as discussion points and designed and made different artifacts (Appendix H). Discussion formed a part of every science lesson and the test teachers drew the children's attention to how the various activities related to various aspects of NoS.

The data obtained from the reflective journals indicate that the NoS elective influenced the test teachers' teaching of NoS issues. In addition to this it would appear that the NoS elective also helped reinforce many of the methodologies and philosophies about teaching and learning science that were covered in the second year science course. The next section explores how teachers' knowledge of NoS facilitated them in using more hands-on, reflective constructivist approaches to science, approaches that are recommended in the Science Curriculum (DES, 1999a).

NoS in the Irish Primary Science Curriculum

The data obtained from the beginning teachers' reflective journals indicated that all four beginning teachers were implementing the Science Curriculum (1999a) (Appendix H). The teachers in the control group had not taken the NoS elective. They were not given time to develop their conceptions of NoS explicitly nor had they been given methodologies for teaching about NoS. It is more than likely that, these beginning teachers did not hold elaborate conceptions of NoS as prior to taking the NoS elective their peers in the test group held 'traditional' NoS conceptions. The beginning teachers in the control group did not explicitly address NoS issues in their written reflections despite being specifically asked about it. Their reflective records indicated that they adhered more rigidly to the non NoS objectives provided in the curriculum documents. For example, in their reflective journals, when commenting on which topics they had taught, and the aspects of scientific investigations, addressed both of the teachers in the control group cited objectives that were taken directly from the curriculum documents (Chapter five and Appendix H).

On the other hand, although the teachers in the test group had planned and taught topics outlined in the science curriculum, they used their own wording for describing which aspects of scientific investigation they had addressed. In addition to this, when referring to aspects of NoS they had addressed, both teachers in the test group described in detail the aspects they had taught (Chapter five and Appendix H). These aspects were not explicitly stated among the curriculum aims and objectives. They were aspects of NoS that the test teachers had addressed the previous year during the elective course and during their final teaching practice.

There are a number of factors that could have contributed to the control teachers not explicitly teaching about NoS. The control teachers had not taken the NoS elective and therefore were not given time to develop their conceptual and pedagogical knowledge regarding NoS. 'Traditional' NoS conceptions and lack of pedagogical knowledge regarding NoS could have contributed to the control teachers not teaching about NoS.

Another factor could be the lack of explicit reference to NoS in the Science Curriculum (DES, 1999a). The data indicate that all four teachers in this study were implementing the science curriculum and adhering to the curriculum guidelines and objectives. If the curriculum documents had explicitly included the development of different aspects of NoS amongst the objectives, the teachers in the control group might have considered these in their planning and teaching. Teachers are more likely to teach about something that is explicitly stated in a curriculum than that which is not. If NoS is to be addressed in primary schools in Ireland, I would argue strongly that NoS be explicitly included amongst the objectives. The extent to which NoS is explicitly addressed in curriculum documents could be a factor in determining whether or not teachers explicitly teach about NoS in their science classes. Teachers are expected to teach what is proposed in curriculum documents and because of time constraints, cannot be expected to cover additional material. If science educators and curriculum designers deem the development of NoS conceptions to be important, it should be explicitly stated amongst the aims and objectives of curriculum documents. Unless NoS is mentioned explicitly in guidelines it may be omitted altogether to facilitate the delivery of what is considered to be the 'core' curriculum.

The findings discussed in this section indicate that the test teachers appeared to have maintained their contemporary NoS conceptions a year after they had taken the NoS elective course. The reflective journals illustrate that the test teachers planned and taught about NoS issues and considered it an important element of primary science. In summary, the teachers' reflective journals indicated that the teachers in the test group:

- Explicitly addressed aspects of NoS in every science lesson
- Included group and/or whole class discussions in all of their science lessons
- Encouraged the children to discuss and reflect on various NoS issues
- Used a wider variety of methodologies for testing, developing and assessing the children's scientific knowledge than the control teachers
- Engaged their pupils in more hands-on science activities than the control teachers did
- Were more enthusiastic and positive about teaching science than the control teachers

The data obtained from the children will be discussed in the next section and the extent to which their NoS conceptions have developed will be explored. The impact that the various teaching approaches employed by the teachers in the test and control group had on the third and fourth-class children will then be considered.

8.6.4 Phase Three: NoS and Pedagogy (Children's Data)

In general the findings suggest that explicit approaches to teaching about NoS were successful in developing more contemporary NoS conceptions among children in the test group (Chapter six, Tables 6.4, Figures 6.1 and 6.2).

Contemporary NoS Conceptions

The data obtained from the children's questionnaires at the exit stage indicated that the children in the test group had developed considerably more elaborate conceptions regarding science as a human endeavour, scientific inquiry and the history of science. (Chapter six, Tables 6.4, Figures 6.1 and 6.2 and Appendix N).

With regard to science as a human endeavour the findings indicate that the children from the test group developed more elaborate conceptions of this aspect of science particularly in relation to creativity and imagination and the subjective NoS. There were considerable differences in the quality of responses made by test and control group children in the discussions regarding science as a human endeavour. Those from the test group were more detailed, diverse and reflective. Both teachers in the test group explicitly addressed science as a human endeavour. (Chapter six, Tables 6.5, 6.6 and 6.7 and Appendix N).

The children from both groups made more references to scientific inquiry in the exit questionnaires, however the test group had a considerably higher frequency of responses (Chapter six, Figure 6.8 and Appendix N). The children in the test group referred to a wider range of skills and processes than the control group. In particular the test group elaborated more on how scientists apply the skills, something that neither group did at the initial stage. Many of the children in the test group referred to scientists, hypothesising, predicting and gathering evidence, skills that were not referred to in the initial questionnaires and were never referred to by the control group in either questionnaire (Chapter six, Table 6.8 and Appendix N).

The findings also revealed that at the exit stage the children in the test group had developed considerably more elaborate conceptions of the history of science than their peers in the control group (Chapter six, tables 6.18 and 6.19). The elements of HoS that were included in the science lessons clearly had an impact on the children's conceptions. The children in the test group made numerous references to scientists and their contributions and recalled numerous details about these accounts. Tao (2003) maintains that many of the history of science stories that were included in textbooks in Hong Kong, were of the 'heroic' type. Tao acknowledges that while these are interesting to children, they are not always true portrayals of NoS. The history of science vignettes and stories the children in the test group were exposed to may not have been true portrayals of the history of science. Indeed in many cases in the current study, the children's reflections 'idolised' scientists and their contributions to some extent (Chapter six and Appendix N). However, these stories had an impact on the children, who remembered them in detail. The inclusion of HoS as part of the science curriculum in phase three of this study has helped humanise science for the children. For example many of the children in the test group referred to aspects of the HoS when referring to science as a human endevour (Appendix N). The extent to which the children in the test group talked about elements from the HoS could be an indication of their interest and enthusiasm towards the history of science (Appendix N).

History of science stories are considered to be an appropriate way for introducing the HoS to primary school children, as children tend to like stories. However, I agree with Tao (2003), in that the teacher's role in scaffolding their pupils' perceptions is paramount. Tao recommended that if history of science stories are to be utilised to illustrate different aspects of NoS, question and answer sessions should be an integral part of the lesson, once children have listened to/ read and discussed the story. Tao's recommendation, if taken into account, could improve the connections children make between NoS and HoS.

Solomon (1991) also devised a number of HoS vignettes that illustrated the social context and the developmental NoS rather than providing a comprehensive examination of exact chronological developments. If teachers were introduced to pedagogical materials like those of Tao (2003) or Solomon (1991), children could be facilitated in making more genuine connections between NoS and the HoS. Such connections could help develop more elaborate understandings of NoS.

The inclusion of HoS in the science curriculum has additional benefits in the Irish Primary Curriculum. Science, history and geography are grouped together under Social Environmental and Scientific Education (SESE) and it is recommended that they be taught in an integrated way. While it is not suggested that the inclusion of aspects from the history of science as part of a science class would 'cover' the entire history curriculum, it is suggested that the inclusion of HoS could begin the process of meaningfully integrating science and history.

The responses regarding science improving the world were similar amongst both groups in the interviews (Appendix N). Many of the children did not distinguish between science and technology when discussing social issues. Similar to the young children in Driver et al's (1996) study, neither the control or test group seemed to be aware of how society influences and prioritises various scientific research projects, and did not elaborate on how society as a whole undertakes decisions. In general the children perceived science as a means of improving the world, inventing new cures and devices rather than developing explanations about the world (Appendix N).

NoS in Science Class

All of the children in the test group discussed a number of activities and occasions where they had learned and discussed different tenets of NoS in school (Chapter six, section 6.2, Table 6.1). The children recalled activities they had done over the course of the year that explicitly addressed the tentative and developmental NoS, the subjective NoS and creativity in science. They eagerly recalled and discussed 'Tricky tracks' and 'fossil' activities (Lederman and Abd-El Khalick, 1998, p 83 - 91, 95-97), and how these aspects illustrated the subjectivity of science. At one stage, two children in fourth class even discussed the differences between observations and inferences (Chapter six, section 6.3.2, paragraph three). They also discussed differences between 'real science ' and 'pseudo' science, concepts that had been presented to them through a video they had seen in school (Bill Nye the Science Guy: Pseudo science, Appendix N).

The children in the test group recalled different design and make activities that they had completed over the course of the year, particularly in relation to the K'NEX challenge. All of the children in the test group who had taken the challenge talked at length about it and reflected on the various stages of the challenge from thinking up and drawing (and redrawing) their designs to making and altering their designs. They reflected on different science skills they had employed over the course of the challenge. The fact that the challenge had been difficult at times was discussed, however all of the children had thoroughly enjoyed the challenge, which was evident from their enthusiastic and detailed reflections (Chapter six and Appendix N).

The history of science was an extremely topical area of discussion in the exit interviews of the test group. All of the children in the test group reflected on and discussed different aspects of the HoS that they had learned about in school (Chapter six, Tables 6.18 and 6.19). They recalled and discussed in detail the lives and contributions made by different scientists they had learned about in school. In particular the children reflected on personal details in the scientists' lives that affected or influenced their 'inventions' (Chapter six and Appendix N). When reflecting on different aspects of the HoS they had learned about in school, the children utilised historical vignettes to discuss science as a human endeavour and the influences society has had on science in the past. The history of science was something the children in the test group were extremely enthusiastic about and could recall huge detail about the lives and inventions of the scientists (Appendix N)

The extent to which the teachers in the test group explicitly related the historical vignettes to NoS is unclear. However, one thing is evident that the children appeared to have a good understanding of science as a human endeavour and how society influenced science over the course of history. They also had developed more understandings of the developmental nature of science. As mentioned before additional methodologies, for example, Solomon (1991) and Tao (2003) could help teachers make clearer links between HoS and NoS.

The enthusiastic manner and the detail in which the children recalled the various activities regarding NoS indicate that the children thoroughly enjoyed doing and discussing the activities (Chapter six and Appendix N). The children's responses and discussions illustrated a good understanding of what the different activities were about. The activities appear to have been successful in that the findings revealed that the children in the test group had developed considerably more elaborate NoS conceptions at the exit stage (Chapter six and Tables 6.4, 6.5 and 6.6). None of the children in the control group referred to the history of science when reflecting on school science in their exit interviews.

8.6.5 Summary of Findings: Document Analysis

Research has indicated that curriculum documents and assessment tests need to explicitly address NoS, so teachers will recognise NoS as an 'important' area that will be assessed (Gilbert, 2003; Lederman,1998; White, 2003). Lederman (1998) suggests that NoS objectives be included as 'subjective' rather than 'affective' objectives. Teachers may be more inclined to teach NoS if it were explicitly addressed in curriculum documents and if it were explicitly assessed. As part of the fourth phase of this study, a preliminary content analysis of seven curriculum documents was conducted which revealed that in the majority of the documents analysed, the development of NoS conceptions was implied rather than explicit. Five of the seven curriculum documents reviewed (excluding California and Northern Ireland), referred to different aspects of NoS understanding amongst their general aims of science education (Chapter seven, section 7.3.2, Table 7.3). These aims are not explicitly linked with developing NoS understanding, rather they implicitly address NoS issues. The Republic of Ireland Science Curriculum (DES, 1999a), for example, acknowledges the importance of the creative NoS in that one of the general aims of science education outlined in the Science Curriculum is:

> 'to encourage the child to explore, develop and apply scientific ideas and concepts through designing and making activities', (p, 11, Government of Ireland, 1999).

However, the aim does not explicitly link designing and making with the development of creative aspects of NoS.

Science as a human endeavour was referred to in the general aims of science education in the New Zealand curriculum:

'developing students understanding of the different ways people influence, and are influenced by science and technology' (p. 9.)

However, this aim was not explicitly linked to science as a human endeavour and its importance in understanding about NoS.

While the documents provided contemporary and elaborate accounts of NoS, (Chapter seven, Section 7.3.1,Table 7.2,), in general the development of contemporary NoS conceptions was not given high priority in the Republic of Ireland, England and Wales, Scotland, Northern Ireland and Californian documents.

With the exception of the New Zealand and Queensland documents, all other documents implicitly rather than explicitly addressed the development of NoS conceptions (Chapter seven, Table 7.8). There were no objectives or strand units that explicitly addressed the development of NoS conceptions nor did the documents contain exemplars regarding how teachers might explicitly teach about aspects of NoS. The absence of strands/ units, objectives or exemplars that explicitly addressed NoS issues in the documents, meant there was no model provided for teachers that could facilitate them in explicitly teaching about NoS as part of the various science curricula.

Research suggests that teachers in general tend not to hold contemporary conceptions of NoS (Bloom, 1989; Loving, 1991; Abel & Smith, 1994; Akerson et al., 1999; Murcia & Schibeci, 1999; Abd- El-Khalick et al., 2000). If NoS aims are implicit rather than explicit in curriculum documents, teachers may overlook the development of NoS conceptions as an aim. Teachers who do not have contemporary understandings of NoS may not be able to decipher aspects of NoS that are implicit amongst aims and objectives. If they do not know what NoS entails, they are unlikely to recognise aims and objectives that implicitly address NoS issues.

Two of the seven curriculum documents analysed (Queensland and New Zealand) include aims that explicitly referred to NoS understanding. Two of the 'key learning area outcomes' in the Queensland Curriculum Framework include:

- The understanding and appreciation of the evolutionary nature of scientific knowledge

- The understanding of the nature of science as a human endeavour, its history, its relationship with other human endeavours and its contribution to society (p.8).

The New Zealand Framework included "the development of student's understanding of the evolving nature of science and technology"(p. 9) as an aim.

In addition to this the Queensland and New Zealand curriculum documents are the only two of the seven documents analysed that contained strands/ units dedicated to learning about NoS and that contained objectives that explicitly address tenets of NoS (Chapter seven, section 7.3.3, Tables 7.4, 7.5, 7.6 and 7.7).

However, despite the emphasis placed on the development of contemporary NoS conceptions in the New Zealand and Queensland curriculum documents, research has indicated that even when the development of NoS conceptions is explicitly addressed in curriculum documents, this does not automatically mean that it will taught in science classes. Often the 'actual' curricula being taught are quite different from the 'intended' curriculum (Rennie, Goodrum, & Hackling, 2001). Other studies in New Zealand have suggested other reasons for the lack of uptake of 'making sense of the NoS and its Relationship to Technology' strand in the science curriculum. Wellington (1998) for example maintains that the Framework places considerable attention on 'fair testing' and does not provide a clear definition or description of what NoS actually entails.

Hipkins et al. (2002) assert that an issue for teachers in New Zealand is the lack of specificity regarding the intended NoS content outlined in the curriculum documents. They suggest clarification needs to be provided regarding what conceptions of NoS should be addressed and developed as part of the New Zealand Curriculum Framework. Hipkins et al. (2002) also found that lack of teachers' personal philosophies and understandings of NoS and lack of pedagogical content knowledge were still impeding the development of NoS conceptions in New Zealand. Bell et al. (1995) indicated that additional curriculum development and teacher professional development would be required to facilitate teachers in the successful integration of 'the Making Sense of the NoS and its Relationship to Technology' strand.

The findings in the New Zealand and Australian research have implications for explicitly teaching about NoS in primary schools. With regard to the Irish primary science curriculum, clearer more explicit definitions of which aspects of NoS are to be addressed could be provided. If NoS was perceived as a 'cognitive' rather than an 'affective' objective, teachers might be more likely to address it when teaching science. In addition to this the inclusion of suggested methodologies for explicitly addressing NoS in the Curriculum Guidelines (1999b) could also facilitate teachers in teaching about NoS. Pre-service and in-service courses that provide teachers with opportunities to develop their subject and pedagogical knowledge regarding NoS are also required to facilitate teachers in developing their conceptual and pedagogical NoS knowledge. Such knowledge might prompt teachers to explicitly teach NoS as part of the curriculum and could increase teachers' interest and confidence in teaching science.

8.7 Summary

There were a number of findings in this study:

1. Teachers with conceptual and pedagogical knowledge of NoS utilised more innovative and hands-on an approaches to teaching science and tended to use less teacher demonstration and more group work than those who had little conceptual or pedagogical knowledge of NoS;

2. Teachers with conceptual and pedagogical knowledge of NoS allowed considerably more time for discussion and reflection in the science classes than teachers with little knowledge of NoS;

3. The children who were taught by teachers with conceptual and pedagogical knowledge of NoS were more enthusiastic about science in school than those thought by the teachers who had not taken the NoS elective course;

4. Explicit methods in addressing NoS issues significantly improved the NoS conceptions of pre-service primary teachers;

5. New-found contemporary conceptions held by the pre-service teachers who had taken the NoS elective were maintained a year after the intervention;

6. Explicit approaches to teaching about NoS as part of the Science Curriculum appeared to result in the development of more elaborate conceptions of NoS amongst 9, 10 and 11year old children;

7. NoS was not explicitly addressed in five out of seven curriculum documents analysed;

8. NoS was not explicitly addressed in two international assessment tools (TIMSS and IAEP).

The results of this study are encouraging in that the aspects of NoS that the test teachers explicitly addressed (science as a human endeavour, the nature of scientific inquiry, the history of science and science and society), were the aspects of NoS of which their pupils developed more contemporary understandings. However, although the children's NoS conceptions had developed considerably, they still held some 'naive' conceptions regarding NoS.

A number of the children's discussions illustrated some understanding of scientists being informed and how past experiences and knowledge influence their work. Such discussions revealed a slight movement away from the serendipitous empiricist, 'shot in the dark' type approaches to scientific inquiry. However, at the exit stage, children in the test and control groups' still revealed simplistic understandings of the role of scientific evidence and patterns. They held more 'discovery' (Solomon et al., 1994) views about scientists' work, ascertaining that scientists 'do experiments' to 'discover things', (often not having any idea what the outcome might be). The children also had limited understanding of the nature of scientific observations, in that many children still regarded science as a process of observation, where outcomes would be obvious.

Many of the children did not distinguish between different aspects of scientific inquiry and often referred to science and technology as one entity, that of improving the world. These responses suggest a portrayal of Aikenhead et al. (1987) 'techno- science' and 'technologist' images of scientific inquiry where societal issues regarding science were related to technology and the role of science was to solve these technological problems. Additional exposure to and reflection on the various aspects of NoS could facilitate the further development of the children's NoS conceptions. Teachers could also be facilitated in explicitly addressing NoS as part of the science curriculum if they were provided with additional in-service courses that were aimed at developing their conceptual and pedagogical knowledge of NoS.

However, only two of the international curriculum documents explicitly addressed NoS amongst the aims and objectives and two international assessment tools did not assess NoS. Teachers are more likely to explicitly teach about NoS as part of science curriculum if it is explicitly stated amongst the aims and objectives. They are also more likely to explicitly teach about NoS if it is to be assessed.

8.8 Limitations

There are potential limitations regarding the generalisation of the findings from this study that need to be considered.

8.8.1 Sample Size

Although some quantitative methods were utilised to gather data, qualitative methods were used for the most part. While these qualitative data generated an in-depth understanding of a selected group of people, the numbers in the samples in the three phases were relatively small and potentially may not have been representative of the population of pre-service and beginning teachers. However, although the first two phases comprised a convenience sample of only nineteen pre-service teachers, these teachers had similar backgrounds and experiences of science as their peers in Ireland (Waldron, Varley, Greenwood and Murphy, 2007) and in this way were representative of third year pre-service teachers.

In the third phase of the study a purposive sample of four teachers, two who had taken the elective and two who had not, was utilised in an effort to ensure that variability amongst the participants was represented in the data. (Cohen et al., 2000; Lincoln and Guba, 1985; Maykut and Morehouse, 1998; Patton, 1990). Maximum variation strategy (Lincoln and Guba, 1985; Patton, 1990) was utilised. That is the researcher's knowledge of the teachers' experiences of NoS resulted in their selection and the sample represented considerable differences in the teachers' experiences of NoS at college. These differences provided a means by which variability, a feature of random selection, could be addressed (Maykut and Morehouse, 1994; a Lincoln and Guba, 1985). A further strength in the small sample sizes was that they permitted a more in-depth and detailed study of the teachers and children's conceptions of NoS and provided qualitative data to support and corroborate the quantitative data obtained. A larger sample of children was administered a questionnaire during the third phase of the study. This larger sample provided quantitative data, which permitted generalisations to be drawn (Maykut and Morehouse, 1998; Patton, 1990, Taylor and Bogdan, 1984).

8.8.2 Influence of Researcher

During phase one, the intervention, which was essentially the Nature of Science elective, was designed and delivered by the researcher. The data obtained from the first two phases were therefore affected by the researcher's stance of what NoS entails. However, this subjectivity was a feature of the research rather than a limitation in that the researcher sought to provide the students with ideas and experiences of NoS that were in keeping with contemporary views and literature regarding what NoS comprises. The researcher's centrality was therefore fundamental in supporting, directing and developing the pre-service teachers' conceptions of NoS. The data regarding the children's conceptions of NoS acquired during the final phase of the study were more objective in that the researcher had no influence on their conceptions of NoS.

8.8.3 Conducting Interviews

Conducting interviews can be the cause of bias in research and therefore a number of measures were taken to eliminate potential biases. Firstly every effort was made to reduce the possibility of the 'Hawthorne effect' (Robson, 1993), where the children might feel obliged to give a 'correct' answer to please the interviewer. Before each interview the children were reminded that there were no 'right' or 'wrong' answers and that it was 'their ideas' that were important (Briggs, 1986). Secondly, every attempt was made to help the children feel at ease during the interviews. The children addressed the researcher by her first name and an informal chat proceeded every interview to allow the children time to form a relationship with the researcher. 'Teacher-like controlling behaviours' (Tammivaara and Enright, 1986) were also avoided. Thirdly, in an effort to avoid the inclination of the researcher to seek answers from the children that were consistent with her ideas and perceptions surrounding NoS, an interview schedule was devised and adhered to.

8.8.4 Affirming Researcher

It is acknowledged that two of the four beginning teachers who took part in the third phase had taken the NoS elective the previous year and as a result may have wished to affirm the researcher's enthusiasm. However, the non-NoS elective teachers who took part in this phase were aware of the researchers' interest and propensity for science and equally may have been eager to seek the researcher's approval.

8.8.5 Length of Study

The study revealed that the beginning teachers appeared to have maintained their interest in and understanding of NoS conceptions a year after intervention. However, a longer study could have established whether these beginning teachers continued to explicitly address NoS as part of the science curriculum and whether they maintained their interest in teaching science. Secondly, with regard to the children, the findings indicate that after a short exposure to NoS, the children's NoS conceptions developed considerably, however they still revealed many naïve conceptions regarding NoS. A further study that would be conducted over a number of years could establish whether continued exposure to NoS would result in the further development of elaborate conceptions of NoS. Such a study could also establish the extent to which reflection on NoS issues and doing NoS related activities as part of the science curriculum maintains children's interest and enjoyment of science.

8.9 Implications and Recommendations

8.9.1 What has been Achieved by the Research?

In spite of the limitations the research has successfully established the effectiveness of explicit approaches in the development of more contemporary NoS conceptions of primary teachers and their pupils. The findings imply that:

- In addition to the development of more contemporary NoS conceptions, explicitly incorporating NoS as part of the Irish Primary Science Curriculum facilitates the employment of hands-on, reflective constructivist approaches to science (Chapters five and six);
- The inclusion of explicit approaches in addressing NoS leads to the development of more positive attitudes towards science amongst teachers and their pupils (Chapters five and six);
- Explicit methods are effective in the development of more contemporary NoS conceptions amongst pre-service teachers Chapter four);
- Primary teachers' elaborate NoS conceptions can be transferred to their pupils when explicit methodologies are employed (Chapter six).

8.9.2 How Much has the Research Moved Along Professional Discussion?

This research is significant for a number of reasons:

- A number of findings from other international studies were corroborated. Firstly, similar to their counterparts in other countries, at the onset of this study Irish pre-service teachers' held naïve conceptions regarding NoS. At the end of phase one and two, these pre-service teachers held considerably more elaborate conceptions regarding NoS (Chapter four);

- Few international studies and no Irish studies have examined whether primary teachers' NoS conceptions can be transferred to their pupils using explicit approaches. The research regarding the translation of teachers' NoS conceptions into practice has largely been focused at second and third level. This study therefore is important as it explored the translation of NoS conceptions within a primary context;

- No Irish research, and very little if any international research, has mapped the development of pre-service teachers' NoS conceptions from traditional to more contemporary views of science, over the course of teaching practice into the end of their initial teaching year. There is a paucity of research that has examined the extent to which teachers have maintained contemporary conceptions a year after intervention. This study is therefore important as it traced the development of pre-service teachers' NoS conceptions from their final year in college and into their initial teaching year. The study also went a step further and explored the effectiveness of beginning teachers' explicit methodologies in developing primary children's NoS conceptions;

- This study has revealed that explicitly addressing NoS as part of the Primary Science Curriculum increases primary children's interest in science. There are concerns in Ireland regarding the decline in the number of students taking science at post-primary and tertiary levels (Organisation for Economic Co-operation and Development (OECD), 2002b). The findings therefore could be significant in informing curriculum developers about approaches to teaching science that could promote students' interest in science, potentially increasing the uptake of science at second and third level.

8.9.3 Suggestions for Future Research Needs

- The beginning teachers in the test group had similar backgrounds and experiences of science as those of their peers in Ireland (Waldron et al., 2007). However, they chose to take the NoS elective in their final year of college and therefore presumably had an interest in science to begin with. Their interest in science rather than the NoS elective could have been a factor in their interest and enthusiasm for teaching science. A further study that would explore the effects of compulsory NoS courses on pre-service and practising teachers could establish the effectiveness of NoS courses in developing teachers interest and enthusiasm for teaching science

- The findings of the study appear to indicate that children enjoyed science more when explicit approaches to NoS were incorporated in their science classes. However, whether its inclusion would lead to improved conceptual and procedural knowledge was not established. Matthews (1994) and Mc Comas (1998) suggest that the inclusion of explicit approaches in addressing NoS can help children's learning of science content and skills. Additional research that would establish whether explicitly addressing NoS as part of the science curriculum helps the development of science content and skill knowledge in this context would be significant.

- The study indicated that learning about NoS facilitated children enjoying science more. A study that explored whether sustained exposure to NoS over a number of years, could continue to keep children interested in science beyond the point of choice at second and third level would be informative. Such research could address some of the concerns regarding the decline in the number of Irish students taking science at secondary and tertiary level.

- An important aspect of NoS is the history of science. In the Irish Primary Curriculum science, history and geography are grouped together under social scientific and environmental education (SESE). The curriculum suggests that these subjects be integrated. Many aspects of NoS, for example history of science, science and society or science as a human endeavour are relevant to aspects of the history and geography curricula. Many of the skills outlined in the history and geography curricula are similar to those outlined in the science curriculum. For example, thinking skills, hands- on and group work, looking for evidence, examining patterns. A study that would explore how different aspects of NoS could be used to facilitate the integration of SESE in the Irish primary curriculum would inform curriculum developers and teachers and help them integrate history geography and science in a relevant and meaningful way.

8.10 Conclusions

While the Irish Primary Science Curriculum does not explicitly address the development of NoS conceptions among its aims, aspects of NoS are implied. The broad aims of the curriculum are that the children will develop conceptual and procedural knowledge and skills and that they will develop positive attitudes towards science. The results from this study indicate that incorporating explicit approaches to teaching NoS as part of the curriculum facilitates the application and development of science skills and leads to greater interest and confidence in and more enthusiasm towards school science.

Irish primary teachers need to recognise that the development of contemporary NoS conceptions is an important aspect of learning about and understanding science. They need to be made aware of the benefits of employing explicit methodologies of NoS in increasing their pupils' interest, enjoyment and learning in science. Pre-service and in-service courses that would provide teachers with the opportunity to reflect upon and develop their NoS conceptions and pedagogical knowledge could facilitate teachers in developing their pupils' NoS conceptions. Such courses could also provide teachers with confidence to implement the methodologies suggested in the Science Curriculum (DES, 1999a). Furthermore, if the development of contemporary NoS conceptions was explicitly stated amongst the aims of the science curriculum, teachers might be more likely to address it in their teaching.

During the 1990s there were concerns in Ireland regarding the decline in the number of students taking science at secondary and tertiary level (Organisation for Economic Co-operation and Development (OECD), 2002b. In 2000 the minister of education established the Task Force on the Physical Sciences in an effort to address the declining interest in science at secondary and tertiary level. The report included a number of recommendations in relation to science at primary level, which included improving the quality of science teaching, in-career development for teachers and the establishment of an integrated national science awareness programme (Task Force on the Physical Sciences, 2002).

This study has shown that explicitly teaching about NoS as part of the Science Curriculum (DES, 1999a) appears to have resulted in the employment of more innovative teaching methods and appears to have resulted in greater enthusiasm, confidence and interest in science. Two of the recommendations of the Task Force on the Physical Sciences have therefore been addressed. The findings of the present study have already informed the New Approaches to Primary Science Teaching and Assessment (NAPSTA) project in Belfast (SMUCB/QUB 2007). They could also inform developers of pre-service and in-service courses in science in the Republic of Ireland and could facilitate the improvement of primary science teaching and help build teachers' confidence in teaching science.

Holding contemporary NoS conceptions is important for existing in a science-dominated world as such knowledge empowers citizens to make informed decisions as members of ever-changing societies. Incorporating NoS as an integral part of a curriculum enables students to be aware of the developmental NoS, humanises science, making it more interesting to learn and highlights the various influences society and culture have had and continue to have on the development of scientific knowledge. A concerted effort to promote the development of contemporary NoS conceptions could assist the fulfillment of the recommendations of the National Task Force 2002 in improving the quality of science teaching, including in-career development for teachers and could be informative in establishing an integrated national science awareness programme.

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APPENDICES

Appendix A

Excerpt from Spector and Strong (2001) Clash of cultures between science and education.

Table 1 The clash of the culture of science and the culture of traditional pre-service elementary methods students: Ethical traditions of science

Culture of Science	Culture of Traditional Pre-service Elementary Methods Students
Desire knowledge	Do not express desire for knowledge; satisfied with extant knowledge
View science as a way of knowing and understanding	View science as a fixed body of knowledge
Value peer review	Don't value peer review; only review from instructor matters
Make work public	Keep work private between student and instructor
Be open to criticism (of ideas and products)	Criticism of products and ideas is offensive and not permitted in a group or class
Reporting methods, procedures, and outcomes of investigations truthfully	Expect to accommodate methods, procedure and outcomes to arrive at the 'right answer'
Respect the rules of evidence	It is not permissible to censure a classmate. That is the responsibility of the instructor
Use empirical standards	Use personal beliefs
Use logical arguments	Use logical arguments
Exhibit scepticism	Exhibit unquestionable acceptance
Strive for 'best possible' explanation - explanation that is subject to change as new evidence becomes available	Explanation should be 'fixed'. Stop seeking or ignore new evidence so as not to change explanations
Explanations must be consistent with data	Explanations need to be consistent with prior beliefs
Explanations must make accurate predictions	One prior personal instance is enough to accurately make predictions

Table 2 The clash of the culture of sconce and the culture of traditional pre-service elementary methods students: Teaching and learning

Culture of Science	Culture of Traditional Pre-service Elementary Methods Students
Learners are rewarded for...	
Identifying problems	Stating answers
Divergent thinking	Compliance and conforming to a 'group think'
Taking intellectual risks	Staying intellectually safe. Not speaking unless sure they are right
Learners expect to...	
Ask questions	Not ask questions
Test assertions	Accept authority's assertion
Have opportunity to investigate	Be told the one correct answer by an authority
Determine for themselves what to think and how;	Be told what to think and how
Collect data from multiple sources	Use one source of data - the authority
Learners assume...	
Knowledge is dynamic	Knowledge is static
Their interpretations matter and so do those of other people in class	Only the teacher's interpretation matters.
Multiple perspectives are valuable	Their interpretations must match that of the teacher
They will have cooperation answering questions and solving problems	There is only one way to think about something; one linear structure exists
Everyone will have an open mind	They will answer questions and solve problems independently
They need to be sceptical and analytical	New information will be consistent with prior beliefs. When it is not, it is dismissed They need to accept without questioning
Learners are accountable for...	
Inventing explanations and testing them	Memorising and following directions
Interacting with other people and ideas	Working independently and protecting my ideas and products
Challenging ideas, questioning others' ideas, and seeking the evidence and logic used. Holding decisions in abeyance, and by tolerating ambiguity...	Being polite by 'yes -ing' ideas
Negotiating among teachers and students to determine course of actions.	Jumping to conclusions and bringing immediate closure
Reflecting and engaging in metacognition	Believing that the teacher alone can determine the course of actions
Documenting processes and findings	Summarising exactly what was given
Supporting any idea with evidence and logic	Repeating through recalls what was received from the authority Appealing to authority to support and idea
Learners perceive ...	
Science as an adventure and 'do-able'	Science as boring and difficult

Appendix B

Letter of Permission to Elective Students

May 2005

I am currently conducting research for my doctorate in the field of primary science. As part of my research I am exploring pre-service primary teachers' conceptions of Nature of Science and their translation into practice. As part of my research I would like to explore and discuss the various reflections your elective group have written over the course of the year. I would like to seek your permission to discuss and perhaps quote some of your written responses in my final thesis. Any quotations or references used in the thesis will be totally anonymous.

I give permission for you to discuss and quote my written work from the following reflections		
	Yes	**No**
'Science is' statements		
History of Science Reflections		
Long Range Experiment (individual reflection)		
Teaching Practice Reflection		
Nature of Science Questionnaire		

If you would like to receive a copy of the final document please tick the box below

I would like to receive a copy of the final document ☐

Signed: ______________________________

If you would like any further information please don't hesitate in contacting me

My email is: My mobile number is:

'Science is' Statements

Initial Stage: Science is….

1. Science is the study of what world around us and how everything in it works. It involves questioning, testing, estimating, making assumptions and reaching conclusions based on your experiments.
2. Science is taking in what is in the world around us, examining what something does, how something works or prediction what you think will happen.
3. Science is the study of plants and various natural forces.
4. Science is the study of living and non-living things.
5. Science is the study of living and non-living things by the use of experiments and close observations and the recording of your results.
6. Science is the study of how things work. Science is about discoveries through experiments.
7. Science is fun/ challenging/ why and how things work. Science is experimenting exploring and discovering.
8. Science is about learning about the world we live in and questioning and experimenting to find out the answers. It provokes wonder.

Exit Stage: Science is…

1. Science is the search for meaning, and truth, through a process of questioning, philosophising, analysing, applying, observing, recording, inferring, hypothesising and concluding. Science does not exist alone and is affected by culture, history and religion. Science attempts to explain all phenomena and all reactions that occur on this planet. Science is about opening your mind in attempting to explain things. The whole idea of white lab coat working with potions is only one definition of many; we have to explain science. Anyone can be a scientist who undergoes the listed skills.

2. Science is the study of all living things. Science tries to explain natural phenomena. Science is tentative and is always changing. Science is influenced by sociology, culture, and philosophy and by context (influenced by what's going on at that particular time in the world).

3. Science is all around us. It affects us in virtually all aspects of our lives. It is a dynamic body of knowledge. It is tentative and subject to change. Religion, history and philosophy affect it. It is difficult to consider it devoid of the elements of Nose... Ethical issues are involved in science. Issues of bias are also evident. Science can't be examined a historically - history humanises science. Scientific methods are used - science builds on past experiences. Science is tangible when NoS is implemented.

4. Science is a dynamic body of knowledge. By this I mean that it is tentative and subject to change. Science incorporates philosophy, history, and sociology. Science is also influenced by each of these. Science includes a certain amount of creativity and imagination on the part of the scientist. Anyone can do science. Science is a way of working but there is more than one scientific method. Ethics can come into science and very often influences the direction science takes. Bias is also another issue; very often it comes into science. Science opens up people/ children into the wider world.

5. Science is more than just investigating the world around us. It involves using all of the skills of science: predicating, hypothesising, using evidence, recording and reporting clearly. Science is not a study that exists on its own. It relies heavily on contemporary culture and also on the values that have been passed on. How we view science depends on the work of scientists from the past. Science is about being creative, picking up where another scientist finished, finding flaws in other scientists' work. The results of science weigh heavily on society and therefore everybody should have a good knowledge of what the process of science involves. If people in today's society do not understand the result of scientific decisions that were made in the past, and the importance this has on culture even today, then they will not develop the ability to think about what science mans, its philosophy not just the answers it provides.

6. Science is a process of understanding the word through various forms - biology, chemistry, physics and technology. It is the means by which one looks at the world intensively, recognising and understanding how things are created and how they work. It is a factual study with reliance on evidence and facts, which lead

one to determine and understand processes, which take place within the world and beyond. It allows one to comprehend the world

7. Science is:

- Something everybody does and everybody uses
- A way of explaining and sometimes answering the why of so many questions
- A method of exploring something from all angles
- An in-depth look at our universe
- Trying to determine if a crazy thought/idea is really valid and significant by investigating and gathering evidence.
- Testing, making changes and re-testing and finally drawing conclusions
- Not taking everyone at face value, questioning and striving to discover
- Not always good, but not always bad
- Not THE answer to everything, often just AN answer

8. Science is the study of the world around us. It deals with living things and non-living things. It involves many skills such as hypothesising, observing, testing, experimenting and analysing. Science is not just a body of facts. It is about being creative. Different people can look at science information and draw different conclusions from it. Science is subject to change. It is tentative. A science theory can change and develop throughout history. It is about experimenting with different item and drawing conclusions from the experiments. A scientist can bring in prior knowledge and experience to draw their conclusions. It is active rather than passive. In science one is active predicting, testing and drawing conclusions. Everybody can work like a scientist, not just the scientists themselves. Science is examining where theories came from and how they came about. It is understanding why the theory is important in the world today.

Analysis of 'Science is' Statements

'Science is' Statements: Initial stage: Final analysis			
	BOK	**Explain**	**Skills**
1	0	1	1
2	0	1	1
3	0	1	0
4	0	1	1
5	1	0	0
6	1	0	1
7	1	0	0
8	1	1	1
9	0	1	1
10	0	1	1
11	0	1	0
12	0	0	1
13	1	0	1
14	1	0	1
15	1	1	0
16	1	0	1
17	1	0	1
18	1	0	1
19	1	1	0
N = 19	**11/19**	**10/19**	**13/19**
	58%	**53%**	**68%**

**** BOK & Explain Categories combined = into one category: BOK***

New BOK category - 18 / 19 students (97%)

'Science is' Statements: Exit Stage: Final Analysis										
	BoK	**Explain**	**Inquiry**	**Hum. End.**	**People**	**Creative**	**Subjective**	**Tent-ative**	**Sc & Soc**	**HoS**
1		1	1	1	1				1	1
2	1®		1	1			1	1	1	
3	1	1		0				1	1	
4		1		1		1	1	1	1	
5			1	1	1		1	1	1	1
6	1®		1	1	1	1	1	1	1	
7	1		1	1		1	1	1	1	1
8		1	1	0				1	1	1
9	1®	1		0						
10	1			1		1		1	1	1
11		1		0				1		
12	1®			1	1		1	1		
13	1®	1	1	0						
14	1®	1	1	1		1	1			1
15	1	1	1	1		1	1	1		
16	1	1	1	1		1	1	1	1	1
17	1®	1	1	1	1	1			1	
18	1®	1	1	1			1	1	1	
19	1®		1	1		1			1	1
Tot N = 19	**14**	**12**	**13**	**14**	**5**	**9**	**10**	**13**	**13**	**8**
%	**74**	**63**	**68**	**74**	**26**	**47**	**53**	**68**	**68**	**42**

* BOK + Explain + Inquiry = BOK category
* Hum. + People + Creative + Subjective = Human Endeavour category

Appendix C

History of Science Reflection Guidelines

History of Science Presentations and Written Reflections

1 Read 2 Photocopied articles
- AAAS – Chapters 1 & 10
- 'History of Science in the Curriculum' by Michael Matthews
- 'Five Big Ideas in Science', by Wynn and Wiggins (372.35/wyn)

2 In pairs become the 'class expert' on one of the following famous scientists:
I. Galileo Galilei (1564 – 1642)
II. Isaac Newton (1643 – 1727)
III. Antoine Lavoisier (1743 – 1794)
IV. Charles Lyell (1797 – 1875)
V. Charles Darwin (1809 – 1882)
VI. Marie Curie (1867 – 1934)
VII. Louis Pasteur (1822 – 1895)
VIII. *Albert Einstein (1879 – 1955)*

NB: You do <u>not need</u> to develop total knowledge of the <u>scientific content</u> & <u>theories</u> developed by these scientists. It took them years you only have a fortnight!

3 Prepare a 10 minute presentation for class (Presentation & Individual Reflections = 20% of overall mark)

Presentation

1 Short biography including historical background
2 Significant scientific contributions
3 Influences of other scientific theories / philosophies to their discoveries
4 Elements of 'NoS' evident in their work e.g.
- Scientific methods used
- Reliability of theories
- Imagination and creativity of scientist
- Observations & inferences
- Tentative NOS
- Influences of culture & society (e.g. religion, role of women etc)
- Bias
- Ethical issue

5 How they used the terms theory / science/ truth / rational / explanation
6 How their theories were accepted and rejected
7 Did their discoveries / theories raise any philosophical questions?

Individual Reflection

Reflecting on the preparation and delivery of your presentation, the various presentations made in class, and the reading entitled, 'History of Science in the Curriculum', discuss the following questions:

- Do you think teaching about the history of science is worthwhile in an Irish primary classroom? Why / why not?
- Outline the kind of history of science programme you think might be included in an Irish primary classroom? How might such a programme be implemented? (Include specific examples where possible)

Points you might consider

- Is history of science worthwhile? Why / Why not?
- What are advantages / disadvantages about teaching history of science to children?
- How much do children need to know?
- Do they need total knowledge of theories?
- Will history of science help them develop better understanding of the NoS?

Long-Range Experiment Guidelines

Long Range Research Assignment (40% of overall mark)

What you have to do!

- Conduct a long – range experiment (LRE) - Pairs
- Submit written report - Pairs
- Oral presentation - Pairs
- Follow- up written assignment (due 15th December 2004) Individual

Examples of previous questions investigated – (do not use these!)

1 How light affects the quality of plant life
2 Which household cleaner is most effective at stopping bacterial growth?
3 What factors affect the spoiling of a banana?
4 How will the addition of oil affect the evaporation rate of water?

***Long-Range Research Experiment (LRE):* Guidelines for Written Report of Work**

1 ***Research question*** - state clearly the question you are investigating
2 ***Hypothesis*** - Formulation of hypothesis – state your prediction regarding the answer to the research question
3 ***Materials*** – list all materials and amounts / number of materials used to conduct the experiment
4 ***Procedure*** written clearly enough so that other 'scientists' could easily replicate the experiment with a step by step list including how you set up the experiment, what are the controls and variables, and what methods were used to collect and record data
5 ***Record of data collected*** – include all data collected during the experiment, in an easy to interpret form. This form could be a table, graphs, organised notes, photographs, or a combination of these. Be as specific as possible in your descriptions of data
6 ***Results*** – write a narrative, which describes the data collected throughout the experiment. Information presented in visual displays should be interpreted for the reader
7 ***Conclusions*** – begin this part of your report by stating whether the hypothesis is accepted or rejected. State your reasons for this decision.

Explain what the 'research community' can learn from the results of your experiment. Include any research questions which you would recommend for follow-up or future research about the same topic or similar topics

8 ***Bibliography*** – list references used to help conduct the experiment

Individual Reports

- Summarise your individual learning that occurred as a result of conducting the LRE
- What did you learn about the Nature of Scientific inquiry as a result of conducting this experiment?
- Discuss how you might structure a long-range experiment with primary school children. What difficulties / issues may arise? How might you overcome these issues?

(Reference: Y. Meichtry, in '*The Nature of Science: Rationales and Strategies*', W.F. Comas 1998)

Appendix D

Nature of Science Questionnaire Template – May 2005

NOSQ 1	Science textbooks often talk about the structure of the sun and the different reactions taking place inside. Nobody has ever seen the inside of the sun. How certain do you think scientists are about the structure of the sun? What evidence **do you think** scientists use to determine the reactions that take place inside the sun?
NOSQ 2	There is some debate about a possible link between the MMR (mumps, measles and rubella) vaccine and the development of autism in children. Some scientists say that there is evidence to support possible links between the vaccine and the development of autism. Other scientists believe that there is no evidence linking the two. How do you think these different conclusions are possible if scientists in both groups have access to and use the same data to derive their conclusions?
NOSQ 3	After scientists have developed a scientific theory, do you think the theory ever changes? **Yes / No / Depends** (*Please circle*) Explain your answer and defend your answer with examples.
NOSQ 4	Scientists conduct experiments/investigations/research. Do you think they use their creativity and imagination during their work? **Yes / No / Depends** (*Please circle)* Please explain your answer. Use examples if appropriate.
NOSQ 5	Some commentators claim that science is affected by society and culture. **I agree / disagree** with this statement? (*Please circle*) Defend your answer with examples.
NOSQ 6	Has your view of the Nature of Science changed as a result of doing the NoS elective? **Yes / No** (*Please circle*) Please explain your answer

Appendix E

Teaching Practice Reflection Guidelines

Teaching Practice Reflection: School Based Assignment

1. Find out children's ideas about the NoS prior to teaching science **5 marks**
2. Science scheme and outline of science lessons. Include questions, description of NoS activity(ies), groups of children, resources, **20 marks**
3. Assessment: Have the children's conceptions about the NoS aspect you addressed changed? Discuss. **5 marks**
4. Reflection of NoS on Teaching Practice **30 marks**

What to Do

1. Find out the children's ideas about the NoS aspect you intend to address. (E.G. Concept map, brainstorming, think and draw, question and answer session, questionnaire)
2. Devise and teach a number (at least 2) of age-appropriate activities that would help develop the children's understanding about your selected tenet. Include these as part of your science lessons and / or as a separate science lesson. Reflections and discussion on your chosen aspect of NoS as part of science lesson could be counted as an 'activity'. Posters, stories, newspaper articles could be used to aid discussion.
3. Assess the children's understanding of this NoS tenet (s) at the end of Teaching Practice
4. Reflect on teaching NoS as part of the Revised Science Curriculum. Discuss the following questions.
   - What are your general comments about teaching NoS with your class? Did you find it easy teaching about the NoS? Why/ why not? Was it easy to transfer contemporary NoS conceptions to your pupils through instructional practice? **(12 marks)**
   - Did your students develop their conceptions about the particular NoS aspect addressed? How do you know? **(6 marks)**
   - Do you think teaching NoS is important? Why? / Why not? **(6 marks)**
   - Based on your teaching practice experience how do you think you might approach teaching NoS as part of the science curriculum when you have your own class? **(6 marks)**

Appendix F

Permission Letter to Parents

September 2005

Dear parents,

I am currently conducting research for my doctorate in the field of primary science. As part of my research I am examining primary children's understanding of science in order to establish areas that need to be given more attention when teaching the science curriculum.

Your child's class is one of the classes that have been asked to take part in this survey. I hope to administer a questionnaire to all the children in your child's class and would like to talk to a number of children seeking their understanding of science. All information gathered from the questionnaires and following discussions will be anonymous and confidential.

If you **do not** wish your child to take part in this study please fill in the slip at the bottom of this page and return it to the class teacher.

I would like to thank you in advance for giving me the opportunity to carry out this research in what is an important area in primary education.

Yours truly

____

Clíona Murphy
Lecturer in science education,
St. Patrick's College, Drumcondra

(Please return this section to the class teacher only if you DO NOT wish your child to take part in this survey)

I do not wish my child to fill in the science questionnaire ☐

I do not wish my child to take part in discussions regarding the questionnaires ☐

Child's Name: ________________________________

Children's Questionnaire

Initial Questionnaire

1.

2. 0Name: ________________

3. I am a girl ☐ I am a boy ☐

Age: ☐

Section 1: Write as much as you can for each question

Q.1. What is science?

Q.2. What kind of things do you think scientists do?

Q.3. Write some questions you think scientists might investigate.

Q.4. Do you think science is important? Yes ☐ No ☐

Why?

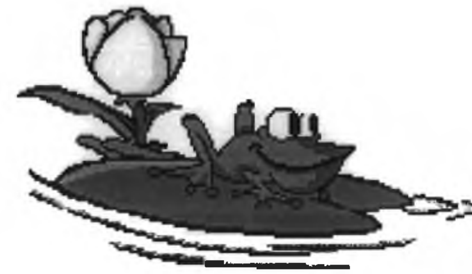
Section 2: Here are some statements about science. Do you agree with them? Colour ONE face each time.

☺ Yes ☹ No 😐 Not Sure

	Yes	No	Not Sure
Science answers questions about the world.	☺	☹	😐
When scientists give an explanation about something it is always true.	☺	☹	😐
Once a science fact is discovered it doesn't change.	☺	☹	😐
Scientists do experiments to prove their explanations.	☺	☹	😐
Scientists use their imaginations when they explain things.	☺	☹	😐
Scientists use their imaginations when they do experiments.	☺	☹	😐
Different scientists can have different answers to the same investigation.	☺	☹	😐
Scientists use their imaginations when they invent things.	☺	☹	😐
Scientists work alone.	☺	☹	😐
It is a good thing if scientists disagree with one another.	☺	☹	😐
Scientists should not invent things that might harm people.	☺	☹	😐
People in society should always tell scientists what to investigate.	☺	☹	😐
Science is interesting.	☺	☹	😐
I would like to be a scientist when I grow up.	☺	☹	😐

Thank you very much for your help!

Exit Questionnaire



Name: ________________

I am a girl ☐ I am a boy ☐

Age: ☐

Section 1: Write as much as you can for each question.

Q.1. What is science?

Q.2. What kind of things do you think scientists do?

Q.3. Write some questions you think scientists might investigate.

Q.4. Do you think science is important? Yes ☐ No ☐

Why?

Q.5. Do you like doing science in school? Why / Why not?

Section 2: Here are some statements about science. Do you agree with them? Colour ONE face each time.

☺ Yes ☹ No 😐 Not Sure

	Yes	No	Not Sure
Science answers questions about the world.	☺	☹	😐
When scientists give an explanation about something it is always true.	☺	☹	😐
Once a science fact is discovered it doesn't change.	☺	☹	😐
Scientists do experiments to prove their explanations.	☺	☹	😐
Scientists use their imaginations when they explain things.	☺	☹	😐
Scientists use their imaginations when they do experiments.	☺	☹	😐
Different scientists can have different answers to the same investigation.	☺	☹	😐
Scientists use their imaginations when they invent things.	☺	☹	😐
Scientists work alone.	☺	☹	😐
It is a good thing if scientists disagree with one another.	☺	☹	😐
Scientists should not invent things that might harm people.	☺	☹	😐
People in society should always tell scientists what to investigate.	☺	☹	😐
Science is interesting.	☺	☹	😐
I would like to be a scientist when I grow up.	☺	☹	😐

Thank you very much for your help!

Aspects of NoS Addressed in Section B of Children's Questionnaire

Statement	Category
Science answers questions about the world (*BoK*)	Body of knowledge, explaining the world
When scientists give an explanation about something it is always true. (*BoK, reliability, tentative*)	Body of knowledge, reliable, tentative
Once a science fact is discovered it does not change	Tentative NoS
Scientists do experiments to prove their explanations (*skills)*	Scientific inquiry
Scientists use their imagination to explain things	Human Endeavour: Creativity and subjectivity
Scientists use their imaginations when they are doing experiments	Human Endeavour: Creativity and subjectivity
Different scientists can have different answers to the same questions	Human Endeavour: Subjectivity
Scientists use their imaginations to invent things	Human Endeavour: Creativity and subjectivity
Scientists work alone	Scientific inquiry
It is a good thing if scientists disagree with each other.	Human Endeavour: Subjectivity
Scientists should not invent things that might harm people	Science and society
Society should always tell scientists what to investigate	Science and society

Coding of Responses for Section A of Children's Questionnaires

	Category Title	Graph Abbreviation	Description of Category
1	Science as a body of knowledge	*BoK*	Responses that related to science as; a body of knowledge that informs us and increases our understanding about the world; a means of providing answers to questions we may have about the world; informing us how and why things work; and specific references to physics, chemistry and biology were typical of the responses that were included in this category
2	Scientific skills	*Skills*	References to science skills and science and the empirical nature of science were included here. (One mark to every skill mentioned and multiple references to same skill)
3	Earth and environment al issues	*Earth*	The responses that referred to the earth, the weather, natural disasters and environmental awareness and care issues were included in this category.
4	Space	*Space*	References to space, the planets, astronauts were included in this category
5	Positive comments about science	*Posit.*	Positive comments about science
6	Negative comments about science	*Negat.*	Negative comments about science
7	Science as improving the world	*Improve*	General mentions of science improving the world we live in; the positive effects science has on society; references to diseases, cures and medicine; science and crime
8	History of science	*HoS*	Specific mentions of scientists and the development of their ideas and inventions; comparisons made between science today and many years ago; references to dinosaurs, Egyptians / Vikings
9	Human endeavour	*Human End.*	References to human issues around scientists' lives. Creativity of science, scientists making mistakes, scientists improving things
10	Tentative nature of science	*Tentat.*	References to the tentative and developmental nature of science
11	Technology and computers	*Tech.*	Science and technological inventions and advances. Science and computers

Second Analysis of Open-Ended Questions

	New Category	Old Categories	Description of New Categories
1	BOK	1+3+4+5+8	How and why things work, answers questions, discover things (general), explains things, biology, chemistry, physics, informative, learning, understanding world,
2	Skills	2 +2a+2b+2c	References to the science skills (one mark to every skill mentioned and multiple references to same skill)
3	Earth & environment	6	Earth and environmental awareness and care, weather, volcanoes, earthquakes etc
4	Space	7	References to space
5	+ comments	9	Positive comments about science
6	- comments	10	Negative comments about science
7	Improve world	11+11a+11b	General mentions of science improving the world we live in, references to cures and information about diseases and medicine, crime
8	HoS	12+12a+12b+12c	Dinosaurs, Egyptians / Vikings, scientists and their inventions
9	Human endeavour	13+14+15	Human characteristics, subjectivity, creativity
10	Tentative & developmental	16	
11	Technology & computers & inventions	19	
12	Like science	19	
13	Don't like	20	

New Categories and Figures: 2nd October 2006

	Test 1		Test 2		Control 1		Control 2		Test Total		Control Totals	
1	57	104	95	152	121	98	84	95	152	256	205	193
2	2	67	43	44	33	35	56	54	45	111	89	99
3	6	9	10	13	16	8	12	20	16	22	28	28
4	2	11	33	23	24	26	20	18	35	34	44	44
5	6	25	23	62	6	34	10	34	29	87	16	68
6	0	0	0	0	0	3	0	0	0	0	0	3
7	5	11	38	64	2	14	30	40	43	75	32	54
8	11	64	4	8	53	26	9	5+	15	72	62	21+
9	0	4	0	1	3	2	2	1	0	5	5	3
10	0	1	0	2	0	0	0	0	0	3	0	0
11	16	7	38	72	7	4	40	17	54	79	47	21
12	-	21	-	28	-	20	-	23	-	49	-	43
13	-	1	-	0	0	?	-	3	-	1		

New Categories and Percentages: 2nd October 2006

	Test (Initial)	Control (Initial)	Test (Exit)	Control (Exit)
BOK	43%	57%	57%	43%
Skills	34%	66%	56%	44%
Earth & envrion.	36%	63%	44%	56%
Space	44%	56%	44%	56%
+comments	64%	36%	56%	44%
- comments	0%	0%	0%	100%
Improve world	57%	43%	58%	42%
HoS	19%	81%	70%	30%
Human end.	56%	44%	82%	18%
Tentative	-	-	3 responses	
Techn & comp	53%	47%	79%	21%
Like	--	--	53%	47%
Don't like	--	--	75% (3 responses)	25%

Comparison of Initial and Exit Questionnaires (test and control separately)

	Test (Initial)		Test (Exit)		Control (Initial)		Control (Exit)	
	No.	%	No.	%	No.	%	No.	%
BOK	152	37%	256	63%	205	51%	193	49%
Skills	45	29%	111	71%	89	47%	99	53%
Earth & environ.	16	42%	22	58%	28	50%	28	50%
Space	35	51%	34	49%	44	45%	54	55%
+comments	29	25%	87	75%	16	22%	68	78%
-comments	0		0		0	0%	3	100%
Improve world	43	36%	75	64%	32	37%	54	63%
HoS	15	17%	72	83%	62	75%	21	25%
Human end.	24	37%	41	63%	19	68%	9	32%
Tentative	0		3		0	0	0	0
Techn & comp	54	41%	79	59%	79	79%	21	21%
Like	-		49				43	
Don't like	-		1		-		-	

Third Analysis of Open-Ended Questions - November 2006: Dinosaurs not in HoS category = changed to BoK category

	Category Title	Graph Abbreviation	Description of Category
1	Science as a body of knowledge	*BoK*	Responses that related to science as; a body of knowledge that informs us and increases our understanding about the world; a means of providing answers to questions we may have about the world; informing us how and why things work; and specific references to physics, chemistry and biology were typical of the responses that were included in this category
2	Scientific skills	*Skills*	References to science skills and science and the empirical nature of science were included here. (One mark to every skill mentioned and multiple references to same skill)
3	Earth and environmental issues	*Earth*	The responses that referred to the earth, the weather, natural disasters and environmental awareness and care issues were included in this category.
4	Space	*Space*	References to space, the planets, astronauts were included in this category
5	Positive comments about science	*Posit.*	Positive comments about science
6	Negative comments about science	*Negat.*	Negative comments about science
7	Science as improving the world	*Improve*	General mentions of science improving the world we live in; the positive effects science has on society; references to diseases, cures and medicine; science and crime
8	History of science	*HoS*	Specific mentions of scientists and the development of their ideas and inventions; comparisons made between science today and many years ago; references to dinosaurs, Egyptians / Vikings
9	Human endeavour	*Human*	References to human issues around scientists' lives. Creativity of science, scientists making mistakes, scientists improving things
10	Tentative nature of science	*Tentat.*	References to the tentative and developmental nature of science
11	Technology and computers	*Tech.*	Science and technological inventions and advances. Science and computers

***Altered Categories and Numbers 30th November 2006* - Changed HoS about Dinosaurs to BOK**

	Test 1		Test 2		Control 1		Control 2		Test Total		Control Totals	
1	57	123	97	153	142	108	85	95	154	276	227	203
2	2	67	43	44	33	35	56	54	45	111	89	99
3	6	9	10	13	16	8	12	20	16	22	28	28
4	2	11	33	23	24	26	20	18	35	34	44	44
5	6	25	23	62	6	34	10	34	29	87	16	68
6	0	0	0	0	0	3	0	0	0	0	0	3
7	5	11	38	64	2	14	30	40	43	75	32	54
8	11	45	2	7	32	16	8	0+	13	52	40	16+
9	10	10	14	31	4	2	15	7	24	41	19	9
10	0	1	0	2	0	0	0	0	0	3	0	0
11	16	7	38	72	7	4	40	17	54	79	47	21
12	-	21	-	28	-	20	-	23	-	49	-	43
13	-	1	-	0	0	?	-	3	-	1		

New Categories and Numbers: 30th November 2006

Comparison of Total Percentage of Responses Made by the Test and Control Group in Their Initial and Exit Questionnaires

		Test (Initial)	Control (Initial)	Test (Exit)	Control (Exit)
1	**BoK**	40%	60%	58%	42%
2	**Skills**	34%	66%	56%	44%
3	**Earth & Environ.**	36%	63%	44%	56%
4	**Space**	44%	56%	44%	56%
5	**+comments**	64%	36%	56%	44%
6	**-comments**	0%	0%	0%	100%
7	**Improve world**	57%	43%	58%	42%
8	**HoS**	25%	75%	76%	24%
9	**Hum. end.**	56%	44%	82%	18%
10	**Tentative**	-	-	3 responses	
11	**Techn & comp**	53%	47%	79%	21%
12	**Like**	--	--	53%	47%
13	**Don't like**	--	--	75% (3 responses)	25%

Comparison of Initial and Exit Questionnaires (test and control separately)

		Test (Initial)		Test (Exit)		Control (Initial)		Control (Exit)	
		No.	%	No.	%	No.	%	No.	%
1	BoK	154	36%	276	64%	227	53%	203	47%
2	Skills	45	29%	111	71%	89	47%	99	53%
3	Earth & environ.	16	42%	22	58%	28	50%	28	50%
4	Space	35	51%	34	49%	44	45%	54	55%
5	+comments	29	25%	87	75%	16	22%	68	78%
6	-comments	0		0		0	0%	3	100%
7	Improve world	43	36%	75	64%	32	37%	54	63%
8	HoS	13	25%	53	75%	40	87%	6	13%
9	Human end.	24	37%	41	63%	19	68%	9	32%%
10	Tentative	0		3		0	0	0	0
11	Techn & comp	54	41%	79	59%	79	79%	21	21%
12	Like	-		49				43	
13	Don't like	-		1		-		-	

***Fourth Analysis of Open-Ended Questions*: January 2007**

Coding of Responses for Section A: Number of responses

Cat.	Test 1		Test 2		Control 1		Control 2		Test Total		Control Totals	
1	65	143	140	189	182	142	118	134	205	332	300	276
2	2	67	43	44	33	35	56	54	45	111	89	99
3	6	25	23	62	6	34	10	34	29	87	16	68
4	0	0	0	0	0	3	0	0	0	0	0	3
5	5	11	38	64	2	14	30	40	43	75	32	54
6	11	45	2	7	32	16	4	1	13	52	36	17
7	10	10	14	31	4	2	15	7	24	41	19	9
8	0	1	0	2	0	0	0	0	0	3	0	0
9	16	7	38	72	7	4	40	17	54	79	47	21

Coding of Response for Section A: Responses in percentages

	Category	Test (Initial)	Control (Initial)	Test (Exit)	Control (Exit)
1	**BOK**	41%	59%	55%	45%
2	**Skills**	34%	66%	56%	44%
3	**+comments**	64%	36%	56%	44%
4	**- comments**	0%	0%	0%	100%
5	**Improve world**	57%	43%	58%	42%
6	**HoS**	27%	73%	75%	25%
7	**Human end.**	56%	44%	82%	18%
8	**Tentative**	-	-	3 responses	
9	**Techn & comp**	53%	47%	79%	21%

Comparison of Initial and Exit Questionnaires (test and control separately)

		Test (Initial)		Test (Exit)		Control (initial)		Control (Exit)	
		No.	%	No.	%	No.	%	No.	%
1	**BoK**	205	38%	332	62%	300	52%	276	48%
2	**Skills**	45	29%	111	71%	89	47%	99	53%
3	**+comments**	29	25%	87	75%	16	22%	68	78%
4	**-comments**	0		0		0	0%	3	100%
5	**Improve world**	43	36%	75	64%	32	37%	54	63%
6	**HoS**	13	25%	53	75%	4	75%	1	25%
7	**Human end.**	24	37%	41	63%	19	68%	9	32%%
8	**Tentative**	0	0	3	100%	0	0	0	0
9	**Techn & comp**	54	41%	79	59%	79	79%	21	21%

***Fifth Analysis*: May 2007 - BoK split into 2 categories - BoK (body of knowledge) and EXPLAIN (Explains phenomena)**

	Test 1		Test 2		Control 1		Control 2		Test Total		Control Totals	
1	56	98	97	102	139	116	84	85	153	200	223	201
2	1	11	2	15	7	9	2	4	3	26	9	13
3	2	67	43	44	33	35	56	54	45	111	89	99
4	6	25	23	62	6	34	10	34	29	87	16	68
5	5	11	38	64	2	14	30	40	43	75	32	54
6	11	45	2	7	32	16	4	1	13	52	36	17
7	10	10	14	31	4	2	15	7	24	41	19	9
Tent	***0***	***1***	***0***	***2***	***0***	***0***	***0***	***0***	***0***	***3***	***0***	***0***
8	16	7	38	72	7	4	40	17	54	79	47	21

Comparison of initial and exit questionnaires (test and control separately)

	Test (Initial)		**Test (Exit)**		**Control (Initial)**		**Control (Exit)**	
	No.	%	No.	%	No.	%	No.	%
1 BoK	153	43%	200	57%	223	53%	201	47%
2 Explain	3	10%	26	90%	9	41%	13	59%
3 Skills	45	29%	111	71%	89	47%	99	53%
4 +comments	29	25%	87	75%	16	22%	68	78%
5 Improve world	43	36%	75	64%	32	37%	54	63%
6 HoS	13	25%	53	75%	4	75%	1	25%
7 Human	24	37%	41	63%	19	68%	9	32%%
8. Techn & comp	54	41%	79	59%	79	79%	21	21%
9. Tentative	*0*	*0*	*3*	*100%*	*0*	*0*	*0*	*0*

Results of SPSS Analysis of Section B of Children's Questionnaire: Cross Tabulations Questionnaires 1 & 2

Cross Tabulations for Questionnaire 1

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
group * ansqs	104	99.0%	1	1.0%	105	100.0%
group * true	103	98.1%	2	1.9%	105	100.0%
group * once science discover	103	98.1%	2	1.9%	105	100.0%
group * do experiments to exp	103	98.1%	2	1.9%	105	100.0%
group * use imag to explain	103	98.1%	2	1.9%	105	100.0%
group * use imag in experiments	104	99.0%	1	1.0%	105	100.0%
group * different scientists different answers to same invest	102	97.1%	3	2.9%	105	100.0%
group * scientists use imaginations when they invent things	102	97.1%	3	2.9%	105	100.0%
group * scientists work alone	102	97.1%	3	2.9%	105	100.0%
group * good thing if scientists disagree	102	97.1%	3	2.9%	105	100.0%
group * should not invent things that will harm	102	97.1%	3	2.9%	105	100.0%
group * society should tell scientists what to invent	102	97.1%	3	2.9%	105	100.0%
group * science is interesting	102	97.1%	3	2.9%	105	100.0%
group * be a scientist when I grow up	102	97.1%	3	2.9%	105	100.0%

Group * ans qs Crosstabulation

Count

		Ans qs			Total
		no	not sure	yes	
group	test	0	2	49	51
	control	2	5	46	53
Total		2	7	95	104

Group * true Crosstabulation

Count

		true			Total
		yes	not sure	no	
group	test	12	7	32	51
	control	2	11	39	52
Total		14	18	71	103

Group * once science discov Crosstabulation

Count

		once science discov			Total
		yes	not sure	no	
group	test	12	27	11	50
	control	19	11	23	53
Total		31	38	34	103

Group * do experiments to exp Crosstabulation

Count

		do experiments to exp			Total
		no	not sure	yes	
group	test	0	11	39	50
	control	2	7	44	53
Total		2	18	83	103

Group * use imag to explain Crosstabulation

Count

		use imag to explain			Total
		no	not sure	yes	
group	test	24	12	15	51
	control	20	9	23	52
Total		44	21	38	103

Group * use imag in experiments Crosstabulation

Count

		use imag in experiments			Total
		no	not sure	yes	
group	test	11	11	29	51
	control	15	10	28	53
Total		26	21	57	104

Group * different scientists different answers to same invest Crosstabulation

Count

		different scientists different answers to same invest			
		no	not sure	yes	Total
group	test	3	6	40	49
	control	8	5	40	53
Total		11	11	80	102

group * scientists use imaginations when they invent things Crosstabulation

Count

		scientists use imaginations when they invent things			
		no	not sure	yes	Total
group	test	6	7	36	49
	control	5	8	40	53
Total		11	15	76	102

Group * scientists work alone Crosstabulation

Count

		scientists work alone			
		yes	not sure	no	Total
group	test	3	6	40	49
	control	3	7	43	53
Total		6	13	83	102

Group * good thing if scientists disagree Crosstabulation

Count

		good thing if scientists disagree			
		no	not sure	yes	Total
group	test	24	11	14	49
	control	27	6	20	53
Total		51	17	34	102

Group * should not invent things that will harm Crosstabulation

Count

		should not invent things that will harm			
		no	not sure	yes	Total
group	test	11	5	33	49
	control	17	5	31	53
Total		28	10	64	102

Group * society should tell scientists what to invent Crosstabulation

Count

		society should tell scientists what to invent			Total
		no	yes	not sure	
group	test	19	16	14	49
	control	18	25	10	53
Total		37	41	24	102

Group * science is interesting Crosstabulation

Count

		science is interesting			Total
		no	not sure	yes	
group	test	0	1	48	49
	control	1	2	50	53
Total		1	3	98	102

Group * be a scientist when I grow up Crosstabulation

Count

		be a scientist when I grow up			Total
		no	not sure	yes	
group	test	20	21	8	49
	control	14	23	16	53
Total		34	44	24	102

Cross Tabulations for Questionnaire 2

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
group * answer questions about world	100	95.2%	5	4.8%	105	100.0%
group * when scientists give explanation always true	100	95.2%	5	4.8%	105	100.0%
group * once science fact discovered it doesn't change	100	95.2%	5	4.8%	105	100.0%
group * do experiments to explain things	100	95.2%	5	4.8%	105	100.0%
group * Use imaginations to explain things	99	94.3%	6	5.7%	105	100.0%
group * Use imaginations when doing experiments	100	95.2%	5	4.8%	105	100.0%
group * Different scientists can have different ans	99	94.3%	6	5.7%	105	100.0%
group * Use imaginations in their inventions	96	91.4%	9	8.6%	105	100.0%
group * Scientists work alone	92	87.6%	13	12.4%	105	100.0%
group * good thing if scientists disagree	96	91.4%	9	8.6%	105	100.0%
group * shouldn't invent things that will harm people	96	91.4%	9	8.6%	105	100.0%
group * society should always tell scientists what to investigate	95	90.5%	10	9.5%	105	100.0%
group * Science is interesting	96	91.4%	9	8.6%	105	100.0%
group * Would like to be a scientists	96	91.4%	9	8.6%	105	100.0%

Group * answer questions about world Crosstabulation

Count

		answer questions about world			Total
		no	not sure	yes	
group	test	1	2	46	49
	control	1	5	45	51
Total		2	7	91	100

Group * when scientists give explanation always true Crosstabulation

Count

		when scientists give explanation always true			Total
		yes	not sure	no	
group	test	0	2	47	49
	control	3	8	40	51
Total		3	10	87	100

Group * once science fact discovered it doesn't change Crosstabulation

Count

		once science fact discovered it doesn't change			Total
		yes	not sure	no	
group	test	14	9	26	49
	control	6	16	29	51
Total		20	25	55	100

Group * do experiments to explain things Crosstabulation

Count

		do experiments to explain things			Total
		no	not sure	yes	
group	test	1	6	42	49
	control	2	3	46	51
Total		3	9	88	100

Group * Use imaginations to explain things Crosstabulation

Count

		Use imaginations to explain things			Total
		no	not sure	yes	
group	test	7	10	32	49
	control	24	10	16	50
Total		31	20	48	99

Group * Use imaginations when doing experiments Crosstabulation

Count

		Use imaginations when doing experiments			
		no	not sure	yes	Total
group	test	2	9	38	49
	control	14	10	27	51
Total		16	19	65	100

Group * Different scientists can have different ans Crosstabulation

Count

		Different scientists can have different ans			
		no	not sure	yes	Total
group	test	0	0	49	49
	control	2	4	44	50
Total		2	4	93	99

Group * Use imaginations in their inventions Crosstabulation

Count

		Use imaginations in their inventions			
		no	not sure	yes	Total
group	test	3	2	43	48
	control	5	4	39	48
Total		8	6	82	96

Group * Scientists work alone Crosstabulation

Count

		Scientists work alone			
		yes	not sure	no	Total
group	test	3	3	40	46
	control	2	11	33	46
Total		5	14	73	92

Group * good thing if scientists disagree Crosstabulation

Count

		good thing if scientists disagree			
		no	not sure	yes	Total
group	test	10	18	20	48
	control	23	8	17	48
Total		33	26	37	96

Group * shouldn't invent things that will harm people Crosstabulation

Count

		shouldn't invent things that will harm people			
		no	not sure	yes	Total
group	test	13	9	26	48
	control	11	4	33	48
Total		24	13	59	96

Group * society should always tell scientists what to investigate Crosstabulation

Count

		society should always tell scientists what to investigate			
		no	yes	not sure	Total
group	test	20	8	19	47
	control	16	18	14	48
Total		36	26	33	95

Group * Science is interesting Crosstabulation

Count

		Science is interesting			
		no	not sure	yes	Total
group	test	1	0	47	48
	control	1	2	45	48
Total		2	2	92	96

Group * Would like to be a scientists Crosstabulation

Count

		Would like to be a scientists			
		no	not sure	yes	Total
group	test	13	22	13	48
	control	21	17	10	48
Total		34	39	23	96

Appendix G

Children's Group Interview Schedule (Initial and Exit)

Initial Interview Schedule (Children)

1 What do you think of when you hear the word science?
2 Do you like science? Why / why not?
3 What is a scientist?
4 What kind of things do you think scientists do?
5 After scientists have invented an idea or a theory do you think the idea ever changes?
6 Scientists know lots about different things like, what the inside of the sun looks like or about dinosaurs. But they have never been inside the sun or seen real dinosaurs. How certain do you think scientists are about these things?
- Do you think they use anything to help them?
7 Scientists do experiments and investigate things. Do you think they use their creativity and imagination during their work? When? How?
8 Do you think that people, or politicians have any control over the kind of things scientists research or experiment on?

Exit Interview Schedule

General Science

1 What do you think of when you hear the word science?
2 Do you think science is important? Why?
3 Do you think scientists have to use their creativity and imagination ever?
- When? Can you give me an example?
4 Do you think science knowledge can change? Yes/No
- Could you give me any reasons why you think this?
- Could you give me an example of how science knowledge has changed?
5 Is science helpful? How?
- Do you think science helps people / help the world around us? How?
- How does science help us in our every day lives?
- Do we find science in the newspapers / news / television? Do we see science in the world around us?
6 Do you think science can be harmful? How?
- Can science (inventions / discoveries) bring harm to people and the world we live in? How? Can you give me an example?
7 Should scientists be allowed to invent / research whatever they want?
- Do you think society / a community should have some say in what scientists might research or investigate? Why / why not?

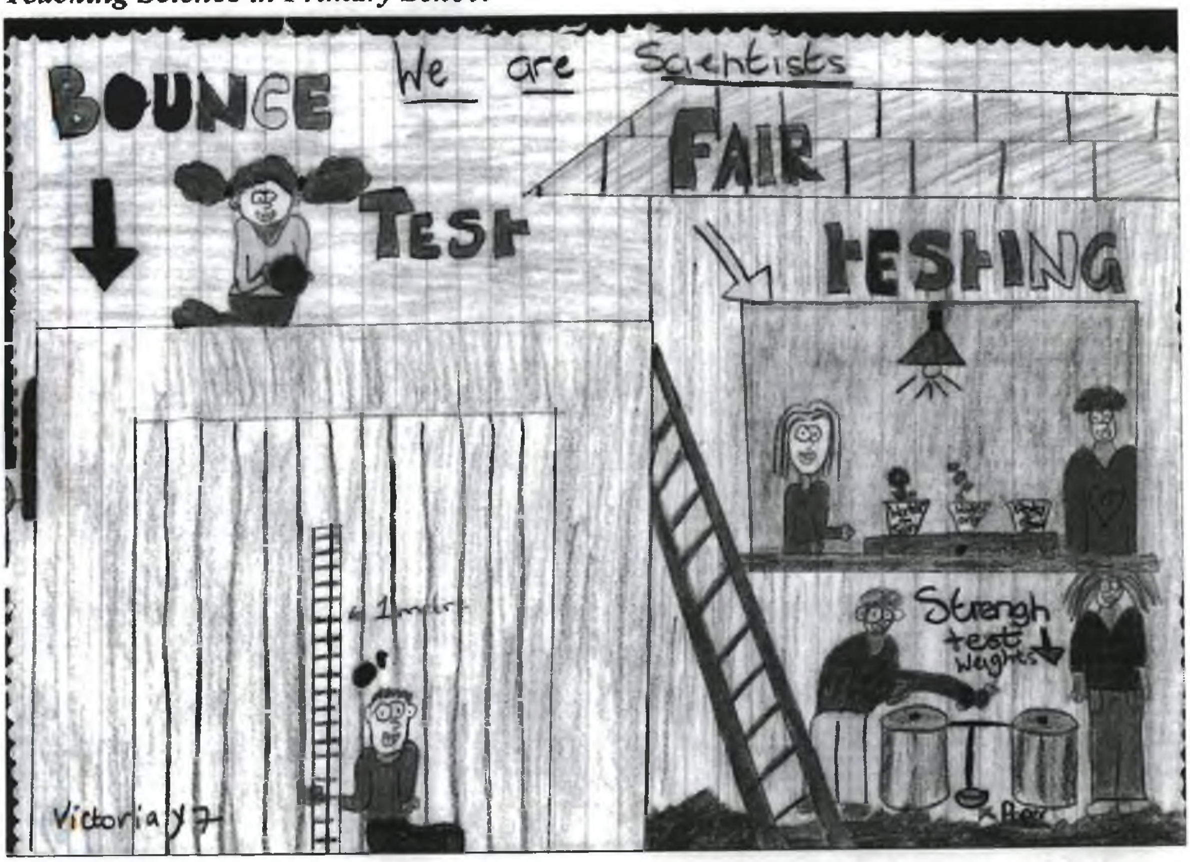
School science

8 What do you like best about science in school? Why?
9 Is there any part of science in school you have not liked? Why?
10 Is there any science you would like to learn more about? What?

Appendix H

Beginning Teachers' Reflective Journal Template

Teaching Science in Primary School



Teacher Journal, January 2006

Important Guidance Notes for Completing Your Journal

These notes have been prepared to guide you through the process of completing your journal. If you feel at any stage that you are unsure about what you are doing, please do not hesitate to contact me on 086 1661379 or 8842153 (work).

1. Thank you very much for completing the journal. It will be treated with **utmost confidence** by the researcher. The journal will provide me with invaluable material regarding your experiences of teaching science during your first year teaching. I am particularly interested in both the positive and the negative aspects of your experience, so please don't hold back!

2. The journal is a document, which has two main sections - the structured section (pages 2-13) and the unstructured section (pages 14-17). The idea is that you answer the questions posed in the first section and use the 'Diary/Notes' part to record thoughts / impressions /feelings / observations as they occur.

3. I am asking you to record your '*structured response*' at the **END of weeks beginning** 16th January, 30th January, 20th February, 6th of March and the 27th of March. The '*diary / notes*' section at the back is for records kept at other times and for overflow when you need more space - please remember always to record the date in this section.

4. Structured responses -please answer the questions as fully as you can and use the area in the diary / notes section if you need more space.

Your name:
Name and address of school:
Class:
Number of pupils in class:
Number of girls/boys:
Other relevant pupil details:

Reflection – END of week beginning 16th January

Which topic(s) did I work on?
Strand:
Strand Unit:
NoS aspect addressed:

1. **Which specific aspect(s) of scientific investigation were addressed?**
2. **How did the pupils respond? Please comment.**
3. What was your view of the lesson? (Strengths / weaknesses?) Please comment.
4. **What did the pupils experience/learn as a result of my work on this topic so far?**
5. **In what way(s) can I improve the way I work with the pupils?**
6. **Using the experience gained from this lesson, how would I approach my teaching of this topic/area in the future?**

Reflection – END of week beginning 30th January

Which topic(s) did I work on?
Strand:
Strand Unit:
NoS aspect(s) addressed:

1. **Which specific aspect(s) of scientific investigation were addressed?**
2. **How did the pupils respond? Please comment.**
3. **What was my view of this lesson** (Strengths / weaknesses?). **Please comment.**
4. **What did the pupils experience/learn as a result of the work on this topic?**
5. **In what way(s) can I improve the way I work with the pupils?**
6. **Using the experience gained, how would I approach my teaching of this topic/area in the future?**

Reflection – END of week beginning 20th February

Which topic(s) did I work on?
Strand:
Strand Unit:
NoS aspect(s) addressed:

1. **Which specific aspect(s) of scientific investigation were addressed?**
2. **How did the pupils respond? Please comment.**

3. **What was my view of this lesson (Strengths/weaknesses?). Please comment.**
4. **What did the pupils experience/learn as a result of the work on this topic?**
5. **In what way(s) can I improve the way I work with the pupils?**
6. **Using the experience gained, how would I approach my teaching of this topic/area in the future?**

Reflection - END of week beginning 6th March

Which topic(s) did I work on?
Strand:
Strand Unit:
NoS aspect(s) addressed:

1. **Which specific aspect(s) of scientific investigation were addressed?**
2. **How did the pupils respond? Please comment.**
3. **What was my view of this lesson** (Strengths / weaknesses?). **Please comment.**
4. **What did the pupils experience/learn as a result of the work on this topic?**
5. **In what way(s) can I improve the way I work with the pupils?**
6. **Using the experience gained, how would I approach my teaching of this topic/area in the future?**

Reflection - END of week beginning 27th March

Which topic(s) did we work on?
Strand:
Strand Unit:
NoS aspect(s) addressed:

1. **Which specific aspect(s) of scientific investigation were addressed in this lesson**

In Summary ...

2. **Which skills do I feel have been best developed over the course of the year to date? Please elaborate.**
3. **What do I think the pupils have experienced/learned in science over the course of the year to date?**
4. **Using the experience gained, how would I approach my teaching of science in the future?**

Beginning Teachers' Completed Reflective Journals

Q.1 **Which topics did I work on?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
Energy and Forces: Sound Working as scientists to develop their designing and making skills and make comparisons of their work to that of past scientists.	*Skills Development:* General introduction and look at the nature of Science. Involved a lot of discussion, observation, questions and analysing. Empirical – tentative nature of Science observation vs inference, body of reliable information, how we can observe/look at the same piece of evidence but yet come to different conclusions/inferences. Human endeavour – observations and inferences.	*Materials: Properties and Characteristics of Materials* 3	*Living Things: Human Life* Teeth
Environmental Awareness and Care: Science and the Environment Explore that scientific knowledge is tentative and often based on subjective interpretations.	*Energy and Forces: Electricity* - Science and Society. - Philosophy of Science: what if there was no electricity today? How would it affect our lives and the way we live?	*Materials: Properties and Characteristics of Materials* 2	*Living Things: Human Life* Healthy Eating, Food Pyramid, Looking at different menus from different children's daily eating habits.

Energy and Forces: Magnetism and Electricity Explore and appreciate the influence that scientific and technological development has on societies through comparisons of past and present technology.	*Forces: Electricity* * K'NEX - Design and make: K'NEX challenge. - Empirical: Bill Nye the Science Guy. - History of Science: Michael Faraday.	*Energy and Forces: Forces* 3	*Energy and Forces: Magnetic Forces* Magnets, different experiments.
Environmental Awareness and Care: Science and the Environment Working as scientists to develop their designing and making skills and make comparisons of their work to that of past scientists.	*Forces: Electricity* * Black Box activities - Human endeavour: design and make circuit. - Human endeavour/Empirical: annotated drawings of circuits. - Human endeavour: creative, designing and making a switch.	*Energy and Forces: Forces* 1	*Materials*

***Q*. 2: Which specific aspect(s) of scientific investigation were addressed?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
- Through questioning, the children discussed the possible first sounds made on the telephone. - Teacher then discusses Alexander Graham Bell with particular emphasis on this invention and how he worked. - The children designed their own phones.	- Observing and inferring. - Questioning. - Analysing.	- Identifying objects made from plastic, glass, metal, fabric and ceramic. - Exploring the properties of each material. - Distinguishing between raw and manufactured materials.	- The children looked at each other's teeth so as to work out how many teeth a child has and also the different types. – The children also examined their own teeth using their finger.

- Discussion on the role or impact of scientists in modern society in terms of technical advancements. - Briefly discussed Galileo's discoveries and how he might have worked: planning, making. - 'Tricky Tracks' image was then used and discussed. Comparisons drawn to work of scientists.	Linking Science and electricity to every day life. The positive role that electricity has played in our society and how we live: - Questioning - Predicting life without electricity - Hypothesising - Analysing	- Investigating how materials are used in construction. - Recognising that materials can be solid, liquid or gaseous.	- The children had to get one item each for our food pyramid. - The children had to recall and then record what their diet/'menu' was for 'yesterday'. We discussed their diets.
Explore and appreciate the influence that scientific and technological development has on societies through comparisons of past and present technology.	- Designing and making: planning, making, evaluating and presenting. - Questioning. - Recording and communicating information. CD presentation of K'NEX project.	- Exploring how objects may be moved. - Exploring how a moving object can be slowed down. - Discovering the effect of friction on a moving object.	The children had to guess the outcomes of the experiments and then carry them out.
- Presenting the poster of Mrs Cahill the teacher points out the desire of Mrs Cahill to keep the room warm. - Children design and make ways of keeping the room in question warm based on previous lessons on insulation. - Discussion on images of kitchens in the past and present in terms of similarities and differences.	- Predicting: will the bulb light? etc. - Analysing: sorting and classifying as conductors and insulators. - Design: planning, making. - Recording and communicating: record how they make their circuit. Use annotated drawings.	Exploring and investigating falling objects.	- Predicting and then recording what happened. - Explore and categorised the properties of different materials. - Observed and commented on the experiment.

Q. 3: How did the pupils respond?			
Test 1	**Test 2**	**Control 1**	**Control 2**
In general, the pupils responded well. They were enthusiastic about the content taught. Most of the children became rather inquisitive about the scientist and were enlightened I felt about how this scientist had a very normal background.	They responded very well. They enjoyed the fact that they quite often drew different but yet equally acceptable conclusions to the various investigations (Tricky Track activities).	Children worked well in groups identifying various materials. Some children found it difficult to identify metal and ceramic objects. They showed a good understanding of the properties of plastic, glass and paper using appropriate terms such as strong, hard, breakable, bendy, tear, smooth …	- Some found it hard to take it serious, as they had to look into each other's mouths. - They found it a fun activity, i.e. counting their own teeth and also trying to find out the position of each type of tooth, i.e. molars, premolars, incisors, canines.
I thought the students responded extremely well to Galileo. They were interested throughout. They enjoyed guessing what the 'Tricky Tracks' image was about. It felt as though many of them understood the concept behind this lesson before it began!	They found it interesting to discover how reliant we are on electricity today and were quite scared when they imagined life without television or the play station, or empathised with people in the past who never had a chance to observe Homer Simpson in action or who had to start fires every time they wanted to cook food.	Children were given a picture of a construction site and were able to locate the materials found and also why certain materials were used for a specific purpose. Children were asked to sort various solids, liquids and gases into groups. They came up with various group names such as food, drinks, wet objects and hard objects. When I discussed the groups further they came up with solids and liquids but they did not use the term gas.	The children found it very interesting and some boys – especially the 'sports enthusiasts' in the class – found it very exciting. They liked comparing their diets also to see who had the healthiest one.

The pupils responded well to this lesson. They were full of enthusiasm and excitement about electricity and the light bulb. A lot of the pupils were very inquisitive about why Edison was interested in electricity and light. The children seemed to be enlightened by the developments made by the light bulb through time.	The children loved the K'NEX challenge and the whole process of designing and making. I believe half the class wanted to be engineers after the two weeks we spent using the K'NEX. They also really enjoyed the Bill Nye video.	Children thoroughly enjoyed these lessons, as they were practically involved in predicting, observing, recording and evaluating. They were asked to design a fair test in groups to investigate what surface a car travels faster on (carpet, wood, sandpaper or plastic).	The pupils responded very positively but on occasion lost interest, as they already knew the outcome of some of the experiments.
The children responded extremely well to the cartoon strip based on Mrs Cahill. Immediately a lot of the pupils drew references to the work of scientists while designing their insulators.	The children loved making the circuits and the whole hands-on approach. There was some excellent discussion amongst the group on how best to design and make a conductor/insulator test.	I showed the children a number of objects – sheet of paper, scrunched paper, a sponge ball, plastic ball, tennis ball, medium-sized sponge ball and a straw. In groups they were asked to design a fair test to find out which object falls the fastest and slowest. They predicted before testing. Groups worked very well together, having one person as the dropper, one timer and one recorder. Children themselves decided they would use a height in the classroom or the height of a child to drop the objects from. They found the activity very enjoyable.	- The children responded brilliantly to the two experiments/investigations. - They were excellent at describing the properties of the different materials and almost all of the pupils wanted to give their opinions or 'theories' to explain what happened in the experiment.

Q. 4: What was my view of the lessons? (Strengths/Weaknesses?)			
Test 1	**Test 2**	**Control 1**	**Control 2**
I thought this lesson went extremely well. I was very well prepared with images and many Internet-supplied information sheets back on this scientist. I felt I had to empathise why AG Bell had such an interest in sound in detail as I thought that this concept was difficult.	The lessons involving the Tricky Tracks and the old woman/young woman, duck/rabbit and various other overheads went very well. The children really enjoyed the experience of questioning, discussing, observing, inferring and then observing and inferring again once new information became known to them. Strengths: not giving much away and letting the [text missing].	Children investigated raw and manufactured materials. They were given pieces of coal, turf, a stick, clay and sugar. The use of visual materials helped them to distinguish between raw and manufactured materials. They were then able to list what objects were made from these raw materials.	I felt the children reacted very well to the 'hands-on' approach of examining their teeth. - I didn't feel that there were many appropriate reinforcement activities after the lesson, other than drawing diagrams.
I felt that I had prepared this lesson well in terms of resources. Also, I thought the children enjoyed the images provided. A weakness would have been, in my opinion, the lack of emphasis I could/should have placed on the fact that scientists use prior knowledge/experiences in order to form a judgement.	Strengths: Using concept maps and brainstorming the class on their prior knowledge of electricity. It brought up some interesting misconceptions but also gave a good point from which to start.	- I should have told the children to sort the materials into three groups only. - Children were actively involved in each lesson both visually and physically.	The main strength was that the boys really had an interest in their diets. They loved the idea of making a menu of their diet and classifying their food onto the different levels of the pyramid.

I thought that this lesson went well as the story of Thomas Edison really brought the concept to life. It attached humanity and reality I felt to the content. The children really engaged with this inventor and enjoyed listening to his story.	Weakness: When I originally had the children designing and making using the K'NEX packs, I did not get them to draw or make a plan of what they intended to make. This might have helped them to get used to the actual criteria of the K'NEX challenge itself. Strengths: Using a digital camera to take pictures of the children designing and making, the different stages in the [missing text].	The children were very involved as we predicted as a class what surface would allow the car to travel faster on, then the groups made their investigations.	- The main weakness was that I didn't have enough of magnets, so each group had to take turns using them, which left some groups waiting. - The main strength of the lesson was making our own compass, as they seemed to have done the rest of the experiments in earlier classes.
I thought this lesson worked well with story, i.e. 'Mrs Cahill' and her dilemma. The children could really engage in the type of work that scientists do. They were planning, designing and making in groups and I felt they could really understand how scientists work and the purpose of their work in society.	I really enjoyed this set of lessons. The children get a real 'kick' out of making the bulb light in their circuits. It was very beneficial to get the children to record and draw their completed circuits using annotated drawings and this helped to reinforce what had occurred and aided their understanding of the concept of electricity and what [missing text]	The lesson was very effective as children were surprised with their results.	This lesson was going brilliantly up until the time for home. I had started the lesson too late in the afternoon and hadn't given enough time for the children to fully respond to the second investigation.

Q. 5: **What did the pupils experience/learn as a result of my work on this topic so far?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
The pupils learned that scientists have a particular motive for doing or discovering things. Also, that their work requires much planning and re-planning and that they do not always succeed in the beginning. The children also began to work as a scientist and designed their own phones.	That observing and inferring are two different things. It also helped to humanise Science more in a way. They liked the fact that they were involved questioning, analysing, observing and inferring just like scientists do in real life. They enjoyed the role of investigating – being part of a team that gathers the evidence, observes it, analyses it and makes predictions/inferences based on the evidence.	- They learned that every object can be classified/put into a group … metal, glass, etc … - We discussed the use of metal and why some materials are/are not made from metal – focusing on the saucepan – children were able to deduce why a saucepan is made from metal and why the handle of a saucepan is not made from metal.	- They learned about the different types of teeth. - They saw that different age groups have different types and amounts of teeth. - They learned the importance of keeping teeth clean.
I thought the children really understood the importance of the scientists in the environment in terms of their inventions. The children did experience the same type of situations that scientists have in terms of not really knowing what the 'Tricky Track' was about due to lack of evidence.	Empathy with people in the past, concept maps and brainstorming and how they can help us to clarify the information that we already know and to identify the information that we would like to learn about.	They learned that all objects might be classified into three groups. They were able to discuss the properties of each group. When I asked them to record what they had learnt about solids, liquids and gases, they showed a clear understanding of each group.	- The importance of a balanced diet. - Why a certain amount of each food type is required. - Understand the right amounts of each food group that should be taken each day, i.e. portions.

The children learned that Science has a place in society and how valuable inventors and inventors [?] are. Through images the children could see the significant impact that Science has on the environment. This was clearly expressed in many of the letters wrote to this inventor.	History: Michael Faraday – that scientists experience failures as well as successes, downs as well as ups, how society and religion has a major role in how and what he came to discover and the discussion, which followed. Pseudo Science: Bill Nye – its relevance to society both in the past and today. K'NEX: working as a team. Planning and designing what they hoped to build. The whole planning process and how it can help. It provides both a structure and a vision/goal.	- They learned that objects could be moved by pushing or pulling. - They experienced friction between different surface areas and the cars. - They learned that objects on a slope move faster than those on a flat surface.	- That opposite poles attract and like poles repel. - Strength of a magnet doesn't depend on size. - How a compass works and how to make one.
The pupils learned that scientists invent things that are of interest or value to them. They did explore this through designing and making purposeful items that 'Mrs Cahill' needed to keep warm. I thought the children gained an excellent understanding as to how scientists work. The children also began to appreciate the work of scientists in society.	What is needed to make a bulb light in a circuit? Designing and making various circuits – making a switch and a conductor/insulator test.	They learnt that the size of an object does not make it fall faster, i.e. they thought the larger ball would fall faster. They learned that the shape of an object will effect how fast it falls, i.e. the scrunched paper fell faster than the flat paper.	- They learned the different materials could have both similar and different characteristics. - That hot air rises and cold air doesn't. - That ice can be melted to water, water evaporates to steam; steam condenses to water and finally water freezes to ice.

Q. 6: **In what way(s) can I improve the way I work with the pupils?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
I thought that I could have allowed the children to explore this scientist on the Internet by themselves and discover items or details that they would have been interested in discovering. In saying this, this method of discovery was not feasible with one computer in the classroom. I thought that allowing the children to then also make a complete circuit unaided by the teacher allowed the children to experience working as a scientist.	It would be nice to record some of the discussion that went on using a tape recorder as well as just through written work so that the children could have another source with which to relay how their opinions and learning has changed. For example – this is what I originally inferred and this is who my learning has changed based on new information that has come to my attention.	Children could have been given more time to record their findings as some children did not get to complete the worksheet where they were asked to write why they think certain objects are made from plastic, glass or paper.	- I should have given them more time to count their teeth, as I gave them the answer before all of them had worked it out. - Instead of reading the text about the different types of teeth (i.e. canines, incisors, molars, premolars) I should have allowed them to describe how each felt and looked.
I could have allowed the children more time to invent their ideas on what the image was about. I should have allowed them to guess or discover how this problem applies to scientists and their findings, rather than explaining it to them. But I felt at the time I really had to guide them or direct them to think about the work of a scientist in having this problem.	Reduce the class size. Interact more with each group or pair as they discuss or talk about different aspects of the effect electricity has played on society. Also, I would divide class up into pairs and get them to do a concept map and then do one on the whiteboard using all our ideas.	There could have been more materials, as I had to group the children in groups of 6. Smaller groups would have been more effective.	n/a

I thought that the children could have explored the works of this scientist in more detail. I could have explained more how T Edison benefited from Ben Franklin's works.	Go through the different pieces in the K'NEX packs so that the children know what each piece is for and what it could be used for. It was also a delight to see that the most innovative design was the winner of the K'NEX challenge. Again it would be nice to record some of the discussion that took place amongst teams as they planned, designed and made.	Children could have had more surface areas to experiment with as some children found it too easy.	By making sure I have enough materials to keep each group busy (or else to make the groups bigger so that I'd need less magnets).
I thought that I could have allowed the children to do more 'hands-on' work when it came to drawing similarities and differences in both past and present kitchens, perhaps allowing the children to search for the images and maybe in groups designing an invention timeline throughout the ages, focusing on one invention.	Have clear roles for each child in each group from child in charge of materials to the reporter. Identify these roles from the start of the year to allow Science lessons to run smoothly. This proved very beneficial once it was in full swing.	Some groups worked much faster than others. In future I will give them a time limit as I found two groups took too long.	- By demonstrating the experiment(s) from a table in the centre of the room. This is because I felt the boys at the back found it difficult to see and get involved. - By making sure I give enough time to my lessons.

Q. 7: Using the experience gained from this lesson, how would I approach my teaching of this topic/area in the future?			
Test 1	**Test 2**	**Control 1**	**Control 2**
I really thought that the children benefited from exploring this scientist in this particular context, i.e. we were just after completing various experiments on sound. They could relate more to the scientist as a result. This has taught me to incorporate the scientist explored into the curriculum area being explored.	n/a	I would have a metal spoon and a wooden spoon and I would put them on the radiator showing the children the effect of heat on these materials. A plastic container and a glass ruler could also be used.	- Give children more time when investigating. - Allow children to investigate everything first, before reading the text.
I thought in general I taught this concept well. However, I will plan to ask more questions in my next lesson and get the children themselves to draw references or comparisons between the concept/idea taught and the work of a scientist.	I would like to have introduced concept maps at the start of the year and to have used them throughout every Science topic and every subject that I have taught.	n/a	I would have allowed the children to try and place the different food on the correct levels of the pyramid before actually studying the food pyramids in our textbooks.

In teaching electricity to the pupils, I found that discussing the inventor of the light bulb had an enormous effect on the content 'Electricity' for the pupils. The story of Thomas Edison really added a sense of humanity and brought I felt a great deal of reality to this area. I will definitely be exploring this scientist in my teaching of this topic in the future of 'Electricity'.	Probably allow the children more free play with the K'NEX prior to the challenge. Some of the children were not very well accustomed to the pieces and how they could be used in the construction process. Also demonstrate a structured approach involving the planning, drawing (notes included) to design and making a K'NEX project.	Children could explore the effect of rain, sleet or snow on a car's ability to slow down or stop.	By making sure I have enough materials to keep each group busy (or else to make the groups bigger so that I'd need less magnets).
I really thought that the design and making challenge made this curriculum area more exciting. The children really enjoyed the challenge and it really, in my opinion, brought the topic 'Insulators' to life. The children got to engage in it in an active manner and also explored the type of work carried out by scientists.	As much hands-on experience as possible. Allow the children to develop their own learning.	n/a	- Give more time to this lesson. - Get a wider variety of materials to describe and categorise.

In Summary **Q.1 Which topics did we work on?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
Materials: Materials and Change Scientific knowledge is tentative and often based on subjective interpretations.	*Forces: Electricity* Design and make: making lighthouses, microwaves and clowns.	*Living Things: Human Life* 2	n/a

In Summary ***Q.2:*** **Which specific aspect(s) of scientific investigation were addressed in this lesson?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
- In pairs the children were presented with a part of an image. Each child will then draw their image piece to a larger scale - The children guess the whole image by simply viewing one part of it. - Discussion on the importance of using one's hypothesis based on limited information.	- Design and make: exploring, planning, making and evaluating. - Investigating and experimenting.	- Developing an awareness of the importance of food for energy and growth. - Developing an awareness of the need for a balanced diet. - Designing and making a food diary for a day used the correct portions from the food pyramid.	n/a

In Summary
***Q. 3*: Which Science skills do I feel have been best developed over the course of the year to date?**

Test 1	Test 2	Control 1	Control 2
I really feel that I have achieved the following Science skills: - Designing and Making: The children have been designing, planning and making items. By drawing comparisons of their work to scientists, I believe the children have gained a huge insight into the work of scientists. - Predicting: The children developed a great sense of predicting through their efforts to complete the whole picture using a small sample. They have also used their imaginations in these lessons.	A wide range of Science skills have been effectively developed over the course of the year, from questioning, analysing to recording and communicating. If I was to pick one it would be analysing. I firmly believe that the children now have a more structured approach to how they analyse. Methodologies, which I have used through the incorporation of the NoS is my class have greatly aided the development of Science skill I believe. After the trick track activities the class tend to be a lot clearer – more precise – on what [missing text].	I feel that the skills of observing, predicting, investigating and experimenting, analysing: (sorting/classifying) and recording have been best developed during the year so far. Each lesson in Science involves most if not all of these skills. I generally begin Science lessons brainstorming the children's ideas to find out their previous knowledge on a topic. They frequently are asked to design fair tests and before each test is carried out I ask them to predict the results. They record their results after experimenting and one group member communicates the results. If there are discrepancies we test again.	- The children's activity to predict. - Investigation skills. - Questioning and also explanatory skills. - Recording skills.

In Summary ***Q. 4*: What do I think the pupils have experienced/learned in Science over the course of the year to date?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
Due to the discussions on the NoS dealing with the scientists lives etc., I feel the children no longer view technological advancements made in the past as merely 'just appearing'. Instead they now view them as being developed and re-developed throughout time. They now attach a sense of humanity to Science rather than observing facts as isolated items. I believe the children now feel they too can be scientists and play an active role in shaping the world.	They have learned that Science and scientists are not some mystical and mysterious concepts and people. The incorporation of NoS has helped to give a human side to Science, to make it more accessible and enjoyable to the children by linking it with every day life, showing the effects that society played on the lives of famous scientists, how these scientists lived lives that were very similar to ours. Also, that Science isn't just about making things blow up, although they do love that part.	I think they have learned how vast Science is – as one child once said 'Science is everywhere'. They have experienced fun and enjoyment in discovering working in groups during Science lessons. They have learned that magnets have a N and S pole and that a N pole is attracted to a S pole and that a N pole repels a N pole. They know what objects are/are not attracted to a magnet. They have learned about the changes that occur to a sycamore tree from season to season keeping a tree diary. They can identify various trees and their fruits. Children have explored the relationships between muscles and bones. Children have learned how to design fair tests and carry out experiences. *[Learning/Experience – See Q5 of Reflections Completed]	- That Science is a subject that can have a very 'hands-on' and 'fun' aspect to it. - That 'teamwork' is often very important in solving questions/problems/experiments. - The value of recording predictions, methods and outcomes.

In Summary ***Q. 5*: Using the experience gained, how would I approach my teaching of Science in the future?**			
Test 1	**Test 2**	**Control 1**	**Control 2**
In general I thought that teaching NoS as part of the Science curriculum was beneficial in many ways. In areas such as 'Electricity' and 'Sound' I thought the inventors explored have really brought the content in both areas to life. I would definitely incorporate this into my Science scheme. It brought out great enthusiasm among the children and I felt the children were rather enlightened by these investors. The designing and making of their own phones etc. is definitely something I would do in conjunction with the Science curriculum as it allowed the children to 'work as scientists'.	First of all I would incorporate NoS from the start of the year, from the very first brainstorming session that I do on the very first topic to the last presentation and dramatisation of a concept explained and put into real-life action.	- I would give children more opportunity to engage in the designing and making process. - I would also try to connect topics explored with other topics and across the curriculum. - I think allowing children to make drawings shows their understanding of a particular topic as well as using semantic maps. I will try to make greater use of these approaches as I have found them very effective in the past.	- Make sure that the children always try to estimate/guess what the outcome of an experiment will be before carrying it out. - The children should experiment in groups of two or three if possible, as bigger groups are less effective. - Make sure to leave enough time to complete the full experimentation and recording of results.

Q. 6: **Diary/Notes**			
Test 1	**Test 2**	**Control 1**	**Control 2**
2nd Feb: - I thought that the message or lesson 'Tricky Tracks' was well received by the pupils but I felt that I was teaching something that they already knew. They felt as though it completely made sense that scientists or people all have different opinions about things due to their outlook or past experiences! - I felt that in fact this was a rather difficult concept to teach. The children did understand that everyone looks at things/evidence differently but they found it difficult to understand why they do so. *20th Feb:* I decided to explore Ben Franklin in this topic also. I found this to be a tremendous help. The children really responded well to the point that Edison did work on ideas originally designed by Ben Franklin. The children have gained a great insight into the idea that technological advancement are being constantly made throughout the ages. *6th Mar:* When teaching this lesson, the children straight way shouted out 'Are we inventing something?' or 'Are we going to be scientists?' The children I feel have already a great sense as to what type of work a scientist does. *7th Mar:* The completion of the whole picture allows the children to work as scientists and discover that scientists use their imaginations.	n/a	*24th Oct:* Children found the term 'gas' very abstract. Some children could name oxygen, helium and carbon dioxide. They were aware that we breathe in O2 and breathe out CO2. One child knew that plants give out O2 and take in CO2 (I was very surprised).	n/a

Appendix I

Overview of Elective (2004-2005)

Areas	Overview	Aspects of NoS Addressed	Some Recommended Readings
1. Introduction	Finish the statement 'Science is' Card exchange activity	Finding out students' ideas about nature of science	• Cobern, W. & Loving C. (1998). The Card Exchange: Introducing the philosophy of science. In Mc Comas et al (1998) The Nature of Science in Science Education, Kluwer publications
2. Developing NoS Conceptions	Introduction to NoS NoS activities (Lederman and Abd-El Khalick (1998), • Tricky Tracks (p 85 - 91) • Doing Laundry (p 100-101) • Aging President (p103 - 108) • Young / old women (p102-103) • Black Box Activities (p108 - 126) • The Hole Picture (p 91-95) • Fossil Activity (p95 -100)	**Science as a Human Endeavour** - Subjective / objective - Creative - Past experiences / knowledge **Scientific Inquiry** - Scientific processes - Hypothesising - Examining evidence - Subjectivity / Objectivity - Fair testing - Reliability - Ethical - Communicating Findings - Community of workers **Science as a Body of Knowledge** - Reliable body of knowledge - Explaining phenomena - Tentative and developmental nature of scientific knowledge	• Harlen, W. (1993). *Teaching and Learning Primary Science*, Paul Chapman Publishing • Driver R. (1983). *The Pupil as Scientist?*, Open University Press • Mc Comas, W.F. (1998) *The Nature of Science in Science Education: Rationales and Strategies*, Kluwer Publications

3. Long-Range Experiment	Planning, preparing, conducting and presenting LRE (adapted from Meichtry, Y. (1998))	**Scientific Inquiry** Scientific processes Devising researchable question Selecting appropriate materials Accuracy in planning experiment (Replicability and reliability) Hypothesising	Measuring and estimating data Fair testing Examining evidence Recording findings Subjectivity / Objectivity Ethical issues Communicating Findings Human Endeavour Body of knowledge	• Meichtry Y. (1998) *Elementary Science Teaching Methods: Developing and measuring student views about the nature of science*; in Mc Comas et al (1998) The Nature of Science in Science Education, Kluwer publications.
4. History of Science	Case Studies (Galileo, Semmelweiss, Curie) Preparation and delivery of presentations	**History and Science** Landmarks and events in HoS How society influenced science Developmental		• AAAS (1989). *Project 2061: Science for all Americans*, AAAS publications. • Matthews, M.R. (1994) 'The Role of History and Philosophy of Science', Chapters 1,2 & 4.
5. Thinking about Science	Philosophy with children (Thinking Time) Religion and science	Thinking Time Topics Where does the tide go? Is umbrellaology a science? (Boersema, 1998, p 265) Evolution Vs Creationism		• Pollard A. & Tann S. (1987) *Reflective Teaching in the Primary School; A handbook for the classroom*, The Open University. • Boersema, D. (1998) *Nature of Science and Mass distinction;* in Mc Comas et al (1998), The Nature of Science in Science Education, Kluwer publications

6. Science and Society	Bill Nye Science Guy: Pseudo Science, Disney Educational Productions Professor Xargle (REF) Pseudo science Vs real science (Craven et al 2002) Science and Society (Current issues) Healthy Tipple (Murcia & Schibeci (1999)	Science in the newspapers Healthy Tipple Thinking Time: Science and technology Recycling Pollution	• Solomon J. & Aikenhead G. (eds) (1994). *STS Education: International perspectives on Reform,* Teachers college Press.
7. NoS in the Irish Primary Class	Science in the Irish Primary Classroom Constructivism NoS in the Primary Science Curriculum Explicit Versus Implicit instruction Devising explicit activities relating to NoS as part of Science Curriculum Critical Incidences Teaching NoS in the primary classroom	A constructivist approach to teaching science Document content analysis Explicit Vs implicit instruction Creating novel explicit activities relating to NoS from Irish Curriculum	• DES. (1999) *The Primary Science Curriculum.* • DES. (1999a) *Primary Science Curriculum Guidelines.* • Matthews, M.R. (1994) *'The Role of History and Philosophy of Science',* Chapters 5 & 7. • Driver, R., Leach, J., Millar, R. & Scott, P. (1996). *Young people's images of science*, Open University Press.

Sample of Lederman & Abd-El Khalick (1998) NoS Activities

Excerpts taken from Lederman N. & Abd-El Khalick F. (1998). Avoiding de-natured science: Activities that promote understanding of the nature of science. In, Mc Comas W.F. The Nature of Science in Science Education: Rationales and Strategies. pp 83-126, Kluwer Publications

Tricky Tracks

- Active Participation - crucial to derive the benefit from the activities
- Conveys to students that every idea counts irrespective of it being the 'correct' answer
- Students will gain experience in distinguishing between observation and inference and realizing that, based on the same set of evidence (observation, or data), several answers to the same question may be equally valid

1. Overhead 3: Written

Write down an account of what you think might have happened in this picture
- Class discussion

2. Overhead 1

What do you observe?
- List answers on blackboard

3.Can you see the birds?

- How can you tell that these tracks are left by birds?
- Bird tracks: The fact that we can't see the birds makes this statement an inference rather than an observation
- Can you give me an observation?

A possible observation would be: Two sets of black marks of different shapes and sizes left on a transparency!

Based on this observation and our familiarity with kinds of tracks some animals leave behind that we inferred that birds made these tracks, they could have been something else

2 species of dinosaurs / mother and child of same species. 2 different sized bird of same species. Even our claim that larger tracks are left by larger animal = inference

4. Why were the animals heading towards the same spot?

All of these are inferences and they're all equally plausible
Based with the same set of observations we can come up with several but equally plausible answers (inferences) to the same question – What has happened?

*5. **Overhead 2***

- What do you observe?
- Marks on overhead = observation
- Birds having fight = inference
- Many inferences are possible e.g. fighting animals, mating ritual, battling over a prey that one has captured

*6. **Overhead 3***

- What do you observe?
- Note the inferences and observations
- What do you infer?

7. Compare your written accounts and what you think of them after the class discussion

Can we ever know, based on evidence available, what has 'really' happened?

8. Input

- Difference between inference and observation
- Based on same set of evidence many equally warranted answers to the same question can be inferred
- Scientists make similar inferences as they attempt to derive answers to questions about natural phenomena
- Their answers might be consistent with evidence available to them, no single answer (story) may solely account for that evidence.
- Several answers are often plausible
- Similar to our tracks, scientists may never find the answer as to what has really happened. Inferences should be based on evidence. Scientific knowledge should be based on and consistent with empirical evidence

Black Box Activities

(Excerpts taken from (Lederman, 1998, pp108 -123)

Aims

- Provide students with challenges similar to those encountered by scientists
- Students examine phenomena and attempt to explain how they work
- They make observations, collect data, draw inferences, and suggest hypotheses to explain their data
- Based on these hypotheses, students make predictions and devise ways to test them
- Based on their test, they judge whether their hypotheses are appropriate or not
- Finally construct models to explain the phenomena investigated and test whether their models 'work'.

They will learn

- The distinction between observation and inference
- Human inference, imagination and creativity
- Eventually empirically based
- Tentative and subject to change
- Scientific models are not copies of reality – inferred constructs that help explain observable phenomena.

Cube Activity

What to do

- What is on the bottom of the cube? Explain your answer (Do not lift cube!)
- Make observations and record the data from your position (i.e. what word / number can you see facing you)
- Share your observations with your group
- Recorder records the data! (Scientists work together and share data)
- Based on observations figure out the pattern on the cube and infer what is on the bottom
- Often scientists can't see the phenomena they are testing!
- Present your answer to class – your reasoning behind your conclusions
- Different views should be presented

All groups same pattern – discuss role of evidence in deciding the pattern – answers were consistent with the available data

Different groups with different patterns – some groups may have inferred patterns inconsistent with data – importance evidence plays in supporting or weakening a certain conclusion – is it possible to tell who is right

The Tube Activity

The phenomena!

- Pull one end of the rope – another end will be pulled in with a seemingly random pattern.
- Pull on the rope ends clockwise at one time, then across the tube at another

Observing and inferring

- Students observe what is going on
- What is inside the tube?
- How does it work?
- What can you infer?

Hypothesising

- Based on your observations / inferences can suggest hypotheses to explain how the tube works?
- Are your hypotheses consistent with evidence and /or prior knowledge?

Testing hypotheses

- Tube and rope
- Give each group rope and tube and see if they can make up what's inside tube.

Designing and testing models

Discussion

- Scientists can't open an atom and 'see' inside it.
- Despite this scientists are about produce relatively reliable bodies of knowledge about the phenomena they investigate
- Observations and inference
- Hypothesisng (based on observations)

The search for patterns or regularities

- Based on these regularities, scientists can, for instance, extrapolate their data in order to predict possible future behaviours of phenomenon under investigation
- E.g. meteorologists collect data on several relevant phenomena (e.g. atmospheric pressure, temperature, humidity, wind direction, cloud formation etc and predict the behaviour of the 'weather' in the near future based on what they know)
- Only approximate and probabilistic – scientists cannot invariably predict the future (since science does not provide absolute knowledge) Only make suggestions as to what might happen. Patterns are partly based on evidence, but are also partly the product of the scientists imagination and creativity
- Science is partly a product of human inference and creativity, is empirically based (based on or derived from observation and experimentation) and tentative (subject to change)

Appendix J

Quantitative Analysis of HoS

Key

1	Humanises science	**4**	Cultural, societal influences on science, and appreciation of contributions to science
2a	Helps learning about science concepts	**5**	Promotes understanding of tentative NoS
2b	Helps learning about science skills	**6**	Interest in science
3	Help develop contemporary NoS conceptions	**7**	Creative NoS
		8	Developmental NoS

1 mark awarded when a category was referred to. When a student made more than one reference to a category only 1 mark was awarded.

	1	**2a**	**2b**	**3**	**4**	**5**	**6**	**7**	**8**
1	1	1	1	1	1	1	1	1	1
2	1	1	□□	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1
4	1	0	0	1	1	1	1	1	1
5	1	1	0	1	0	1	1	1	0
6	1	1	1	1	0	0	1	0	0
7	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	0	0	0	0
9	1	1	0	1	1	1	1	1	1
10	1	1	1	1	1	1	0	1	0
11	1	1	1	1	1	1	1	1	0
12	1	1	0	0	1	1	0	1	0
13	1	1	0	1	1	1	1	0	1
14	1	1	0	1	1	1	1	0	1
15	1	0	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	0
17	1	1	1	1	1	1	0	1	1
18	1	0	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	0
Total (N=19)	**19**	**16**	**13**	**18**	**17**	**17**	**15**	**15**	**11**
Percentage	**100%**	**84%**	**68%**	**95%**	**89%**	**89%**	**79%**	**79%**	**37%**

Quantitative Analysis of LRE

Key

3	Hypothesising = 19 (100%)	**10**	Technology = 8 (47%)
7	Working as scientists = 15 (79%)	**4**	Safety = 7 (37%)
12	Process Skills = 15 (79%)	**5**	Evidence = 7 (37 %)
6	Fair testing = 14 (74 %)	**11**	Society = 7 (37%)
2	Records = 14 (74%)	**8**	Reporting findings = 6 (32%)
13	Developmental = 13 (68%)	**9**	Testable = 6 (32%)

1 mark awarded when a category was referred to. When a student made more than one reference to a category only 1 mark was awarded.

Student	**3**	**7**	**12**	**6**	**2**	**13**	**10**	**4**	**5**	**11**	**8**	**9**
1	1	1	0	1	1	1	1	1	0	0	1	1
2	1	1	1	1	1	1	1	1	0	1	1	0
3	1	1	1	1	1	1	0	1	1	1	1	1
4	1	1	1	1	1	1	1	0	1	0	0	0
5	1	1	1	1	1	1	0	0	1	1	0	1
6	1	1	1	1	1	1	1	0	1	0	0	1
7	1	0	1	0	1	0	1	0	0	1	0	0
8	1	1	1	1	0	1	0	0	0	0	0	0
9	1	1	0	0	0	0	0	1	0	0	0	0
10	1	1	1	1	0	1	0	1	0	0	0	0
11	1	0	1	0	1	1	1	0	0	0	0	0
12	1	1	1	0	1	0	0	1	0	1	1	0
13	1	1	1	1	1	1	0	1	1	1	1	1
14	1	1	0	1	1	1	0	0	0	0	0	0
15	1	1	0	0	0	0	1	1	1	1	0	0
16	1	1	1	1	1	1	0	0	1	0	0	0
17	1	0	1	1	1	0	1	0	0	0	1	1
18	1	1	1	1	0	1	0	0	0	0	0	0
19	1	0	0	1	1	0	0	0	0	0	0	0
Totals (N = 19)	**19**	**15**	**15**	**14**	**14**	**13**	**8**	**7**	**7**	**7**	**6**	**6**

LRE Responses: Final Analysis (Quantitative) Science is a Human Endeavour

	Creative	Past Experience	Subjective / Inferences	Human End. General
1	0	1	0	Yes
2	1	1	0	Yes
3	1	1	1	Yes
4	1	0	0	Yes
5	1	1	0	Yes
6	1	1	1	Yes
7	1	1	1	Yes
8	1	1	1	Yes
9	0	0	0	No
1-	0	1	1	Yes
11	1	1	1	Yes
12	0	1	0	Yes
13	1	1	1	Yes
14	1	0	0	Yes
15	1	1	1	Yes
16	1	0	0	Yes
17	1	0	0	Yes
18	1	0	0	Yes
19	0	0	0	NO
Total (N=19)	**14**	**12**	**8**	**17**
Percentage	**74%**	**63%**	**42%**	**89%**

Quantitative Analysis of NOSQ

1 mark for each category even if they referred to it more than once.

	A	E	J	H	B	C	K	G	I	F	h	ex	r	th e	L	M
1	/	/	/	/	0	/	/	/	/	/	/	/	0	0	/	/
2	/	/	/	/	0	/	/	0	/	/	/	/	0	/	/	/
3	/	0	/	/	/	/	0	/	/	/	/	/	0	0	/	/
4	/	0	/	/	/	/	/	/	/	/	/	/	/	/	/	/
5	/	0	/	/	/	/	/	0	0	/	/	/	0	0	0	/
6	/	0	/	/	/	/	/	/	/	/	/	/	0	/	0	/
7	/	0	/	/	/	/	/	0	/	/	0	/	0	/	/	/
8	/	/	/	/	/	/	/	/	/	/	/	/	/	0	0	/
9	/	0	/	/	/	/	/	0	/	/	0	/	/	0	/	/
10	/	0	/	/	/	/	/	/	/	/	/	/	0	/	/	/
11	/	/	/	/	/	/	/	/	/	/	/	0	0	0	/	/
12	/	0	/	/	0	/	/	/	/	/	/	/	/	0	0	/
13	/	0	/	/	/	/	/	/	/	/	/	0	/	0	/	/
14	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
15	/	/	/	/	0	/	0	/	/	/	0	0	0	/	/	/
Total (n = 19)	**15**	**6**	**15**	**15**	**11**	**15**	**13**	**11**	**14**	**15**	**13**	**12**	**6**	**7**	**11**	**15**
%	**10 0**	**40**	**10 0**	**10 0**	**73**	**10 0**	**87**	**73**	**93**	**10 0**	**87**	**80**	**40**	**47**	**73**	**10 0**

Body of Knowledge

A Reliable body of knowledge
E Context is important
J Tentative
H Developmental

Empirical

B Evidence and patterns
C Observations / inferences
K Skills
G Technology

Human Endeavour

I Subjective
D Past experiences / knowledge
(Merged with I)

F Creativity & imagination
(h) Hypothesis
(ex) Experiments
(r) Reporting results
(th) Formulation of theories

Culture and Society

L Culture and society
M Science and society

History of Science (HoS) Reflections: Sample of pre-service teachers' responses regarding NoS

Learning About the History of Science…	
Human Endeavour	• *"Throughout the presentations it was evident how creativity and imagination are linked with science. Children in the classroom will discover that without imagination nothing new would come about. Imagination is the basis of creating something new"* • *If the conditions of the day were known then it would be so much easier to see how creative and imaginative and ingenious these scientists were and also how they were not always right in their discoveries"* • *Help give a clearer concept of the NoS and how for example scientists' ideas can be limited by the time in which they live, their ideas and theories can be rejected by the church and other authoritarian institutions, how their ideas and theories can be stumbled on accidentally and how their own personalities and beliefs can hugely influence their work.*
Scientific Inquiry	• *"By exploring the history of a concept we can understand that the concept itself evolved and was refined many times before the theory was proven"* • *"Children will learn about the mistakes made by scientists, how their theories were accepted or rejected etc. Science will become more realistic for children instead of learning facts"*
Science and Society	• *"Many scientists came up with very important and fundamental theories and discoveries which are vital to our lives today e.g. The discovery of penicillin. So I feel it is important for us to know more about the extraordinary people who have made such major contributions to our lives"* • *"Looks at the social and historical conditions that impacted, in a lot of cases quite severely, on the work of scientists, for expel Darwin and his theories going against the bible or Galileo and his understanding of the earth orbiting around the sun as going against the church also"* • *"Provides us with the opportunity of talking about how culture and society affect scientific investigations and how scientific discoveries in turn fit into society and relate to other fields of study"*

BoK	• *"Through the HoS students get exposed to the tentative NoS. They will see that knowledge has a certain dynamic quality and that it is quite likely to shift in meaning and status with the time.... Students will realise that because of the temporary status of scientific knowledge that is should not be accepted as unquestionable truth. Continuing research and questioning is part of the dynamic nature of science"* • *"...is fundamental in the development of contemporary NoS conceptions"* • *" ... is indispensable for the understanding of science"* • *"Gives children a better understanding of why they are studying science"* • *"From listening to the various presentations made in class and also from our research on the history of Charles Lyell, I found that I grasped a far greater understanding of the concepts and theories they dealt with, by following how they researched, hypothesised and inferred, continuously refining their ideas and theories."* • *"Help children to understand scientific concepts more clearly and as well as that it would encourage their individual thinking on scientific matters."*
Interesting	• *" It makes science more interesting"* • *" ...will ensure a fuller understanding of science and will cultivate a greater interest in the subject"* • *"... relates science to their own lives and this evokes interest"*

Long-Range Experiment (LRE) Individual Reflections: Sample of pre-service teachers' responses regarding NoS

Empirical Nature of Science	
Hypothesising	• *"We developed a hypothesis at the beginning of our investigation, predicting what we thought would happen to each plant"* • *"I learned that initial hypotheses can be and were both rejected and accepted. I learned that the importance of identifying a rejected hypothesis as the foundation for a further hypothesis or investigation. The LRE highlighted for me the importance to reiterate to future pupils the value of rejected hypothesis, every experience has a learning opportunity" "some of our hypotheses were accepted while others were rejected"* • *"I learned that the fact that some of our hypothesis were rejected does not make our LRE any less scientific…"*
Working as Scientists / Scientific Methods	• *"I learned that many obstacles can be encountered when conducting such an experiment"* • *"The importance of process was highlighted to me throughout our and other people's experiment"* • *"Throughout the experiment I recognised some of the challenges and problems, which would have been faced by scientists … we became aware that in reality scientists spend a lot longer on their investigations"* • *"…We got a vital insight into the way scientists work"* • *We got very disheartened at one stage and thought we may have to change our research question but all our hard work paid off and we finally got teeth of two local dentists. I guess scientists may often feel disheartened and feel like giving up just as we did."*
Record Keeping	• *"I learned that results must be taken accurately and recorded clearly"*
Fair Testing	• *"It is important to repeat experiments following strict procedures to try recreate the exact experiment and therefore the exact identical results"* • *"We decided we had to carry out a fair test to get proper results therefore we had to measure out the same amount of each liquid into the beakers"* • *It is important for the experiment to have a control…without a control you cannot be sure that changing the variable causes your observations…. Our experiment had far too many variables and as a result it was an enormous task trying to draw our conclusions…"*
Process Skills	• *"I learned that science is about inquiry…"* • *"… developing a hypothesis conducting a valid experiment, and collecting and interpreting data…"*
Developmental	• *"Our LRE has opened up a world of additional questions which in turn form the basis of further investigations…"* • *"… science helps answer questions and also creates new questions to further our curiosity…"* • *"Science is asking questions yet never fully know…"* • *"The inquiry process is a never-ending search for knowledge incorporating trial and error…"*
Technology	• *"We developed a short video to accompany our presentation. I learned the value of having multimedia within the science classroom. The use of video allowed us to effectively display the experiment and the results"* • *"I learned that a camera is a useful resource for recording data…"*

Safety	• *"I also learned how important it is when conducting an experiment to ensure it is safe and will remain so throughout the course of the experiment..."* • *"Safety issues must be considered carefully when planning LRE..."*
Evidence	• *"We tried to make sure there was enough evidence to back up our inferences"* • *Scientific knowledge should be supported by evidence (we used observation, record keeping and took photographs)*
Science and Society	• *"I wondered if our results are of any benefit to anyone and I thought for example, that in the catering world, chefs have to take the shell off eggs manually for salads and other foods and I was wondering would there be any way that you could make a suitable acid solution that would remove the shell easily and quickly without damaging the food"*
Reporting Findings	• *"Recording and communicating the results was really enjoyable. We met up every second evening to record the results. The teeth were horrible and it was shocking the changes we observed over the three weeks. We recorded the data using a pictorial graph, photographs and written data."*
Testable	• *"It is important to repeat experiments following strict procedures to try recreate the exact experiment and therefore the exact identical results. This needs to be done to ensure an experiment's validity"*

Science as a Human Endeavour	
Creative	• *"Creativity and imagination and open mind play a role in the nature of science... from the planning stage where many ideas were bandied about right through to the presentation, we were using our imaginations whilst making various decisions"* • *"I am glad we tried to incorporate some creativity into the experiment by using the olive oil, as I had no idea what type of an effect the oil would have on the plant."*
Past Experience & Prior Knowledge	• *"I certainly got a better insight into how my previous knowledge, experience and influences can influence an experiment e.g. when making a hypothesis, all of these things came into play"* • *"I realised that what I brought to the project by way of prior knowledge, experience and expectations is of huge significance particularly in formulating hypotheses..."*
Tentative	• *"Our LRE highlighted to us the tentative NoS. We feel subsequent experiments of this nature could possible produce different results..." Science does not (always) provide complete answers – our LRE has opened up a world of additional questions which in turn form the basis of further investigations*
Group	• *"I learned that working in pairs could be very beneficial. My partner and I were able to pool ideas together..."* • *"I also learned valuable team and friendship building skills (as a results of conducting the LRE)"* • *"Working as part of a group required discussion, compromise and integration of ideas"*
Subjective (Inferences)	• *"I learned that the nature of science is subjective as with the same evidence, we were both coming to separate conclusions on the data. I found this interesting that two people, who were faced with similar information, could come up with completely different conclusions!* • *"I also noted that with the case of this experiment, that background knowledge can effect the interpretations of the scientist.."*

Individual Learning	
Conceptual	• *"I was quite surprised to learn that the apple immersed in oil did not go black while the apple in the airtight container did..."* • *I have also learned the components of compost and how to maintain it at the correct pH, the factors that effect its' pH and why sometimes it isn't suitable for potted plants ..."*
Enjoyable	• *"This assignment was one that I really enjoyed"* • *"I found the whole experience both enjoyable and educational"* • *" ...we looked forward to seeing the changes that would occur in the following week"*
Hands-on	• *"It was pleasing actually completing my own experiment rather than just reading about one"* • *Overall I have learned that there is no better way to learn scientific method than actually doing, 'hands on learning'* • *"Doing experiments rather than just learning or hearing about them is more advantageous"*

Appendix K

Teaching Practice Reflections: Sample of pre-service teachers' responses regarding NoS and general teaching issues

Phase 2: Teaching Practice Reflections: Sample of pre-service teachers' responses regarding NoS	
Human Endeavour	• *AS I had such a young class I felt that Creativity and Working as a Scientist – hands-on, concrete approaches, were the best choice for my class as other aspects of NoS focussed more on the origins of a specific theory and dealt with more in-depth factors. Choosing the aspects I did meant the children got very involved in the lessons and picked up on the NoS without being explicitly aware of it.* • *As part of my scheme of work on this topic the children explored the creative side of science by designing and making a rainy day outfit for teddy.*
Scientific Inquiry	• *At numerous times during their work, the children were asked to work as scientists, required to following the same procedure a scientist would and practice the skills of a scientist e.g. observing, predicting, hypothesising, testing and drawing conclusions. The children used these skills to define the various materials, to test the effect water had on them, to create a waterproof outfit for teddy and to test if they had chosen the correct materials. Many of the children had never been required to or given the opportunity to use these skills before. I also think that their use of creativity and the ability to see how scientists need to be creative developed over the lessons. The children were asked to come up with an outfit, which would keep teddy dry using the materials provided and also to think of some way they could test if the outfit would keep teddy dry. I certainly feel that as the children noted themselves working as scientists their knowledge and understanding of the selected NoS aspects greatly improved and evolved.* • *When doing the next week's lesson on conductors and insulators with the children they had to guess, initially, whether the item they were about to test was a conductor or an insulator. I asked the children did they think scientists made guesses about things and a short impromptu discussion on this aspect of the nature of science ensued.* • *The various activities that related to observations and inferences were also embraced by the children. Once again they were eager to offer their inferences about the pictures. The majority of them showed similar reactions to hearing that all the stories were correct and a possibility. Presumably they, like us in college, are used to getting the 'right' answer at the end of an activity or question. Many were clearly frustrated when an 'answer' wasn't given.* • *As discussed in question 3 (assessment) there were a number of interesting responses from different boys, which would suggest to me that the children's conceptions of the NoS were being developed e.g. "Teacher every time you show me a different picture I change*

	my mind about what is happening". I feel that a response such as this from an eight-year-old boy was a very positive reinforcement for me as a teacher that I was in fact 'opening' the pupil's minds to the various elements of the NoS. During the 'whats in the box?' activity I also feel that to a point aspects of the NoS were developed in particular – scientific knowledge is tentative, as more evidence becomes available knowledge may change and thinking challenged. For the first part of this activity the boys were not allowed to lift the box, they could only use the 'evidence' that was available to them. (The object of the lesson was to investigate what was in the box). During the course of the lesson the boys firstly were able to eliminate certain objects e.g. objects that were too big to fit into the box. The boys were then able to handle, lift, shake, and listen to the box, in their way new evidence was available to them, they used their prior knowledge of 'objects' to make inferences as to what, what might be in the box, e.g. knowledge of t4eh weight of things, the sound of things when moved, shaken etc. I didn't allow the boys to open the box as I wanted to show them that scientists don't always find complete answers (NoS). • *I got the children to hypothesis what they think an electric circuit would look like. They found this quite unusual as they were used to teachers just showing them diagrams of various science equipment and explaining it to them. Some had problems with starting this diagram but with a little help from me they understood what to do. Some of the children came up with excellent and correct circuits straight away. I thought this was excellent, as the children had never experimented with electricity before. I then asked the children to be creative and to now design their circuit using the equipment I gave out to each group. The children worked extremely well in groups and I was proud of how cooperative they were with each other and helpful they were. I felt the children learnt a lot about creativity during science, as they were able to describe why the circuits worked as the electricity moved around in a circle.* • *The children learnt more about observation during their science lessons over the four weeks. They used observations to understand what they were meant to do.*
History of Science	• *When I began studying the life of Newton and his amazing discoveries I suddenly found that science and the life of scientist scan be rather fascinating and enthralling. I personally loved learning about Newton and making a presentation on him earlier in the year. Delving into the HoS allows childe n to empathise with the scientists and the times they lived in - what their discoveries meant to the people of the time, how had they lived/ managed before these discoveries how these discoveries effected change their lives.* • *I initially focussed on the history of science with the children. The lesson I taught on Volta and Edison was a high interest lesson for them. A full lesson was devoted to the topic as I felt I would not have been able to adequately cover the history of Science tenet of the NoS teaching it as part of ongoing instruction i.e. alongside electricity. If I had the class for a year that would be different but not when I only had them for 4 weeks... I made reference to Volta and Edison whom we had covered in the previous lesson. This helped the children make the connection between our science lesson*

	today and the history of science lesson from the last day. I think the children looked at the resources in a different way because of the previous lesson and with a greater awareness, interest and appreciation of what they were working with. • *With both junior and senior classes I would also use story to teach NoS. Children at all ages love story. Story is a good way to teach historical aspects of Science and how Science is tentative and has changed with all the technological developments. Telling a story also humanises the whole idea of Science. Telling stories about how Scientists might have failed in the start but kept going gives children incentive to keep trying even if things initially go wrong.*
Science and Society	• *From the point of view of the children developing their conceptions relating to the various tenets of Nature of Science, I believe as a result of their exposure to the various activities their views did change. Perhaps changed is not the correct word, instead maybe their views are now more in tune with what they already innately know and are aware of. From overhearing different conversations while they experimented I believe that the children are definitely more aware of the interconnectedness of Nature of Science. For example how technology, history and creativity and imagination are interwoven throughout. It simply cannot be avoided! I believe they are more appreciative of what science has given us in terms of inventions and gadgets albeit on a very superficial level. I am not saying that the next time one of them turns on a light they will pause for a minute and thank God for everyone who helped invent it however they might be more aware and appreciative of having it on some level.*

Phase 2: Teaching Practice Reflections: Sample of pre-service teachers' responses regarding general teaching issues	
Constructivist Approaches	• *At times it was difficult to transfer contemporary NoS conceptions to the class through instructional practice. I walked myself into trouble on one occasion simply by using language that was slightly too complicated such as 'inferring' but I addressed this, I overcame any problems with regard to instructional practice by engaging the children in 'thinking time' like settings, very much drawing on constructivist learning, engaging the children in discussions and debates over the four weeks.* • *I feel that when I approach planning my science scheme for the year, that would naturally be influenced right through by the NoS, whether this be from finding out the children's ideas through discussion,, brainstorming, concept-mapping to science investigating and experimenting, the way in which we observe thing and interpret and infer. NoS would very much make up and have an effect on the skills that we use in the science curriculum - that it is a methodology behind effectively and interestingly teaching children about science and how it affects our lives.* • *AS I had such a young class I felt that Creativity and Working as a Scientist – hands-on, concrete approaches, were the best choice for my class as other aspects of NoS focussed more on the origins of a specific theory and dealt with more in-depth factors. Choosing the aspects I did meant the children got very involved in the lessons and picked up on the NoS without being explicitly aware of it.*

	• *As part of my scheme of work on this topic the children explored the creative side of science by designing and making a rainy day outfit for teddy.*
Assessment	• *By comparing their Think and Draw worksheets to the completed outfits it is clear that many of the original misconceptions the children had at the beginning of the scheme of work were changed and evolved into a greater understanding of the concepts.*
Teaching Science	• *By integrating NoS and HoS with the science content being taught, teachers can give children a context, a prologue, an interesting background and a prior knowledge of sorts which is vital if children are to become enthused about the subject, and which also greatly aids their understanding of the concepts being taught.* • *The tenets I had focused on had well-defined activities that I had previously experienced myself in college. As a result of this I was more comfortable and enthusiastic in teaching them. I believe had I not experienced them first hand I would not have had the same level of confidence in teaching them to a class regardless how eager a class they were. I believe that depending on the selected tenets and the related activities this would influence the ease to which the transfer of contemporary NoS conceptions would pass to pupils through instructional practice.*
Benefits of NoS	• *I found that when I was both planning and teaching these lessons that the NoS aspects seemed to just fit into the lesson naturally and were most often things that I would have included in my lessons anyway. As a result, although I was addressing aspects of NoS in my lessons it didn't feel like I was having to add on extra bits, yet an extra dimension was realised.* • *If, as we have learned, NoS is about the history, sociology and philosophy and the actual process of understanding science, then it follows that truly understanding and experiencing science requires some understanding of these elements. Exploring scientific theory from a historical, sociological and philosophical angle can help in coming to a greater understanding of the origins and thinking behind a theory and the process involved in the development of this theory.* • *One of the most important factors for me, and indeed one of the most enjoyable for all concerned was the creativity and freedom afforded to the children. This allowed them greater scope to experiment make observations, test and re-test and finally draw conclusions. I would hope to attempt to include this element to some degree in all my lessons as I feel it was invaluable in terms of the development of the children's knowledge base and understanding of the process of science.* • *In general I found it quite easy teaching about the nature of science. It incorporated well into my science scheme and lessons. It formed part of what I was doing anyway. I would have to admit that when I was teaching about NoS I didn't relaise that I was teaching it. I was delighted that it integrated so well in my lessons.* • *Overall I found the class very receptive to the various Nature of Science activities. In general they were more than willing and very co-operative with regards to anything we did in Science. Owing to the fact that they had relatively little 'hands-on' experience I felt they embraced anything and everything with great levels of enthusiasm.*

	• *I felt eh activity of drawing their idea of what a scientist looked like was an interesting starting point for the science lessons. While I felt it immediately got their attention it was also an interesting way to ascertain their conceptions relating to science. Indeed strong stereotypical views were beginning to emerge. Interestingly not all of these strong views carried across into the discussion as stated earlier. I enjoyed this activity as the children clearly enjoyed it also.* • *The NoS should be included in a curriculum that makes science more interesting for the child, one that makes it real for the child, humanises it, given it a cultural context and therefore gives it a foundation. When included in a curriculum such as this I believe that the children's views of science will change form a negative of a positive one. Children will also learn that science is dynamic rather than static and that as new evidence becomes available science will change children to know. The NoS will teach the children how to deal with information, a deeper understanding of the NoS will help the child assess the reliability of claims, this is an important life tool for the children to have and it will equip them in many different areas of their lives.*
Children's Thinking Skills	• I *believe the NoS has the capacity to open up discussion in the classroom that hugely benefits and help foster the children's natural curiosity. By engaging the children in the discussions that we held about the tentative NoS, the creative aspect, the imaginative aspect, helped to devle into their natural curiosity, that inquisitive part of us that evokes critical thinking and analysis that makes us wonder and question everything around us. Instead of concepts and theories out there, now the class are open and confident to question things that are in front of them instead of just taking things for granted. NoS engages their creative side, it engages children in independent enquiry and creative action and helps children to think for themselves and construct their own learning. I believe that this is just one of the excellent qualities that NoS has to offer the primary school child and the primary teacher.* • *Above all else the NoS is essential for successful learning of the science content. Science for me has even been made more meaningful by doing this science course. It is nice sometimes to reflect and question for a while and not just to rush into the facts. In this sense I feel that the philosophising part is important.* • *Throughout T.P. the children were posed questions, which related to the topics we discussed and provoked much thinking. This related to 'habitat' and the work we conducted on suitable and non-suitable habitats. This involved a debate on suitable habitats for animals, and incorporated a sociological aspect in that the children expressed their ideas on whether or not they think zoos are suitable for animals to live. They also drew pictures as to what their idea of a scientist is and the work they do.* • *With the junior classes I would use Circle time to help the children philosophise. I could start the circle with a statement like, "Where does the moon come from?" Or "who made the world?" This activity is excellent for oral language along with getting the child to think and use their imagination. You are also not supplying the child with the correct answer and getting out of the whole 'banking' idea of Education. Religion and Science come into play here and*

	the child through discussion should realise that the two don't clash but complement each other.
Teacher Reflection	• On reflection I would have assigned more time, if not the majority of the *lesson, to discuss the role of scientists and the worthiness of their jobs. While I did not rush this part of the lesson I didn't afford it or the children the time they deserved. I felt the discussion was a high level and intense nature and could have continued on for longer had I permitted it. I found it easy to explore the Nature of Science with these children, as they were willing to discuss and had opinions. From my experience now I would have also recorded the children's discussion. The recordings would have afforded me the opportunity to review their conversations and ideas more thoroughly.* • *To reiterate I would have thought the timeframe was too short to see any significant changes, if indeed any, relating to the change of views of the class relating to the Nature of Science. As previously mentioned while it was quite a short timeframe I had underestimated where the starting point of the children would be. This starting point would be integral to the degree of potential change in view. I had taken for granted that the class would not have a clue about concept of Nature of Science and the various elements. As a consequence of this I thought that they would first have to establish their ideas about this and then they would be in a position to develop these ideas.*

Appendix L

Mapping the Change in Test Teachers' NoS Conceptions

Phase 1: 'Science is' Statements (Test Teacher 1)

Initial Statement:
Science is a body of knowledge, which is put into practise through experimentation and analysis. It provokes wonder and allows us to question the world in which we live
Exit Statement:
Science encompasses many things
1) *Is a body of knowledge that is constantly changing and never really objective (Tentative)*
2) *Is a 'living' subject that allows for differences of opinions and changes with context, age and circumstance (cultural and social)*

It incorporates all scientific skills such as observing, inferences and predicting, which illustrates that the body of knowledge in science was derived from a 'process' of carrying out those skills (it has an origin not abstract)

Phase 1: Nature of Science Questionnaire (Test Teacher 1)
NOSO 1
I think that they are never certain, they can never really be. They have based their "theories" on whatever information they have attained about the sun, but these theories are subject to change. Elements of subjectivity also come into play as scientists interpret data based on their previous knowledge, or experiences.
Scientists use evidence that is probably obtained by satellite or whatever records that have been kept on reactions inside the sun. They can not exactly go there so they try to "recreate" the same circumstances inside the sun on earth, but problems emerge here. Subjectivity and reliance on one test and influence of present culture come into play. The scientists own interpretation or data is used. It is subject to change, as another scientist may view data differently. Scientists have to constantly test and re-test their experiments and ensure they come up with reliable and consistent results. This never can actually be done, in relation to the sun.

NOSO 2
Scientists have tested and re-tested their ideas on this matter. Their data is probably inconsistent in relation to the above matter, however scientists view this data differently. They all have had different experiences etc and this leads to their own unique outlook. This is called subjectivity. Each one of us has a different lens in which we observe the world, hence no two people are going to see the data in the same light.

NOSO 3
When scientists develop a theory, their subjectivity not only comes into play, but also the reliability of their results. Theories, I believe are made so that they can attempt to explain what is happening, but they are tentative and subject to change. Other scientists improve the theory present, or prove the theory wrong altogether.

What might have been accepted then, might not be now. People in different societies, cultures all have a role to play. In a society that allows questioning, open and freely, theories will change also. But one theory can never be the final "answer" e.g. long ago, people believed that earth was flat, it was accepted but today, we have seen it is not the case.

NOSO 4

Scientists have to deal with issues that are not necessarily concrete, or present before their eyes. They often have to use their own imagination to determine what perhaps dinosaurs in the past might have sounded like. There is simply no way of finding our scientists have to use their own creative imagination and based on their own past experiences determine what and how dinosaurs sounded like. This leaves them open to criticism as often others can view things differently, as everyone's past experiences are different.

One has to be creative in order to change or come up with a possible theory in the first place.

NOSO 5

As science attempts to deal with issues that effect our everyday lives, the society in which these theories are made influences the way the experiment is carried out as well as the acceptance of the final result of the theory. In Galileo case, the Catholic Church literally rejected his claim that the earth revolved around the sun. It went against the prevailing view at the time. Thus, his theory was not accepted in society. Also Marie Curie theories were affected by the fact that she was woman and she was not seen as capable of solving such a complex problem.

NOSO 6

I believe that is has, as now I think that science encompasses more than just theories that are concrete and static in time. They can change and what is accepted now, might not be in the future. Also, the way in which scientists work, I took for granted that they do all the human actions of planning, hypothesising, predicting. They actually part take in human life and deal with issues that have affected them and society in general. They do not just deal with abstract notions. I feel that HoS really brought this aspect home to me. I did not believe before in the effect society and culture would have in the acceptance of theories or the ultimate reflection of them. NoS has made me realise that science is a "fluid" subject rather than static.

Phase 2: Teaching Practice Reflection: Excerpts from Reflection (Test Teacher 1)

At the beginning of first lesson NoS I must admit that I was quite unsure as to how the children were going to respond and if they would actually comprehend what I was trying to teach. However ....the implementation of my chosen aspects of NoS into the classroom proved to be an enjoyable experience. I felt that in general it facilitated the understanding of the abstract concept of sound and fostered the deeper understanding among the students about the how science works...Their initial idea of how science works was, I feel as the transcript depicts rather one of isolation. They themselves never felt that they could embark in creating and designing objects as the scientists do. However NoS provided the children with invaluable opportunities to take part in the active process of how science works. Since I dealt with how "science impacts society", I have come utterly convinced that this aspect along with the NoS needs to be implemented into the classroom.

As I decided to teach the principle that "scientific knowledge is durable but tentative", I thought that story would be a great aid in this context. By utilising the story of Alexander Graham Bell the children observed what phones were like in the past. Hence, through comparing and contrasting the images of past telephones to those of today, the children I feel could get a good understanding to this ever changing process of knowledge. Also by simply getting the children to discuss the importance of electricity and telephones, they are comprehending and appreciating the sufficient input science has to modern technology.

I found that teaching the principle that "scientists are creative" came rather innately to the children. It was in fact quite easy to get the children to comprehend the create side to science. I did this through presenting a dilemma to the children, whereby Mr. Cahill's room was always cold and she wishes to ratify the problem. This method worked extremely well as the children has to use their creative power to work like scientists. By utilising objects that the children could relate to such as the telephone and electricity, I believe that enabled me to teach the NoS with relative ease as it reflected on objects in their reality. I was struck at the ease at which the children could understand what the significance of the stories were in relation to NoS. They grasped straight away the processes the inventors had to go through in order to come up with an invention, which was reflected superbly in their drawings.

As I had Junior Infants I decided to teach the HoS aspects of the Nature of Science whereby the main emphasis would be on story. Through the stories of Alexander Graham Bell and Thomas Edison, the children engaged in a first hand account of how science actually works. I found these stories quite effective in teaching my chosen principles of NoS as they provoked the natural wonder and awe in the children about while engaging them in how science operates. For me I found that the stories captured a number of characteristics of NoS simultaneously, ranging from the tentative nature of science, impact of present cultures on scientific concepts and impact of science of technology being but a few. The children were brimming with questions about the two scientists. These stories capture the humane aspect of science, as opposed to subjecting the children to a body of static information as my class started to laugh at the thought that Alexander Graham Bell spilling a liquid on himself.

In these stories the children listen to the processes that is undertaken in science, as the children I felt understood that it took a lot of trial and error before the scientists actually succeed. ...The creativity exercises that I undertook were quite easy to teach as the children delighted to take on the role of being a scientist. Their designing and making skills were obviously enhanced by the activities. I would argue that perhaps the children would have a natural comprehension to this aspect of NoS as at this young age the children tend to be creative. Other than this I had no problems in teaching the principles I had chosen in the classroom through instructional teaching.

Do you think NoS is important? Why/Why not?
Yes. I believe that NoS on Teaching Practice fostered a better understanding of some of the more abstract concepts that I was dealing with such as sound. After telling the story of Alexander Graham Bell, I believe that the children were exposed to a wider variety of ways of thinking about how sound can be utilised. NoS opens up another dimension of the curriculum objectives, which leads me to interpret their meaning in different contexts. For example, "Observing" is now no longer simply looking, but it encompasses one's past experiences and is therefore always subjective. This type of two-dimensional thinking should be I feel transferred to pupils as it would remove the stigma that exists in science whereby knowledge is presented as "fixed" and "static". NoS I found provokes a huge amount of interest and awe towards the subject. The children were constantly asking questions about the two scientists I explored and were engrossed in the fact that Alexander Bell, the great inventor spilled a liquid on himself when he invented the telephone. This also reflects the importance of NoS, as it humanises the subject, making it more interesting and easier to understand and relate to. A major aspect of NoS I feel is that fact that it promotes

the idea of critical reflection and questioning. Children are encouraged to observe and model the questioning that past scientists undertook against the then prevailing "truths". I believe that children would benefit if they modelled this type of critical attitude, as it would prevent them from becoming passive participants in the wider society.

Based on your teaching practice experience how do you think you might approach teaching NoS as part of the science curriculum when you have your own class?
I firmly believe that NoS should be integrated into the Primary Science Curriculum during the teaching of the main strand units, as opposed to being an Add-on at the end. NoS helps the children to understand the scientific content and skills and develops a positive attitude towards science as it humanises the subject.

Based on my teaching practice experience I found the easiest way to explicit prior understanding and develop children's ideas was simply through Dialogue. Hence why I believe that Philomena Donnelly's "Thinking Time" would serve the Nature of Science very well. Thinking Time promotes the children's critical consciousness, which enables them to develop a more question-based mentality towards life. Through this approach, whereby the children engage in an active inquiry community, the pupils could discuss the implications of science on society and this would serve as an excellent assessment tool of their prior understanding what science is before one embarks on a NoS programme in the classroom.

Another excellent medium in which NoS could be taught is by using story. As "Story" can be integrated across the curriculum subject areas, it serves as an easy and practical method to use in order to teach about the HoS. I found in particular on Teaching Practise a number of the characteristics NoS being addressed through this method. I would implement this history of science while I would be teaching a specific strand unit and this would be done throughout the term on an annual basis.

On teaching practise I tended to dichotomise the NoS and the curriculum content. In my own classroom I would probably allow for more integration whereby I might start of with the curriculum content and then during the development of the same particular lesson, introduce HoS thus increasing both sets of objectives. I would especially allow this to occur during a particular Skill developing lesson such as observation whereby Subjectivity, Inference and Hypothesis could be developed using a variety of practical activities such as "Tricky Trails", "Mole Pictures" and "Double image pictures". On Teaching Practise I found that NoS made science more interesting and helped the children to comprehend the content taught better. Hence this is why now I would favour integration.

Phase 3: See Appendix F

Phase 1: 'Science is' Statements (Test Teacher 2)

Initial Stage:
Science is a continuous study and investigation of everything in the world, how they function and live.
Exit Stage:
Science is a dynamic and ever changing body of knowledge. It is never exact and never will it ever be as long s there's freedom of thought. Although we can sometimes observer the same events, we may still infer different meanings / explanations for what is happening. That is all to do with the tentative nature of science. Science incorporates everything in the world, indeed one might say it is a dynamic study of the nature of our world and beyond. It is influenced by many areas including culture, society, philosophy and ethics. Science and discovery within science involves a lot of creativity and always will, it is the creative side of us, our imagination that helps us discover, to invent, to explain and to embrace the world of science that is out there.

Phase 1: Nature of Science Questionnaire (Test Teacher 2)

NOSQ 1

I believe that scientists know that the sun is made up of various properties about it but they can never be certain to any significant degree of its structure, they will (never) be able to test their theories, they cannot take samples so most of what they know. Although scientifically based its only waiting to be disproved.

[Illegible text]

Pictures of the sun – observing it

Temperatures – changes in temp over time

Remaining particles emitted by the sun

NOSQ 2

All to do with the tentative nature of science. I think this will always be the case no matter how conclusive one side is. There will almost always be those who strive to disprove it or strike up an argument against it. This is no bad thing as it pushes scientists to go further, dig deeper, and develop more concrete and undeniable facts and evidence so that hopefully eventually, the doubters/disapprovers will eventually say/draw similar conclusions.

Wouldn't life be awfully boring if we all thought along the same paths, different people will always see things differently, it is not just to do with the tentative nature of science, it is fundamentally the nature of life.

NOSQ 3

I believe that most scientific theories are open to change/improvement revision. If more facts become known, new technology is developed; it opens up a wider format/process by which we can examine things. I can't think of any scientists off hand who changed or disproved their own theories, but if Newton had just taken Copernicus theories for granted, we would not have heard so much about the nature and make of the galaxy from him. Once upon a time they believed the world wasn't a sphere, factual examinations resulted in this not being the case.

NOSQ 4

I believe that all scientists use their creativity and imagination. I believe that they have to. It is hard to imagine Copernicus/Galileo and Newton ever conducing investigations and research about the stars without them having to use their imagination and creativity. They relied on their imagination to draw scenarios. I believe that it is truly great scientists creativity and imagination that gets them apart from others.

NOSQ 5.

Science is, without question, affected by society and culture. One need look no further than religious authorities have played in scientific studies. Science has disproven so many aspects of religion from evolution and the creation of the world, to the [*illegible text*] should being scientifically dated to disprove that it was genuine. Although society and culture will always play a role in scientific study, I believe that it is having a less significant impact today in stalling/intercepting scientific freedom today as it once did not so long ago.

NOSQ 6

I did not even know anything about the nature of science before doing this course, I did not even know that there was such a thing as the nature of science. So it has been something of an awakening about the whole thing. It has certainly helped to humanise science and to give it another and more interesting dimension.

Phase 2: Excerpts from Teaching Practice Reflection (Test Teacher 2)
I can honestly say that I loved teaching children about the nature of science during teaching practice. Not only was it fun but it also helped the children to become interested in my science scheme of work. Although I had the tentative nature of science and the history of science – Newton and Gravity – as distinct parts of my scheme, I would like to think that I implemented an NoS methodology right behind my science teaching and right throughout my science scheme. I believe that NoS is such a positive teaching and learning resource for science that has to be implemented in the science curriculum.

At times it was difficult to transfer contemporary NoS conceptions to the class through instructional practice. I walked myself into trouble on one occasion simply by using language that was slightly too complicated such as 'inferring' but I addressed this. I overcame any problems with regard to instructional practice by engaging the children in 'thinking time' like settings, very much drawing on constructivist learning, engaging the children in discussion and debate about the tentative nature of science. We had some great discussions and debates over the four weeks. See Discussion transcript for examples of this.

I did a lesson with the class about Isaac Newton and how he came about making his discovery of Gravity. This lesson was an additional lesson, which was not incorporated into my science scheme on electricity but one, which I wanted to do to tie in with my 'Nature of Science' project. I wanted to do a lesson about the history of science and how scientists come up with their discoveries. When I was younger, I must admit that I found science rather abstract and vague and, at times, not very interesting. When I began studying the life of Isaac Newton and his amazing discoveries, I suddenly found that science and the life of scientists can be rather fascinating and enthralling. I personally loved learning about Newton and making a presentation on him earlier in the year. Delving into the history of science allows children to empathise with the scientists and the time they lived in – what their discoveries meant to the people of the time, how had they lived/managed before these discoveries, how these discoveries effected/changed their lives. I really believe that learning about the history and nature of science gives science a human side, i.e. that it humanizes science.

I wanted to see if doing a lesson with the class about Newton, the falling apple and Gravity would have the same enthralling effect on the class as it did on me. The class really loved this lesson and without a doubt it was my favourite lesson over the course of teaching practice. I incorporated this lesson with the well-known nursery story about 'Henny Penny and Chickin Lickin' and how the world was coming to an end – the one where the acorn hits Chickin Lickin on the head and how she thinks that the sky is falling and starts going around telling everyone that the world is going to fall down on top of them, and that they have to tell the King. I explained to the class that the idea for this story came from the life of Isaac Newton and the falling apple incident and how he made his discovery about gravity. I began my lesson about Newton with the 'Chickin Lickin' story and asked the class what they thought had happened – why the acorn fell on poor Chickin Lickin's head. The class loved the lesson and learning about Newton and I really think that incorporating the history and nature of science into the science curriculum would be a brilliant idea and an amazing learning resource for children to have. It can only work to help children become more enthusiastic about the world of science, and if it only served that purpose, well then it would still be an amazing success.

I wanted the class to be able to observe and critically interpret the evidence that is put in front of them, and to understand that although we might all be looking at the exact same piece of data, that we can still all infer different meanings and explanations about what data represents, i.e. the tentative nature of Science. More than anything I wanted to create an interest in the children about what we were doing. I also wanted to introduce the class to the history of science through my lesson about Newton. I hoped that I could create an interest in the class about Newton and his life and I definitely believe that I have done this. The image of the apple falling from that tree and the concept of gravity is something that I think that they will never forget. By humanizing this science concept, not only was I able to make this concept enjoyable for them but I also gave them a memory and understanding about gravity that is very clear, positive and strong. By humanizing the concept ultimately helped to make what we were doing so much more enthralling and memorable. I know that the children developed their conceptions about observing/inferring (NoS) from engaging the children in a discussion about it at the end of my teaching practice. I recorded this discussion and have detailed it below as in part 3.

I mainly concentrated on the areas of history of science – Newton and Gravity – and the tentative nature of science – observing and inferring – and was very interested in finding out the children's ideas about looking at evidence/pictures/optical illusion of young lady/old hang/the Time Detectives Left Luggage Game, and how we all interpret/infer different meanings and explanations about what we see. We are all looking through our own unique pair of eyes and our brains, our creativity, our imagination affect the way in which we observe/infer different things.

...I guess that greatest pleasure came with the understanding that the class now know that although we maybe all observing the same evidence, the same picture, the same data – the way in which we interpret this information is entirely unique to each and every one of us – that although we may be observing the same picture, we may all infer different things about that picture. The children now understand this NoS concept and in a way it had some very funny outcomes, in that by the end of the four weeks the class were questioning everything I did. I could not put up a simple picture on the board in the last week without someone in the class inferring different things than me about it. I think that long is gone the day when this class will ever again accept a simple explanation for anything without being allowed to question it.

The Nature of Science has such a creative role to play in the teaching of science in the Irish primary classroom. I believe that the Nature of Science is important because I believe that it humanizes science, it gives it this interesting quality that is sometimes not there, it engages the children and instils a lot of debate, questioning and discussion in science... It helps children to think a lot more about what they are doing and allows them to empathise with characters throughout science and history. I believe that solely for the debate, discussion, engagement and development of the children's oral language skills, that it is extremely beneficial and can be counted as a super teaching and learning resource for both teachers and pupils respectively.

Scientific concepts can appear very abstract to children, almost as if they are being taught out of context. Children are often just landed with scientific concepts such as electricity, light, magnetism etc without as much as any pretext, without discussion or debate, as if these concepts came from nowhere. By integrating the NoS and HoS with the science content being taught, teachers can give children a context, a prologue, an interesting background and a prior knowledge of sorts which is vital if children are to become enthused about the subject, and which also greatly aids their understanding of the concepts being taught.

I believe that the Nature of Science has the capacity to open up discussion in the classroom that hugely benefits and helps foster the children's natural curiosity. By engaging the children in the discussion that we held about the tentative nature of science, the creative aspect, the imaginative aspect, helped to delve into their natural curiosity, that inquisitive part of us that evokes critical thinking and analysis that makes us wonder and question everything around us. Instead of concepts and theories out there, now the class are open and confident to question things that are in front of them instead of just taking things for granted. NoS engages their creative side, it engages children in independent enquiry and creative action and helps children to think for themselves and construct their own learning. I believe that this is just one of the excellent qualities that NoS has to offer the primary school children and the primary teacher.

I would incorporate the 'nature of science' right throughout the year. Now that I have completed this elective, I just feel that when I approach planning my science scheme for the year, that it would naturally be influenced right through by the nature of science, whether this be from finding out the children's ideas through discussion, brainstorming, concept-mapping to science investigation and experimenting, the way in which we observe things and interpret and infer. NoS would very much make up and have an effect on the skills that we use in the science curriculum – that it is a methodology behind effectively and interestingly teaching children about science how it affects our lives.

I think that 'Thinking Time' could be very beneficial in incorporating the nature of science throughout the year, as a way of getting children to openly discuss things such as Newton and gravity and Darwin and evolution, questioning whether our views about this will ever change, and discussing different opinions and views about concepts in science. (See previous answer)

I would definitely include the history of science and the lives of scientists right throughout any course of science that I teach. I firmly believe that learning about the different scientists should be part of every strand within the science curriculum from Faraday and Einstein to Newton. Each science strand should incorporate learning about scientists in that particular field, eve as an introduction to that field. I would integrate it with History, English and drama and learn about the fascinating lives of these great scientists through literature, projects, discussion and role-play.

Appendix M

Children's Ideas about School Science: Data Gathered from Questionnaires and Group Interviews

Data from Children's Group Interviews Regarding Specific References to their Experiences of School Science

Examples of Children Discussing or Referring to School Science *Throughout* the Exit Group Interviews	
Hands-on science in school (throughout interview)	
Test Group	**Control Group**
• *' ...get to experiment with all stuff.. Well one time we put a tissue in a glass and we... put it in a bucket and put water in it and we put it down and the tissue didn't get wet because the air was pushing it, the water out of the glass, instead of up it.'* • *'We had to make a switch for a circuit... and me and C. and V. did a brilliant job. C. had this metal... and there was a metal bar, kind of like a right angle, and we had this swirly thingy, we swirled it up and we cello-taped all the wire onto the top of it, so when we turned it up to the top, the metal piece touched it, which lit the entire surface... so we (had to use our imagination) to make the switch'* • *... we put them on books and then they went down onto a plate and the first one to hit the plate won...* • *' I like doing science in school because sometimes you get to go outside and do experiments outside and then sometimes you can do it inside, and one time we got a mirror, and we got a flash-lamp and we shone it*	• *'I think of all the experiments we've done in school...'* • *'I think science is a fun learning experiment and it's very educational... it does lots of fun experiments and it teaches you a lot of good stuff.'* • *'I think of fun and learning more stuff... like when you... do magnets'* ——— • *'I don't like (working in groups) when my best friend in school is not there... Like sometimes you're used to asking him questions... but when he's not there... you miss him'* • *' It's not fun working with friends that you really don't' know ...'*

against the mirror and we seen if it came back and like somebody stood behind the mirror and then it shone on them...' • *'...one day we were doing science and we had a race with butter, sauce and vinegar... to see which one was fastest.'* • *'... at the count of three we poured them all, we poured all the ingredients down and the first one to get to the end you're just seeing which one is a better liquid. (it was a fair test because we all got at the count of three, we all poured at exactly the same time)* • *'I like science in school because it's fun and it lets you investigate stuff'*	
Creativity in school science (throughout interview)	
Test Group	**Control Group**
• *We had to make up a kind of a green machine...we had to draw a diagram... we used our creativity and imagination...* • *We had to draw (a design) and we drew one but then...we didn't make it ...exactly the same...* • *Once we had to design our own telephone when we were learning about Alexander Graham Bell. We had to make our plans and our designs and then we had to write how it works.... It was really fun and all our ideas came out different, none were the same...* • *We had to use our imagination in the KNEX Challenge. You didn't actually know what pieces you had so you had to, come up with a design and you had to try and make your thing as close to your design as possible. An you had to have three sections for your, recycling material: plastics, glass and paper*	**No Comments**
Science and society in school science (throughout interviews)	
Test Group	**Control Group**
• *An engineer is a scientists... There are lots of different types of engineers. There's like computer engineers and there's lab engineers...*	**No Comments**

• *My mum used to be an engineer and she used to make submarines... shed drew out the plans... and they helped other people... (drawing designs is important) cause if we didn't really draw them out ... they (designs) might be stuck in our heads but we would make a lot of mistakes*	
Nature of Science (including HoS) in school science (throughout interview)	
Test Group	**Control Group**
Scientific Inquiry (observations & inferences & examining evidence) • *I have an example of figuring out things...teacher gave us a little tiny piece of a picture and you had to figure out what it ...(it was working like scientists because) scientists have to guess from the stuff (evidence) they have and we only had, they only have a small piece, and we only had a small piece and we had to guess what (the rest)* • *Well I learned that even though someone tells you that like this is real they could've just faked it.... Like in the video they had... I weigh one ton and he stood on the weight scales and he said one ton and then he went on an ordinary weighing scale s in a bathroom... in order to believe you need proof...so if you don't have proof it would be... well science needs proof so you can actually learn from it* • *What the pseudo science, just the HB ice cream ad, it says scientists can prove that HB ice cream makes you happy. (Why don't you believe this claim?) Because I'm always happy.* **Creative NoS** • *I think scientists (have to use creativity) because...when we were using that little piece of paper, we had to use our imaginations to think what it was but we had to create like what the other part of it was as well... I was thinking about Nature because it looked a lot like outside and trees or stones or something...*	**No Comments**

Science as Human Endeavour (Subjective)	
Science as Human Endeavour (Subjective) • *I think science is interesting because ... em not all scientists can be right... they often disagree... they should all agree but they can't always be right...(Why can't they always be right?)... well (take for example) the sound of dinosaurs (scientists) mightn't be sure because they weren't there at the time... they'd have to use evidence, like, bones...* **Science and Society** • *An engineer is a scientists... There are lots of different types of engineers. There's like computer engineers and there's lab engineers...* **History of Science** • *Michael Faraday... well he got taken out of school at 13 'cos he was very poor and he was a bookbinder and he read all the books that he binded. And his brother gave him money and he spent them all on lectures that Humphrey did... he took notes of his lectures ... and he sent them to Humphrey and Humphrey invited him for tea and gave him a job as an assistant ... he was trying to prove that you can make electricity from magnets, but people were trying to say no you can't...he proved them wrong...* • *I think of the way Louis Pasteur made the medicine and how it helped everyone and how people like Ben Franklin discovered electricity...* • *I think of Alexander Graham Bell how he like helped people by making the telephone...*	

Examples of Children's Responses in the Exit Interviews to the Questions: Do you like science in school? I like science in school because...	
Test Group's Responses	**Control Group's Responses**
• You get to do experiments and figure out things • *'I like doing science in school because it's fun and you learn a lot and all your questions are answered* • *I like it because it is fun. It's fun to figure out how to light a light-bulb. If we didn't' have science how can anything possibly be fun at all.* • *I like doing science because I like figuring out what makes light and what makes things levitate and also what is a 'hokse' and what isn't. I also like seeing what is a conductor and what is an insulator* • *I like doing science in school because its interesting and we're learning something that might be valuable in the future* • *I like science in school because it's fun and it lets you investigate stuff* • *Yes, because I can do science with my friends and my teachers. I like doing science because if I wanted to make something and I keep getting it wrong then I could keep trying until I get it right* • *You get to learn new stuff and you get to experiment with all stuff* • *I just think science is really fun and I really like it in school...you get to experiment on things and in other subjects you just kind of draw something.* • *I think science is interesting because like... it's fun when*	• *I like it because you're with your friends and you're not alone and you know your best friend is there...* • *I like doing it (science) with other people...because you could get stuck on one thing and you could ask them ...* • *I think science is a fun learning experiment and it's very educational... it does lots of fun experiments and it teaches you a lot of good stuff.* • *I like science because you learn stuff and do experiments* • *I do like science. I think the best things are, every time we do science in school we learn more and more about it ... and we didn't do it in this school... but making stuff* • *I think of fun and learning more stuff... like when you... do magnets* • *... you get to do experiments and you find out stuff that you didn't actually know before* • *You learn different activities and you learn how to turn on a bulb or a battery and stuff like that... We learn how air can blow up a balloon...* • *I like science because it's mostly different from other subjects. I like to try new things and I like to do more experiments. I like to work in groups with my friends so like we do experiments together and you're mostly not arguing* **Don't like science:** • *Yes and no... we don't do it that often so I just enjoy it when we're doing it and I don't' like it because we sort of do the same stuff* • *(I don't like) when teacher is explaining things that we all kind of already*

we have our different answers and then when we disagree like we always have big arguments

- *Yeah, its' fun because you get to learn like all the different stuff like the scientists an all and it's fund because when the whole class is arguing like about this is it and that's it that's wrong and all*
- *It's more fun 'cause you get to do it the experiments and you don't , can't do experiments in English or Irish*
- *I like science in school because when you're doing experiments it's 'funner' than writing them*

know...

I think it's like what X said. Teacher kind of doesn't get to the point as quick and like if you know it then you just get really really bored

Yes I do like science in school... well sort of .not really... I don't find it that fun...

A bit... but we could be given different experiments maybe...we don't do so much experiments

... (the science we do in school) *it's not the stuff I like... it's boring stuff like magnets...* (would prefer to) *making fake rockets and other things...*

I don't like it when you don't get it and then like you still don't get it and you can't figure out what you think, you're looking through your book and then once you find it then you're ell all right, I got it now, I can get on with the experiment

Well I think maybe, I think the school is not giving us much time to have science...

Example of Children's Responses in the Exit Questionnaires to the Question: Do you like science in school? *(This question was not asked in the initial questionnaires)*	
Science in school is fun/ interesting/ exciting…	
Test Group Exit Questionnaire	**Control Group Exit Questionnaire**
Yes • *It's really fun and we get to make stuff like circuits and other things* • *It's fun, it makes you intelligent and you ask questions* • *I think science is interesting and fun* • *If we didn't have science how can anything possibly be fun at all* • *It makes you think about stuff* • *I love doing science in school because I am a very curious person. Science fascinates me.* • *I love doing science in school its so cool and so interesting. I couldn't thing of anything else I'd rather do (I'm not just writing this to sound good!)* • *The teachers always brings in stuff and it's fun and it's one of my favourite subjects in school* • *…it's very exciting and interesting*	**Yes** • *I like doing science in school because it's fun …* • *I like science because it's fun and exciting* • *I like science because it is fun and interesting. I also like doing science because we don't do it much so I enjoy it more* • *It is a lot better and funner than maths and Irish* **No** • *I do and sometimes I don't* • *I don't like it so much because we don't get to do all the experiments* • *Sometimes it will be not fun to do.* • *No I don't like doing science in school*
You learn a lot in science	
Test Group Exit Questionnaire	**Control Group Exit Questionnaire**
• *I like doing science in school because it's fun and you learn a lot and all your questions are answered* • *You get to know stuff …* • *You get to know things that you don't know* • *Yes… because it helps us when we grow up* • *Because we find out new things* • *Yes because it's fun, it makes you intelligent, smart, happy and*	• *I like to do science in school because I get to find out more about stuff and lean stuff I never knew…* • *I love science in school because we learn a lot with just a little lesson* • *Yes because I love to find out stuff like why play dough floats* • *I like doing science in school because you can find out stuff about magnets and stuff like that* • *I like science in school because it is intelligent to know about it*

find out things and you ask questions • *I like science because ... you find out things around us* • *I like science... because you learn things and all your questions are answered* • *(In Science) you are learning something that might be valuable in the future* • *Because every time I do something in science in school I learn something* • *Because you learn a lot an you might want to become a scientist yourself* • *... you get to find out important things*	• *... we learn fun stuff*
I like experiments	
Test Group Exit	**Control Group Exit**
• *You get to do experiments and figure out things* • *Yes ... because we get to make things like circuits* • *I like science because you discover things and do experiments* • *You can experiment stuff ...* • *I love doing science in school because we get to do stuff that we have never even tried to do before like make a full circuit to make the bulb light with only a wire, crocodile clips a battery and a light bulb*	• *I like to do science because you do experiments and make things happen* • *I like things like dissecting* • *I like science because it's fun to do experiments and make things happen* • *... every time we do an experiment it is quite fun* • *I like doing magnets* • *I like (science) it because we do experiments* • *I like doing science in school because the experiments are fun...* • *I like it in school because we do good things and experiments and other cool stuff*
I like DOING investigations	
Test Group Exit	**Control Group Exit**
• *I like science in school because it's fun and it lets you investigate stuff* • *I like doing science because I like figuring out what makes light and what makes things levitate and also what is a hokse and what isn't. I also like seeing what is a conductor and what is an insulator.*	**No Comments**

• *... we find out how to do things* • *We get to figure out how to light a light bulb* • *I like doing science in school because you can invent things… I like to do science because if you invent something new you might be able to use it again* • *You never what is going to happen when you pout things together* • *My favourite kind of science is electricity...I like finding out how things work*	
References to History of Science in school science	
Test Group	**Control Group**
• *and we learn about who invented electricity and the light bulb…* • *... you get to learn about people all over the world*	**No Comments**
Nature of Science in school science	
Test Group	**Control Group**
• *I like guessing about what the things are* **(when referring to tricky tracks activity… inferences & observations)** • *I like finding out about nature and guessing and then experimenting to find out if it would be my guess* **(testing hypotheses)**	**No Comments**

Appendix N

Children's Ideas about the Nature of Science

Description of Categories of NoS that Emerged from Analysis of Open-ended Questions in the Children's QUESTIONNAIRES and GROUP INTERVIEWS	
Category and Abbreviation	**Rules for Inclusion**
Body of Knowledge **(BoK)**	• ***Facts:*** *Responses that related to science as; a body of knowledge that informs us and provides us with information about the world; specific references to physics, chemistry and biology were typical of the responses that were included in this category.* • ***Explain:*** *Seeking to find explanations, a means of providing answers to questions we may have about the world; informing us how and why things work;* • ***Tentative body of knowledge:*** *Responses referring to how scientific knowledge has changed and/or developed*
Human Endeavour **(Human)**	• *References to human issues around scientists' lives. Creativity of science, scientists making mistakes, scientists improving things*
Scientific Inquiry **(Inquiry)**	• *References to science skills and science and the empirical nature of science were included here. (One mark to every skill mentioned and multiple references to same skill)*
History of Science **(HoS)**	• *Specific mentions of scientists and the development of their ideas and inventions; comparisons made between science today and many years ago; references to Egyptians / Vikings*
Science and Society: Improve World **(Improve)**	• *General mentions of science improving the world we live in; the positive effects science has on society; references to diseases, cures and medicine; science and crime*
Science and Society: Technology and Computers **(Tech)**	• *Science and technological inventions and advances. Science and computers*
Questionnaires: Sample of Children's Written Responses Regarding NoS in the Open-ended Questions in the Initial and Exit Questionnaires	

Category	Test Group Initial Questionnaire	Control Group Initial Questionnaire	Test Group Exit Questionnaire	Control Group Exit Questionnaire
Body of Knowledge (BoK)	• *About the world and the ground and all around you mini-beasts and lots of bugs* • *Chemicals and things like that* • *Scientists discover a lot about the world* • *Science is about trees, mini-beasts and soil* • *I think science is nature, electronics and chemicals* *Why is science important?* • *Because how would we know what things are inside us and what things go boom*	• *When I think of science I thing of floating and sinking…* • *If there was no scientists we wouldn't know that dodos ever existed* • *Gives us information* • *Tells us what to eat and what to do and how we exercise* • *If we thought science wasn't important we wouldn't know anything about space or dinosaurs* • *If there was no science we wouldn't know a lot of important stuff*	• *Is about trees, mini-beasts and soil* • *I think science I important because then nobody would know what the hell gravity is...* • *Science is a lot of things. Science is light, science is magnets, science is power.* • *Science is finding explanations for like how everything is made and doing experiments and answering questions that people would like to know'* • *Science is important because you wouldn't know a lot of stuff If it wasn't for science* • *Science is important because it helps you learn new things and without science, we would still be in the olden days*	• *Chemicals and things like that* • *Science is about discovering stuff and getting explanations to things we don't know* • *Science is something where scientists answer important questions about the world* • *If we didn't have science we wouldn't know about global warming*
Human Endeavour (Human)	• *Science is smart people doing research …*	**No Comments**	• *Scientists discover things and sometimes they make guesses. They are not*	• *Science is about geniuses work...* • *Science is a bunch of people… (who do mad experiments)*

	• *Science is important because people (scientists) use their minds*		*always right but they do their best* • *... scientists all have different answers*	• *Scientists often get close to their work. They sometimes risk their lives, but do it for mankind*
Scientific Inquiry (Inquiry)	• *Science is making stuff like chemicals and sweets* • *It is when people (scientists) investigate* • *'They discover things* • *They mix things and invent new things* • *Investigate in space* • *They make loads of chemicals and inventions* • *Find out ways to do things* • *I think science is about testing things and making things explode*	• *Finding out the answer to a question* • *What happens if you mix different chemicals* • *It is where you do experiments and test things that you think don't' work but do...'* • *Do experiments to find things out* • *I think science is experiments* • *(Scientists) look into microscopes and looking at the stars...* • *They try to find out things about the world and go back at things and test to see if they were right. They go on the computer.*	• *... (science) it can be tested as may times as you want ...* • *Scientists discover things and sometimes they make guesses. They are not always right but the do their best* • *They look at evidence of anything, like dinosaurs and guess and work on their guess and discover more and more.* • *I think scientists gather evidence and try to guess by what evidence they have* • *Scientists find out things and tell us. Sometimes scientists are not right because they guess from the evidence they get* • *Science is where people investigate or create things that have not been discovered before and*	• *Science is an experiment where you are making something* • *Science is putting chemicals together to make new anecdotes for medicines* • *Scientists might investigations on how do boats float and how planes fly and stuff like that* • *Do experiments to find it out stuff* • *Scientists figure out things like what chemicals to put into acid to make it explode or test human bones to see what time they lived but they mostly do experiments* • *Scientists prove things are possible or not possible* • *Mix things together to cure sickness*

			they their best to do things that children might or might not understand	
History of Science (HoS)	• *They examine old things and handle them with care* • *From a long time ago they (scientists) found them and looked at them* • *Without science we would not know anything about a long time ago'* • *They might find stuff out about the past*	• *History to find out what they did and how they did it*	• *Scientists make electricity like Michael Faraday but people long ago did not care about scientists.* • *'Science is like things where people discover things or invent things like Michael Faraday inventing the lens of glasses or Newton discovering gravity'* • *When Galileo discovered the world was round and when nobody believed him…* • *Scientists discover things from the past. Then they examine them and put them in a museum* • *…because if Louis Pasteur did not make penicillin some people would die*	• *Science is important, because without science we probably wouldn't know about the past* • *They might find stuff out about the past*
Science and Society: Improve World (Improve)	• *They invent things and warn you about different diseases* • *Scientists invent stuff and make the world a*	• *It helps make the world a better place* • *Scientists find out smoking is bad for you and that germs makes*	• *I think science is good for the world and the environment. Some people think science is not good*	• *Science is people making cures for stuff* • *Science is important because it figures out how someone died or cures for diseases* • *Help investigators to solve murders, crimes and break-ins*

	better place other things	*you sick* • *Because science finds out a lot of stuff that is good and bad for you* • *If you have something wrong with you they (scientists) will try and cure it*	• *Science helps the world like about the weather and it helps us about the temperature. Science normally helps us every day.*	
Science and Society: Technology and Computers (Tech)	• *They (scientists) make electricity so people can watch TV. and cook food and makes lights* • *Science is technology and lots of other things* • *Bringing people to space*	• *They (scientists) make machines to go into space* • *Scientists invent things like machines* • *I think scientists make space ships that do not need a pilot to go to the moon* • *Science is important for machines and cars* • *If there was no science there would be no cars or bikes*	• *Without science we wouldn't have cars, electricity, clocks* • *I think they create things and invent things like hovercrafts, TVs, rockets and lots of different gadgets* • *Science is where they invent stuff like televisions, electricity, telephones, light and even video-cameras*	• *If there wasn't science we wouldn't know how to build spaceships and fly into space* • *Without science most things wouldn't be invented*

Group Interviews: Sample of Children's Responses Regarding Science as a HUMAN ENDEAVOUR		
Category	**Test Initial Interview**	**Control Initial Interview**
Human Endeavour	**No Comments**	**No Comments**
Subjective	**No Comments**	• *Em, yes, it can, because you know like the way Dinosaurs are extinct. Well scientists think that they, some scientists think that they died of an asteroid. Some think they died in a volcano, some think they died of poisoned plants and all. So that can change*
Creativity	• *...they (scientists) might use their imagination if they were making a medicine because they could get all herbs and all different kinds of stuff and put it together and that would be making their imagination and then cure something.* • *I don't really think they use their imagination when they are doing their experiments because they use facts and imagination well sometimes...sometimes when you use your imagination, sometimes things might not be true.* • *I agree with R. but also sometimes they do and sometimes they don't. When they do it's like when they're saying what if, when they say loads of what if theories and then it will eventually end up to be the right one somehow. Like for some years people have studied some facts but they eventually get it.* • *I'm not really sure. They could have some kind of electric machine or something but they might use their imaginations too* • *cause they might us it (creativity) if they seen a skeleton, they might use it to think over what it could be*	• *Well, like em...The person who invented the light, he must have thought of something to make it not so dark in your house or in your basement* • *Well, I think they kind of might try to build rockets to send into space* • *Well, I think they would use their imagination and their creativity because em like when they were thinking of the names of the Earth and the planets and the Dinosaurs, they would have had to use their imagination.* • *I only think they do it sometimes because if like they were mixing chemicals, they would have to think what, probably use their imagination to think what they could use like water and different kinds of liquid and when like they are naming like Dinosaurs and planets, they would use their imagination. But if they are putting bones together of some animal, they can't really use their imagination because they have to look through them and place them very carefully* • *Well I think they don't really because if they are*

		using creation they could get it from something was ages back like and then they use your own imagination to get stuff more to add onto it so it would be more powerful than the one that was from ages back • *Yeah well because you know that lab rat sort of thing – they have this big table and it's a maze and they have to try and get through to the cheese and it shows that rats are more clever than you think Yeah they (scientists) have to think of a way to do it and then they have to think of an original way of doing it*
Category	**Test Exit Interview**	**Control Exit Interview**
Human Endeavour	• *An engineer a scientist... Well, there's lots of different types of engineers. There's like, computer engineers and there's lab engineers, engineers like that, they just like, architects and they make stuff and design houses and stuff....* • *My Mum used to be an engineer and she used to em, make, em, submarines... well she drew out the plans and I think she built a little bit, the stuff and helped other people out...*	**No Comments**
Subjective	• *They always disagree most of the time... No, they should all agree, but like, they can't be always right....* • *And, and, when, like, they can't, like A. said, they can't be always right because they can't know everything, everything in the world* • *... their (Scientists) childhood, if something went wrong they'd try and make it better...Alexander Graham Bell made the phone* • *And em, he just invented it because his parents were deaf and he wanted something that you could talk to someone from a distance*	**No comments**
Creativity	• *Yeah, em, scientists would happily use their imagination, to, like for diagrams, they would have to use their imagination, to make like a hoover, they have to use their imagination to see what it would look like... Things like that. But you wouldn't be able to build anything without your imagination*	• *Well they sometimes use their imagination, but they don't always, 'cause like, em, when they're em, inventing something, they can use their imagination, they can go wild.*

	• *Things like that. But you wouldn't be able to build anything without your imagination.* • *They use their imagination to make toilets so, em, the pipes will go down to the factory and into the sea* • *Yes, because when they're seeing, what to feed their pets they must have thousands of guinea pigs feeding all this time, and if they're alive the next morning then they know it's okay for them. And if they're dead then they'll just knock it off their list. ... Because they are using their imagination to see what they would, em, eat, like feeding them all sorts of things, like flowers as well.* • *Like, when they're doing medicine and like, when they're just, their first time taking a go at, I think they use their imagination the second time, I think they'd learn stuff the first time so they wouldn't, they wouldn't, eh, like they just know things so they wouldn't try it again* • *I think you use both (imagination and creativity) because this morning when we were using that little piece of paper, we had to use our imaginations to think what it was but we had to create like, what the other part of it was as well. I was kind of thinking about nature because it looked a lot like outside and trees or stones, or something* • *You see scientists, they don't get it at first, they have to try and try because everyone thinks that they just go dedda dedda and it's done, but it's not that easy. It takes like a while, and a lot of like, planning, and designing and back to, like, planning and ... they're, they're doing like the creativity and the imagination and, like, they, they're really trying, it must have been really hard, like, to discover such, like the light bulb and the Metallic strip and things* • *I think, I think they used both. Like first, they used their imagination to, think of it, and do all that and then they would have to have their creativity to put it all together. Yeah, like, if, if, you didn't have the, a light bulb, connected to the battery, if you had something else, it wouldn't work*	• *I think scientists do use their imaginations on inventions because, if you think about it, if they didn't use their imagination would they really have come up with the word computer ... and they'd have came up with all the stuff that the computer does. And also the telephone, like, you have to use your imagination 'cause back then, if you wanted to call somebody you'd probably have to walk down to their house.* • *Em, when they're naming things like M. said like em, computers and stuff, they might seem weird names to us and they probably just, you'd probably think that they just em, made them up or something. Maybe they have made them up, but em, maybe if we don't really know they might name it after something they knew about...* • *Em, like washing machines or something to wash our clothes out of instead of washing them by hand... I need, I'm too tired of washing my clothes. I need a machine that can do it.* • *Yeah because like on the TV you've buttons to change on the zapper and stuff to change the channel... Because they invent, they created buttons to save us getting up.* • *I think that they use their imaginations because without their imaginations like, the ancient people would never have invented the alphabet, we never would have found energy sources and without scientists' imagination we wouldn't have figured out the secrets of like, the atom or anything*

Group Interviews: Sample of Children's Responses Regarding SCIENTIFIC INQUIRY	
Test Initial Interview	**Control Initial Interview**
• *I think the way they know is because the fossils that they dig up there's evidence there that like they had eyes in the head in the way the body is shaped and they've done so much research that they probably like know they don't even have to give, they have to give a big study but it would be easier the way they've studied and everything but we wouldn't exactly understand because we haven't exactly studied it for years* • *They test out things – or they magnify them they have this sort of – they probably grow the tiny – the germs and they look at them through the magnifying glass... I don't know what you call but it is the thing where you look through there and it shows it bigger* • *They test out things – or they magnify them they have this sort of – they probably grow the tiny – the germs and they look at them through the magnifying glass* • *They would try and investigate. They would try to solve matters that people are being puzzled by.... Try to find solutions to things.... Like to try and find a solution to a healthy ozone layer and to help world hunger* • *Yeah very certain because see, if they found a few bones from dinosaurs, they might do loads of experiments on it. And about the Sun they'd do loads of experiments on it so, yeah you'd be fairly sure.... And you can always keep a close eye on it and if anything ever happened, you could just go to it and see what's wrong and if there is something wrong, you should just warn everybody* • *When they are trying to figure out something they'd have to like use research and stuff like that*	• *Well, when I think about Science, I think about them going out and investigating Dinosaurs and other things like that.* • *Well, I think scientists go and discover bones and you know the way scientists might get a bucket or something with water, I think they might do something like that and try all types of stuff and see will they float or will they sink and all that.* • *I mostly think that scientists like they get the readings from the satellites and like how the weather is going to be and like they would be very into stuff and they would be trying to invent new ways to help the environment* • *They are going out and trying to find fossils and dinosaurs and they don't know what they are until they get back to the scanning machine and they put the fossil in the scanning machine and then they just scan it and it comes up on the machine like TRex or...* • *I Well I think that scientists they sort of find out the limitations of science and what happens if you connect this with that and something like that and what happens if you cross this wire with that wire and you know sort of like that – they are creative* • *They might go somewhere – in a desert or somewhere like that and get fossils of dinosaurs and do a DNA test* • *I think that different scientists have different jobs – biologists study living things – chemists study chemicals and astronomers study space – that's what different scientists do?*

Test Exit Interview	Control Exit Interview
• *You see scientists, they don't get it at first, they have to try and try because everyone thinks that they just go dedda dedda and it's done, but it's not that easy. It takes like a while, and a lot of like, planning, and designing and back to, like, planning and ...* • *think, em, experiments and, labs and em, investigations... Em, maybe that em, they em, the scientists go and investigate stuff where people have, sighted U.F.O.s.* • *Yeah, like, that's why they test everything before they go and sell it like. ... They don't just go and put it in a shop without getting it tested* • *cause, yeah, scientists have to guess... With the, stuff they have, and we only had, a, they only have a small piece, and we only had a small piece, and we had to guess what it was*	• *I think of dinosaurs ....I think of like clues and looking for like, the claws and like other dead dinosaurs that have been eaten and all.* • *Well, there was this movie called Independence Day. Well it was sort of something like you'd think was really bad because what you see in the movie is, that you actually see an alien getting cut open like it had a mermaid's [?] skin. I wouldn't really believe in any of that stuff because you wouldn't sort of believe, 'cause all you'd really believe is that it's either a man in a suit or it's a couple of bones stapled together... A lot of science things need proof... to actually know what's happening* • *When I think of science, I think of, em, science is beakers and pouring different chemicals into bottles and how, em, the world was formed.* • *Eh, experiments and like, different chemicals mixed together to make another chemical and stuff like that*

Group Interviews: Sample of Children's Responses Regarding SCIENCE AND SOCIETY		
Category	**Test Initial**	**Control Initial**
Science is Helpful	• *Because long, long time ago scientists made TVs and lights and without scientists we'd still be living the way long, long time ago* • *Yes the way it helps is, our food groups now the healthy food and the sweets well if we didn't have scientists to figure out that sweets are bad for us we probably be eating sweets for dinner... Yes the way it helps is, our food groups now the healthy food and the sweets well if we didn't have scientists to figure out that sweets are bad for us we probably be eating sweets for dinner* • *Like to try and find a solution to a healthy ozone layer and to help world hunger'* • *Yeah because sometimes they make medicine to help people...*	• *Yeah because they make rockets and they discover what you can do with them so if nobody was working up in space, we would die because they are saying that the world might blow-up in six years because they might stop working in space* • *... figure out if smoking is bad for you or if germs make you sick or...* • *Well I think when some people say scientists are only helping themselves – they're not - they are helping you too to make the world a better place... well they just tell what is going to happen (hurricane) so we can be ready for it instead of just sitting there and waiting for it so that way we would have more better things to do and we would be ready for what's going to happen* • *Sometimes old people, they need something to pump oxygen into their body and if we didn't have scientists, they wouldn't know how much oxygen they actually need.* • *Yeah I think it does. Like scientists can tell you if you have like cancer or something and they can help prevent cancer from happening... scientists can also help the poor people... by making something to stop the illness go around in the air because the poor people only live in dirty places which would give them lots of germs and make them sick but they can't afford to buy medicine so I am thinking that scientists could make a special medicine*
Science is Harmful	• *If one of the scientists were doing something, just mixing up to see what would happen, it could...If you were going to drop it, it could explode because the chemicals could*	• *Well sometimes it could be harmful cause if they were making a chemical and they put too much of something in, it could like go every where and it could be something that*

	upset it. • *Science can be bad for you if you spend too long in the lab.... Because the radiation and it might be kind of dark in there... It (dark) can hurt your eyes* • *Well, if they're trying out things that explode maybe there'll be a big kaboom and people might die.* • *Yeah but when they use their imagination, what, if they done this potion that you put into another potion that could just explode the whole world* • *Yes, it (science) can be harmful but not all the time. It can be harmful to animals cos they do test things. .... Yeah it's been banned but some people still do it*	*would harm their skin.* • *I think if they make this chemical, which, they could sell, it could be a bit dangerous and burn people, all their skin off and then they could die.* • *I think it is harmful [laughs] because scientists are mixing chemicals all the time and they might blow themselves up'* • *Yeah I do because when the scientists thought they could make something like dangerous but they had these two acids and they were very dangerous and you mix them together like you wouldn't know what would go on because he is just trying to make something and it could explode and it could be very dangerous*
Technology is Helpful	• *Yeah, because they invent wheelchairs for sick people and they invented chairs for sitting down on when you get tired.* • *They invent new inventions to help people around the world.* • *Yeah, because they make radiators and oils and they make metals* • *Yeah, because they invent wheelchairs for sick people and they invented chairs for sitting down on when you get tired.*	• *It does help us, like, the car is very helpful, 'cause without a car we wouldn't be able to drive to school or anything and we'd have to walk.... and if you lived far away from school it would take hours to walk.* • *Yes because like the overhead projector – you used to have to write on a chalkboard and it takes long to do that...you just get the sheet or whatever and put it on the screen and that helps...* • *As M. was saying about the telephone, I think that em, that's em, very helpful because if you were very, very sick and like you had something even worse than a bug like cancer or something, you'd need a telephone to call the hospital*
Society Should Tell Scientists What To Do	• *If the scientists... You know this sickness or something. Maybe they might investigate it if they asked really really nice. .... we should suggest, not order* • *I think yes, they should in maybe really dire emergencies*	• *Yeah because like weapons – people have weapons like machine guns and shotguns and bazookas and nuclear bombs and people should be telling the scientists don't make any more bombs or guns or anything.*

	where illnesses kill like thirteen and fifty million. Like thirteen in half an hour	• *Yeah because say if people like that take a bike and they ruin it – going quite fast and it was a bike that they invented and do you know the speed limit – and it wouldn't go over that – like they would stay on that speed limit* • *Well I think like they should each have their own say – if one disagrees and the other doesn't disagree they should just not do it. If they should both say no or both say yes they are allowed do it so you shouldn't actually - if one disagrees and the other says – you shouldn't one of them go off and do it*
Society Shouldn't Tell Scientists What To Do	• *I do not think scientists; eh I do not think that politicians should tell scientists what to research on.... Scientists' research on what ever they think is important* • *No because if they told them what to do for all they care it could be something' looney' like do you think I should win, figure it out or something like that. .... I think they should use their own minds and not someone else's.* • *I think, maybe scientists might have a good reason not to do it... because they might say, well if we do that it'll just make it worse... And so if they don't think it's right, like scientists would do it if they thought it was right but if it wasn't right I wouldn't say they'd do it so they should let them work at their own* • *I don't think that like that these big politician people should be bossing the scientists around because like, I suppose a head scientist, like, could pick it out and he would have his little team, but they should only have to obey him or her, probably her* • *Because scientists are sort of like their own people. They do what they want really.... And so if they don't think it's right, like scientists would do it if they thought it was right*	• *I think scientists should pick what they want, people shouldn't be saying "Ok, my son wants a light, so can you invent him the light", or something like that. They can't just say that, they have to invent it themselves. ... Or inventors should tell them but not normal people just going around.* • *Wouldn't scientists find out for themselves if people were like that, like, they would notice? So I think they should just check around different parts of Ireland to see if that's happening and then they might invent something.* • *I think it's ok if they went up and said something important like a computer or something, if something happened to the computer or something.* • *Well, I think the scientists should just come up with the things themselves cause the person that asks them might not want the thing that they wanted for a good reason, it might be something bad. So then the Scientist would make the thing themselves and....* • *Well, I don't really think that they should tell them what to do. I think they should ask them if they could make something to make them better.*

	but if it wasn't right I wouldn't say they'd do it so they should let them work at their own • *I don't think they, em, should, well if they wanted to they could but if a scientist didn't want to, they shouldn't force them to do it. ... So, em, they can if they want but if a scientist doesn't want to, they shouldn't force them to do it.* • *Em, no, 'cause you can't trust people when you're trying to figure out something about, like, around space and planets and all that, you can't, like, trust them....I think, no. I agree with D. and all, like, they're not, well, scientists can't do that sort of thing, I think, workmen should do, like, with water, if they're low on water or anything.* • *Because you can't just order them around all the time, then scientists would just stop doing their job and try to live a normal life.. Yeah, it would, because they'd stop trying to look up things about the World and things like that and then people wouldn't know as much as they know* • *Em, I think they shouldn't, because, like D. said, em, if scientists shouldn't just keep doing what other people want them to do because they'd just quit, so, if I was them, I just leave the scientists to figure out that by themselves and I wouldn't just go up to a scientist, 'now do this for me now or I'm just going to scream'. They shouldn't just go over and do that*	• *Well, I think in the different kinds of reasons. but they shouldn't go up and one person be going like that. They should just go up say "my hand is like that, will you invent something for me". If there is a whole group of people like that, then they should.* • *Well one bit people or society should have a say like if something is dangerous but they shouldn't be telling scientists what to research they should just let them do their job but dangerous stuff the people and society should have a say in. so the local community could do something about the dangerous weapons that science makes but they could also... but they couldn't tell them what to do research on because that would just be like bossing them around*
Category	**Test Exit**	**Control Exit**
Science is Helpful	• *Em, we wouldn't exactly know what to eat cause we wouldn't know if it was good or bad... Because, they wouldn't, em, find out what we need to have, what our basic diet would be every day, like what we need to eat. We probably wouldn't even be the dominant species... The like, leading species*	• *Well I think of curing sicknesses like cancer. Without Science we wouldn't know about germs or anything.... Germs can some, it doesn't always make you sick. Some germs aren't like that. Like there's actually a germ, I saw this in a book, there's actually germs that on your skin and it stops other germs from getting into you.*

	• *Eh, they wouldn't know why, em, everything stays on the ground but when you go into space, em, you just float around... we wouldn't know what to feed our pets...* • *'Science is really important, because, em, almost everything has Science in it, like, em, a piece of paper with writing on it, you use ink, to write and even if you write, write with a pencil, to make the pencil you have, to put the lead inside the, pencil... And the rubber on the metal, and stuff..., even the smallest of things have Science in them'* • *If we didn't have the candles we'd be really lost, cause, then you'd be bumping into everything, walking into walls and walking into doors* • *It's helpful because... if the light bulb wasn't made you wouldn't be able to see and it's helpful because you would probably hurt yourself, by walking into walls. And if the, if the, lightning, thing that goes down the wall wasn't invented, the top of your house would probably get struck and then some people in your family could die.*	• *I think of scientists and making the world better and inventions and all stuff like that. We need to know a lot about the world... If you're going to listen to some music, or try anything that we'd like to enjoy our day ...science can always just to help maybe to make our day better... there's other inventions like computers. They make our day better and you can learn stuff from it and the website... but also you mightn't, it wouldn't be very good for you sitting all day in front of the computer, so ...* • *I think science is very important because if you didn't know about the sun or anything, sometimes the sun does be very hot and it could sunburn you and you could be very sore, and if you stayed out all day in it and you didn't know about it you could get very, very sore and like you wouldn't be able to do anything at all* • *And em, really, I mean there are thing that Science can explain but I mean I think science is really important for our way of surviving... And I mean without Science, the human race would have died out eventually, because, I mean, we wouldn't, yeah we wouldn't be able to get food as easily or, but then again without Science the world isn't on the break of annihilation from pollution'*
Science is Harmful	• *I think it can be harmful because if he was testing medicine or something, and, and he, just after inventing it, and he didn't know what was going to happen, it could have been banned and he could have died from it or, something* • *I think science can be actually dangerous, especially to the scientists, because they were mixing like, chemicals that you, most times, see on TV. They could be, like, spilling it and then it could blow up in their face* • *'Em, I think it was Albert Einstein, em, he cut the, eh, an*	• *Yeah, it is. It helps us but it pollutes as well... It makes our lives easier but then we, like we paying the price 'cause it pollutes.* • *I think science is harmful because they build a big ship that can carry oil, but it hits off a rock and bursts and all the oil falls out but if they separated iron [?] it would fall out and then probably just stay there for a while* • *It's just if people, if people, if nuclear waste got poured into the water and people drinked it, that could actually harm the person, like if they were going to have a child or*

	atom in half and made the nuclear energy, and he didn't mean it, he didn't mean it to be bad but em... And em, he didn't mean it to do bad, he just made it cause, he [inaudible] would be a big explosion. Em, but he didn't mean it to kill lots of people in wars or anything • *But like, they should, em, in a way, they should be and they shouldn't because like everything is dangerous. The chairs we're sitting on are dangerous you could fall off them and ... Everything is kind of dangerous, so like, em, like, they shouldn't be able to like, make stuff that could like, literally kill you on purpose*	*something, 'cause that means like the child could be born with something like no legs or half a body like Scott was saying there* • *One, em right now, this very second, they're developing super germs in a lab and all it takes is just one absent-minded scientist to let this loose. I mean they could mix something with the wrong thing, make a chemical reaction, blow up the lab and all the germs would be like, set free and they'd destroy everything in their path* • *Yeah. Emotionally as well as physically, 'cause long ago they used to use real skeletons instead of those model ones... Yeah, you wouldn't like to see like your relatives' bones hanging up in a lab somewhere*
Technology is Helpful	• *Computers and technology and stuff like that... About people if they went into space, actually, they wouldn't be able to go to space, because they wouldn't have the technology* • *I think it's (science) is helpful in every way, because we'd be still using a telegraph or something now if we didn't have it and like it (telegraph) takes a long time to type out when you could just like ring someone..* • *I just think like, if we didn't, if we didn't have, like, if we didn't invent the light bulb or the, or the telephone or anything like that, we'd be going around with candles and we'd, and we, we'd have to go a long way to talk to someone* • *Iit's helpful because... if the light bulb wasn't made you wouldn't be able to see and it's helpful because you would probably hurt yourself, by walking into walls. And if the, if the, lightning, thing that goes down the wall wasn't invented, the top of your house would probably get struck and then some people in your family could die.*	• *I think science is important because where we are now we wouldn't have gotten there if Science hadn't invented all the stuff that we need...and ... technology has improved the life of a lot of people and without computers or anything we'd probably be stuck for answers and all that, 'cause you can go on the internet and get answers...* • *...we wouldn't have cookers or anything. We'd have to cook it over a fire and wait ages... And stuff like that, yeah. Because they found out electricity, and gas and petrol'* • *Because if science wasn't invented we wouldn't have telephones or any of the electric stuff.* • *I think science is important because where we are now we wouldn't have gotten there if Science hadn't invented all the stuff that we need...and ... technology has improved the life of a lot of people and without computers or anything we'd probably be stuck for answers and all that, 'cause you can go on the internet and get answers...* • *Yes, very important because really without Science, we*

	• *We'd have no Simpsons... Cause you'd need a TV and a TV is electrical... And you'd have, em, you'd have to, cook stuff over fires and, you'd have to wash your clothes in a lake and you wouldn't have a washing machine.* • *Em, you wouldn't be able to travel to different countries on planes cause you'd need like, all the software and the technology and all the stuff to build the,* • *I think it's (science) is helpful in every way, because we'd be still using a telegraph or something now if we didn't have it and like it (telegraph) takes a long time to type out when you could just like ring someone...*	*wouldn't have the machines to build all this room and when we're sitting here we'd just be sitting on the ground really.... We wouldn't be sitting on chairs or anything because we need machines to do that. And em, really, I mean there are thing that Science can explain but I mean I think Science is really important for our way of surviving... And I mean without Science, the human race would have died out eventually, because, I mean, we wouldn't, yeah we wouldn't be able to get food as easily or, but then again without science the world isn't on the break of annihilation from pollution*
Technology is Harmful	• *Scientists was making something, or, even, testing out a car to see if it would work, em, they could have, put the gears in wrong, or did something ... wrong and they could have pressed on the pedal and it, went out of control and they could have crashed the car* • *...I'm sure everything they've made, was probably very harmful at the start. And they have to test them and get stuff like that'll like stop it and then do loads and loads of different stuff to make it safe*	• *Em, all the cars' petrol, em, is of the world's resource and cars have petrol and if you're driving around a lot it will ruin the world's resources.* • *Like in Chernobyl when the nuclear tank...exploded... It was very dangerous, loads of people died... They maybe died or they lost an eye or somethinh* • *...we're on the brink of extinction (because of) pollution and, I mean because of science we've got nuclear weapons and all it really takes is a leader of a country with a bad temper to start a nuclear war and if a huge nuclear bomb goes off then, really, the country of Russia would be entirely wiped out... Yeah, yeah, yeah but, it really, really isn't that helpful. I mean, I'm starting to wonder if em, all that trouble we're going through is worth it*
Society Should Tell	• *It should be balanced like, if scientists have an idea, they should ask permission to research it, but if, the em, Government ask the scientists to research something, they should have their own, em, part in it. Like, say, 'Well, that could be dangerous, so we'll have a check and we might say no'.*	• *I don't think scientists should just do whatever they want. They should have a big meeting. 'Cause if they went ahead with something, like a weapon and it backfired, it could blow up their country rather than the other country that they want to blow up.* • *I think laboratories should have a special room for*

		suggestions… Yeah but they shouldn't do whatever they want. They should discuss the idea first. • *They should like, they shouldn't be making up their own things. They should have, like, a meeting of society and all the scientists and if it's good yeah you can do it, but if it's bad, you can't.*
Society Shouldn't Tell	• *Well, em, you know if they were, if they did actually make what people, told them to make, then we could actually, em, the Government might actually tell them to make more weapons, so, and they'd be… No, I don't think, I think that it's, it's balanced, like it depends on what it is* • *It should be up to the scientist, cause you can't have this evil toy em, on the loose, like you go; 'hello robot, what are you doing [?] today? Kill D., kill D.'* • *But like it should be balanced and like say, em, they want to build, em, a really tall building, but then the Government say it might fall down, but then the scientists say 'well we could reinforce it, and that could help it', but the Government say, 'well em, we'll try that and test it on old buildings and then, we'll see if it works.* • *Em, I think, society shouldn't tell them, but like maybe they should have a responsible person to kind of, like tell them what to make, and what not to make*	• *I don't know. Maybe yes they should do whatever they want because, maybe what other people say would be really bad like if they said eh, tall people, no scientists to make all these real, like every chemical and it would maybe destroy the earth…. And the scientists would know more so they could do something that's not harmful.* • *Well I think that scientists should do what they want if they think it might be useful. into something.* • *Em, I think yes and no because scientists can do their own thing and they can do whatever they want and they might not help the world, but some people might find it helpful.*

Group Interviews: Sample Children's Responses Regarding SCIENCE AS A BODY OF KNOWLEDGE		
Category	**Test Initial**	**Control Initial**
Body of Knowledge	• *Well I think it's a very vast subject. I think about space and stuff ...A meteorologist which I want to be when I grow up...They get to study satellites on the computers and report back to the weather place.... Hurricane Rita and Hurricane C.* • *I think about nature and all around the worlds* • *Science is found around the world underground and long time ago* • *I think of space*	• *When I think of Science, I think of different types of chemicals and I think about space and different types of things like that.* • *I think of ...and plants and the solar system.* • *It can help us find out about facts... Like a fact what can float and what can't float* • *I think about Dinosaurs and space and planets.* • *Well I sort of think of different chemicals that I can learn about. I think its very fun learning about chemicals because there are so many of them* • *I think all about sorts of stuff – astronomy, chemistry, forgot the name! [laughs]* • *Well we wouldn't learn like stuff about... you wouldn't even know like what's outside your stratosphere – you wouldn't know em how to treat your environment because scientists made all that happen*
Tentative Nature of Scientific Knowledge	• *Yes, I think that science can change if they invent something because if they are just fiddling around and they invent something really helpful and then they said Oh, I'll make loads of these and sell them, it will be a great invention but they might have got it wrong the second time and never get it right again, they were just fiddling around and they don't know what they did.* • *Cos eh, about a hundred years ago people when Christopher Columbus set off, people thought the world was flat and Christopher Columbus proved it was round* • *They used to think that every 50 years there was going to be a*	• *Some of the science technology could change like in the past few years but it could actually improve on the rating and like it could also be very dangerous improving the science –* • *Yeah it has – an example some scientist guy who I've forgotten the name thought that everything was made out of fire, water, earth and air – and although later he would prove that everything was made out of atoms* • *Well yes sometimes. One scientist could make this*

	meteor and 50 years ago they thought there was going to be a meteor but there never really was. So that theory changed cos they thought that every 50 years there was going to be a meteor • Because they might discover something or it might be wrong. Then they change it. • On my papers, I write, I didn't, but I actually do now with what I heard because something bad can happen and then they might have to change it. • Em, yeah, 'cause em, if they were experimenting on something, like all the others said as well, something could go wrong and they'd have to change it.	really complicated equation and he puts in the answer and another scientist proves him wrong by doing the equation again and getting it right so really it can change until you get it exactly right and you perfect your invention or whatever you are doing sort of and that's it. • Yeah because over the years something will have to change in the time that's going to bring back something and when that changes the scientist who found it will be proven wrong and his budget will go – everybody will think its true but over a few years it will change. • Yes like in when Christopher Columbus discovered America and you know they all think the world is flat and they stick with that and science thought that for a couple of years and then Christopher Columbus thought the world was round and then scientists found out that it was round and then it changed.
Category	**Test Exit**	**Control Exit**
Body of Knowledge	• Em, we wouldn't exactly know what to eat cause we wouldn't know if it was good or bad... Because, they wouldn't, em, find out what we need to have, what our basic diet would be every day, like what we need to eat • but about the food chain, different animals are in different places at the food chain for different reasons... Like, elephants for survival, but and their intelligence but not for actually being able to, em, be killing, able to kill other animals, just is able to, stay alive... But like a lion would be able to kill other animals, so that would be high as well... So, not just the predators, would be at the top • No, people around is us is all science, cause inside of like people	• I think of dinosaurs and all and their world... and I think of like clues and looking for like, the claws and like other dead dinosaurs that have been eaten and all. • I Yes, I think it's very important because if we didn't know about the earth we would still be thinking that the world is, em, like a circle as well, like spherical and we would still be thinking that everything goes around the earth and we wouldn't know about gravity... • Em, well, you need Science to know if you found a big group of bones to find out, like em, what they're

	work on Science like, all around, in, inside, us like, so Science is really, everywhere and in us, and everything. • *Em, flowers, and nature is sorta science... I think when I look at flowers and nature, I think it's science*	*from, if they're from an animal or human, or how long they, like when did the person die or anything like that* • *I think of just the words 'a study of the earth'. That's all I think of*
Tentative NoS	• *Yeah. Because, like a long time ago, they, when sailors like getting on the boats they couldn't take a clock with them on the boat to see what time it, no, yeah, a clock, to see what time it is, because a long time ago they were pendulums.* • *Yeah it's like when the things are changing, like, the cars like, they used to be the old Fords and Morris Minors, and now they're all like, new cars like, Hondas and Subarus.* • *Yeah, cause em, they thought the world was flat and now it's like they know that it's rounder.* • *Em, yeah because, like, the houses are changing. Like, long time ago, like, you'd have like, houses that like are half built and they're not really that good but now like, you've houses that like, have electricity in them and they can fit like, like, they can fit like, couches and tellies and they're bigger and better.* • *And, and, when, like, they can't, like A. said, they can't be always right because they can't know everything, everything in the world* • *I don't really agree with A. because Science is all around us and, like there could be someone like, right, right, now trying to invent like, a new toy or something. Right now and like, so, Science is with us like everyday and it's not just in the past.* • *Yeah, because, when Thomas Edison, invented the electric light bulb, bulb, it's after changing like, to, like, all fancy ones and designs and like original and all different ones, it's not just like the one that he invented like.... Yeah, and he, he's em, people think that em, like it's, like, if the, if the light bulb like, hadn't of*	• *Yeah, for example, a couple of hundred years ago people used to think that earth was always, that everything was always made out of fire, water, air and earth. Now they know that everything is made out of atoms.* • *Yeah, and at first they thought the nuclear bomb was a good thing then they discovered it was a bad thing.* • *...Because scientists, it's like what D. said, scientists know that a lot of things are actually made out of atoms. It's something like, em, the rubber on the back of your pencil. They know what that's made of but we don't know what it's made of. It could be made of anything like atoms or something like that. It's like one of those white boards over there, it could be something like.... it could be made out of whatever scientists know what it is 'cause they examine what it's made out of* • *Well yeah like say the person that invented the car, they could go, eh this car is going to stay on the ground forever, then maybe in like twenty years it could be flying...* • *It's like when Christopher Columbus thought that he'd go over and he'd find a new way to go to India to get spices and stuff. But when he went over he found America. He thought it was India but it*

	been there, like, there's not like, none of us would have had light and ...... • *Yeah because when like, they found, like cats... they found a, completely different cat to the cats we have now like. Their eyes are different and their faces are different, and. And they have completely different colour skin and, they, it's kind of like, an, it's kind of like, a cat from a different, like place, because we never, ever, saw it before.* • *You see scientists, they don't get it at first, they have to try and try because everyone thinks that they just go dada dedda and it's done, but it's not that easy. It takes like a while, and a lot of like, planning, and designing and back to, like, planning and ...* • *Em, yeah it can change, because, em, when, em, he invented the telephone, people changed it and now they got mobile phones and, new modern phones, so it's able to change.* • *' ...because when Galileo said that the world was round, and, and, everybody didn't believe him cause they thought that the world was flat and then they, they, trapped, they locked him in his house, so ... cause they all said that it was flat and then when he said they, they found out, and, em, they sort of did, cause they did experiments to see'* • *It can change like, facts, facts sometimes can change everyday. Well, people thought the, the world was flat, but then, eh, Christopher Columbus, was that who it is... Sailed right round the world and he proved it was round* • *this is how my Gran started smoking, cause scientists used to say that smoking was good for ya... cause it relaxes ya. They thought and so, loadsa people started taking it up cause they thought it was good for ya, and then, all of sudden one day they came along and said,' We changed our mind it's not good for ya'... they kinda, changed, science*

wasn't, he found a whole new place.

- *Well I think that they aren't always right because they could say that there's ten planets but there's probably millions, em and ...because then a year later they could discover another two planets.... NASA...they're just looking in their telescope and then simply they discover a planet that they've never seen before*
- *I think Science can change because everybody, there was a scientist who said that the world was flat and if you went too far you'd fall off it ...... and that changed because now we know that the world is a circle*
- *I'd say, when F. was saying about all the planets, I heard just about a few months ago that they discovered a new planet and I also think that scientists are always working 'cause they're probably, they said they're going to investigate it a bit more ... and I think they're always working, so they're probably doing it right now*
- *Em, I think it can change em, 'cause like, they said that some drink, no some kind of like, a drink is fattening, like say a fizzy drink, and then there's another, it's kind of peach water one, it's a fruit one, they discovered that the two of them, if the peach water one if fattening as well, em that mightn't be true because it's made from peaches and all......... Even though, 'cause they might say, no I think that is fattening 'cause there's fizz in it, and like they might think that there's sugar in it and all because of the taste of the fizz but it mightn't*

	• *Yeah, because, like people thought it was impossible to go to the moon and things but then people went up and did it.... And things like, em, like, if you have the information on something and someone looked at a certain point of view cause they wanted to think something, like, they wanted to think that at the end of a rainbow there is a pot of gold, they wanted to think that, so they made up information, to make so, that, so that, they got the information so that, then somebody came along and proved them wrong.... So for them, the facts changed* • *Yeah, well facts can change like, all the time, cause like, like you say like, the life expectancy of a, of a human is up to like, 80, and then, now, and then, and then, everybody starts living up like 'til 90, like, they could change the facts like any time* • *Gravity) they thought it was just, a world where everything was sticking to the ground like glue. ... They thought like, there was no gravity, they thought gravity didn't even exist*	

Group Interviews: Sample of Children's Responses Regarding the HISTORY OF SCIENCE		
Category	**Test Initial**	**Control Initial**
Landmarks and Events	• *Eh, science is found around the world underground and long time ago.* • *I think about ...a long, long time ago.* • *I think of inventors* • *Because long, long time ago scientists made TVs and lights and without scientists we'd still be living the way long, long time ago.* • *I was reading an Albert Einstein story And also my friend was*	• *Em, the first thing that comes into my head is probably Albert Einstein, and then it's probably chemicals and magnets and all sorts of different things.* • *I know this other science, well he's sort of an invent, well there were two of them and they were inventors. They were the Wright Brothers who made the first powered, invented the first powered plane.*

	watching the Discovery Channel and it said that a scientist has made this car that can fly • *Cos eh, about a hundred years ago people when Christopher Columbus set off, people thought the world was flat and Christopher Columbus proved it was round*	• *I've heard stories about wacky scientists, but weird ones. And em, stories about those, and em they've said that they're not actually that weird at all, that they make great inventions... heard of a man, I forget his name, but he got really bored of telescopes and little things, so he made an invention and, I forget what that was as well but, he, em, got patients in and he could have detailed drawings of what they had, like what germs there were.... (C1)*
Science and Society	**No Comments**	• *' someone finds out electricity and they think it's amazing and all but maybe years and years ago, like in cavemen time, they could've invented all really weird things... but they just couldn't do anything like that (invent electricity), or maybe they could. But, em today em, like, we know electricity is normal to us.' (C1)*
Category	**Test Exit**	**Control Exit**
Figures and Landmarks	• *Miss, em, I, I would have said though as well the world was flat because back then you wouldn't a known anything about them, she wouldn't 'a been teached really about that.* • *Em, the reason they probably thought the world was flat, they might have em, walked a long way or something and realised it wouldn't turn or something like and thought it was all just flat...he invented the telescope.... Well you could just see, and like, eh, look at the clouds and see how they went down... Yeah, because if like, he might have looked at them and say the clouds were down and then went over to that place.* • *Because they didn't really have science, they wouldn't have invented the telephone or they wouldn't have invented all those things that we really need.* • *Em, yes, because when Louis Pasteur made the medicine like*	• *'Well I think of the like, the scientists that kind of risked their lives for the better of mankind and all that.... You know, all the things that we'd found out of the last, well, fifty years and that and how we made the microchip, we've made it to the moon and we've unlocked many of the secrets of the universe, loads of physics and all that'* • *I sort of think of it as inventors and you know chemicals and stuff.*

	people could have died if he didn't make the medicine, with infections and all that. ... So, like people could have died, but, if he, like, if we, didn't have them today there'd be a lot of people dead. • *And em, only because, em, Alexander Graham Bell and, Ben Franklin and all, if they, if they, if they didn't invent it then probably, we wouldn't have had it now.* • *Eh, when we're doing Science, it's like when, when eh, Thomas Edison made the, light bulb and if he didn't make the light bulb it wouldn't be light anywhere in our homes or in the street.* • *Em, Isaac Newton and the apple... It fell off the tree, and it fell, yeah, hit him in the head, and he said, why didn't that just go up in the air and, eh, why did it come down* • *Well, well, he got taken out of school at 13 cause, he was very poor and he was a book binder and he read all the books that he binded. And he, and his brother gave him money and he spent them all on lectures that Humphrey did.... and then, well, then, Humphrey invited cause em, he took notes of, of the lectures and he sent them to Humphrey and Humphrey invited him over for tea, and Humphrey gave him, a job as an assistant. And the.... everybody was saying like, that, but there's a reason for electricity and he made like, he was trying to prove ...*	
Science and Society	• *'...because when Galileo said that the world was round, and, and, everybody didn't believe him cause they thought that the world was flat and then they, they, trapped, they locked him in his house, so ... cause they all said that it was flat and then when he said they, they found out, and, em, they sort of did, cause they did experiments to see'* • *'Just the thing about the food chain, that all comes em, down to, em, the, the Buddhas, because, they, think that... Yeah, if they say, if they were a good animal or a good person they would be reincarnated with a higher form of like'*	• *I think there was this man, no one believed him at the start. Em ... And no one believed him at the start and then he found out, somehow, I forget how ...* • *Em, you know the way M. said, or inventing electricity, we couldn't really invent it because, you know em, someone finds out electricity and they think it's amazing and all but maybe years and years ago, like in cavemen time, they could've invented all really weird things but they just couldn't do*

	• *' He was trying to prove that you can make electricity from magnets, but, em, people, were trying to say no you can't. Magnets, em, magnets can em, get rid of em, electricity not the other way around'* • *Em, scientists, can't always be right like, C. said because when Galileo said that the world was round, and, everybody didn't believe him cause they thought that the world was flat and then they, they, trapped, they locked him in his house, so ... Em, I don't think so, cause they all said that it was like, he did a little bit, they all said that it was flat and then em, when he said they, they found out, and, em, they sort of did, cause they did experiments to see...*

anything like that, or maybe they could. But, em today em, like, we know electricity is normal to us.

- *Well I think of the like, the scientists that kind of risked their lives for the better of mankind and all that.... You know, all the things that we'd found out of the last, well, fifty years and that and how we made the microchip, we've made it to the moon and we've unlocked many of the secrets of the universe, loads of physics and all that*