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**Learning Aspects of the Nature of Science at
an Interactive Science Centre**

A thesis

submitted in partial fulfilment
of the requirements for the degree

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Abstract

The nature of science (NoS), while seen as an important part of science education, is also acknowledged as difficult to teach. Researchers have claimed that interactive science centres and the exhibits they contain have the potential to teach students about the NoS. This project investigated what aspects of the NoS are represented within the exhibits of an interactive science centre and what aspects of the NoS students may learn from a visit to the centre.

This project involved a class of year five and six students on a visit to Exscite, a local interactive science centre. The research was conducted within the interpretive paradigm of educational research and data was collected using a variety of qualitative methods. The class of students were split into six focus groups, and data was collected using a three phase approach: pre-visit interviews; an observational visit to Exscite; and post-visit interviews. During the two interview rounds, students answered a variety of questions about their experiences in science and their understanding about aspects of the NoS. During the observational visit general notes were taken about the whole class, and two focus groups were given additional discussion questions to answer as they interacted with the exhibits. All data were thematically analysed.

The findings indicate that, while interactive science centres provide a novel and entertaining environment for learning about science, NoS aspects were often not immediately clear. Closer examination of the exhibits suggests that understanding of some aspects of the NoS could be developed through engagement with the exhibits and two of the Exscite exhibits, considered to have strong NoS links, were focused on in this research.

Prior to the visit, students had poorly developed understandings of some aspects of the NoS, such as the development of scientific knowledge and the use of models in science. During the visit students were excited about this new environment and immediately explored everything that moved, rather than reading the information that accompanied exhibits. After visiting Exscite, students provided more detailed responses, including scientific ideas, which indicated that they had learnt new information about the NoS about how and why science is done and the use of models in science. Students, however, were still unable to

make the links between the models they had engaged with and what the models represented. The students in the two treatment groups had a better understanding of what they had done at the centre, but like their peers, were still unable to make links to the aspects of NoS associated with models.

This thesis concludes that while some aspects of the NoS may not be clear within exhibits at an interactive science centre, careful analysis did provide some NoS links and with facilitation, an interactive science centre can increase the students' awareness and understanding about the NoS.

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Chapter One
Introduction

1.1 Background to this Research

There is a national and global awareness of the importance of the nature of science (NoS), and promoting this quality to our students (Barker, 2003). Understanding the NoS has been an integral part of science curricula for a long time (Wong & Hodson, 2008). The NoS is a key emphasis in the recently revised New Zealand Science Curriculum, and there are four NoS strands: understanding about science, investigating in science, communicating in science, and participating and contributing (Ministry of Education, 2007). However, teaching the NoS is not simple, because many teachers tend to hold naïve views of the NoS and teach science in a way that suggests it is a formulaic process; in which a scientist always strictly adheres to the so-called ‘scientific method’ (Hume & Coll, 2008).

Research has indicated that an interactive science centre, which is an example of a free-choice learning environment, may have ability to teach students aspects of the NoS. This is mainly due to the fact that the exhibits at interactive science centres, if managed well, may show students some of the qualities of being a scientist such as: understanding specific vocabulary, exploring teaching models, participating and contributing to a wider knowledge, working together, and carrying out investigations.

There has been a long standing stigma attached to the notions of formal and informal learning. Formal learning is where most science education is focused (Gerber, Cavallo, & Marek, 2001), and this type of learning occurs within a school or university based institution (Falk, 2005). Here the learning is highly structured and organized, and its main agenda is to fulfil curricular goals and tends not to regard students prior knowledge and experiences as important (Gerber et al., 2001). Informal learning is a direct contrast to formal learning, thus it is a learning that occurs outside of these settings. An example of an informal learning environment is an interactive science centre or a zoo (Falk, 2005). In this informal learning environment in science, also referred to as a free-choice learning environment (e.g., Falk, 2005), students will have an opportunity to learn

about scientific phenomena, scientific literacy, develop inquiry skills, and engage in discourse with teachers, science officers, and their peers (Gerber et al., 2001).

The literature that has been read indicates that interactive science centres, along with museums and zoos are potential sources of this notion of informal education, or informal learning (Rennie, 1994; Rennie & McClafferty, 1996). Interactive science centres are not perceived as places that communicate a lot of factual knowledge (Hodder, 2010; Miles, 1987); rather they have an agenda of “promoting scientific understanding in the community” (Hodder, 2010, p. 10), increasing the level of engagement between science and young people (Hodder, 2010), and offer a chance for people to develop an interest in science (Hodder 2010; Miles, 1987). This opportunity for developing an interest in science typically involves students or other visitors with hands on activities as they try to solve puzzles or solve problems posed by exhibit designers (Bolstad, 2001; Tofield, Coll, Vyle, & Bolstad, 2003), and Wilkinson (1993) reiterates this notion as being the strength of Exscite – an interactive science centre in Hamilton, New Zealand. The literature indicates that such activities, if managed well, can help students understand how scientists go about their ‘business’, and thereby learn aspects of the NoS.

This research project combines the ideas that are outlined above: teaching and learning about the NoS and acknowledging that it is an important part of science education, but is often a difficult task for teachers; and it is postulated that interactive science centres may have the ability to portray and teach students some aspects of the NoS.

1.2 Research Questions

The research questions that will be investigated in this thesis are:

1. What aspects of the nature of science can be represented in a science centre?

2. What aspects of the nature of science do students learn when these specific aspects are highlighted to them at an interactive science centre?

1.3 Researcher Background

From a young age I have had a curiosity about everything, always asking why and how things worked the way they did. Then when I started high school, many of my questions were starting to get answers in my science class. From here, my interest in science developed. I took science classes throughout high school and after completing chemistry, physics, and biology in my final year I decided to carry on along this path and begin a Bachelor of Science with chemistry and physics as my focus. As well as my science degree, I also started a Bachelor of Secondary Education with the goal of becoming a chemistry teacher to inspire and invigorate young minds as mine was at high school. Four long years of studying passed, and I graduated with my two degrees ready and excited for the next challenge.

Even though becoming a teacher was my goal, and I was now well qualified to do it, I still wanted to continue learning at university. I felt I had only conquered the ‘tip of the iceberg’ and could do more. With that in mind, I enrolled in a Postgraduate Diploma in Science Education. It started well, although was difficult to begin with as the academic level I had to write at was much higher. Over one year I completed my postgraduate diploma where I learned many things about science education, from the purpose of science education, through to educational research paradigms – and everything in between. This gave me a strong understanding and appreciation for educational research in the science education domain, while also forming the foundations for my first research project – which took place over the Summer (via a summer research scholarship) before I started teaching. The development of this project and writing of the report carried on into the following year where I had started my first teaching job. With this small piece of research under my belt, I was hungry for more!

During my postgraduate diploma year, I found an interest in the idea of learning outside of a classroom. Switching from formal environments where most science is taught at school to informal environments such as museums, science centres and even amusement parks. I was excited when I was approached by members of the University of Waikato on behalf of the Exscite Trust to undertake sponsored research. What this meant for me was that for the next two years I would be carrying out my own research towards my Master's degree (part-time, while teaching full-time) and thus I would really be entering the world of educational research with this exiting research project.

1.4 Overview of this Thesis

An overview of the next five chapters of this thesis is as follows:

Chapter two provides a review and in-depth discussion of the literature which establishes a context for this research project. The literature review is divided into three key focus areas: firstly, free-choice learning environments; secondly, the NoS; and lastly, learning science at interactive science centres. The literature review highlights ideas and details research that has already been conducted, which in turn develops the argument behind the importance of this research.

Chapter three outlines and discusses the methodology that was used for this research. Here the notion of educational research is explained along with current paradigms in educational research, and why an interpretive paradigm was used for this study. It is also gives details about the research participants and ethical considerations for research involving children as data sources. Furthermore, detailed information is given about the research methods and the research design.

Chapter four presents the findings from the research methods. This chapter is broken up into four key areas: firstly, details about the context of this research project including information about the interactive exhibits; secondly, findings and excerpts from the focus group pre-interviews; thirdly, information and findings from the observational visit to Exscite which focuses on two treatment

focus groups; and lastly, findings and excerpts from the focus group post-interviews.

Chapter five discusses the findings that were presented in chapter three by exploring the relationship between the literature that was outlined in chapter two and the theoretical framework and research questions in chapter three. Here the research questions are answered, and I provide a detailed analysis on how Exscite can be used as a teaching tool to teach students about aspects of the NoS.

Chapter six uses the analysis from chapter five to draw a conclusion about this research project as well as highlighting implications for teachers and interactive science centres. This is then followed by ideas about future research in this area of science education.

Chapter Two

Literature Review

2.1 Introduction

The intention of this research was to ascertain whether or not a free-choice learning environment such as an interactive science centre could be used to teach students aspects of the nature of science (NoS). However, before an examination of student experiences in an interactive science centre could take place, a comprehensive literature foundation was required that examines current research, knowledge and ideas on this topic. This literature review would then use this current knowledge to form an argument that justifies the approach taken for this research.

While there is a lot of literature relating to interactive science centres and teaching and learning about the NoS, this review will focus on three central aspects:

- a) The notion of free-choice learning. This investigates and discusses the nature of learning science, the nature of free-choice learning, how modern interactive science centres have developed from museums, and the development of interactive science centres in New Zealand.
- b) The notion of the NoS. This investigates and discusses the argument and debates about defining the NoS, how the NoS is represented in the New Zealand curriculum, and teaching the NoS.
- c) The notion of learning at an interactive science centre. This investigates and discusses views of learning, learning from exhibits, facilitating the learning process, and learning aspects of the NoS at an interactive science centre.

Each of these key aspects is discussed in detail below with reference to relevant and current literature, and this is followed by a short summary of the main points.

2.2 Free-Choice Learning

2.2.1 The Nature of Learning in Science

Throughout the 1980s, much of the science educational research community had adopted a cognitive constructivist view on learning (Dole & Sinatra, 1998). This

view on learning was consistent with Piagetian theory as well as cognitive psychology in terms of explaining how students acquire knowledge about scientific phenomena. This constructivist view on learning subscribed to the idea that knowledge is not something that can be acquired by a simple teacher-student transfer process (Dole & Sinatra, 1998), but rather advocated that knowledge is constructed over time by the learner (Driver, Asoko, Leach, Mortimer, & Scott, 1994). This construction of knowledge by the learner as they are involved in tasks within the classroom (Driver et al., 1994), requires the learner to develop new and existing theoretical frameworks and understandings about a diverse range of scientific phenomena. This was characterized as a process of ‘conceptual change’ (Abd-El-Khalick & Akerson, 2004; Dole & Sinatra, 1998; Driver et al., 1994; Duit & Treagust, 2003; Leach & Scott, 2003; Palmer, 2003; Posner, Strike, Hewson, & Gertzog, 1982; Vosniadou & Ioannides, 1998).

The idea of conceptual change has been a central topic for research in science education since its original conception (Hovardas & Korfiatis, 2006). It was first proposed by Posner et al. (1982), and with this proposal came a rationalization of how conceptual change may take place. Posner et al. (1982) suggested a clear process that would take place for a student to be accommodating and change their original conception. This process indicated: firstly, that must be a sense of dissatisfaction with the existing conception (Palmer, 2003; Posner et al., 1982), whereby the new ideas and knowledge presented do not coincide with the existing conceptual framework. Once this process is complete, the student is able to move into the next phase of conceptual change. The student must consider the new conception that the teacher is offering to be intelligible (Posner et al., 1982), in that the students are able to understand the new concept (Palmer, 2003). While being intelligible, the new concept also needs to be plausible (Posner et al., 1982), that is, the new concept makes sense to the students (Palmer, 2003), and it must also have “the capacity to solve the problems generated by its predecessors. Otherwise it will not appear a plausible choice” (Posner et al., 1982, p. 214). Finally, the new concept should also be fruitful (Posner et al., 1982), meaning that

the new concept should have the potential to solve new problems (Palmer, 2003; Posner et al., 1982).

Succinctly, the process of conceptual change is that teachers employ pedagogical techniques that challenge student conceptions (that may be alternative or misconceptions), by presenting ideas and new knowledge that do not coincide with their existing conceptions (Duit & Treagust, 2003). Throughout this process, student misconceptions may be minimised, and scientific conceptions may be developed (Palmer, 2003). However, it is important to note here the significance of misconceptions from a sociocultural view on learning. Within this view, “misconceptions simply represent ways of communicating in everyday social language. This is the mode of communication that prevails in day-to-day living, and those ways of communicating are ‘viable’ in that they are widely understood” (Leach & Scott, 2003, p. 101).

An avenue worth outlining here when discussing the idea of conceptual change within a student’s thought process is the use of various models in the classroom. Models have been described as being a useful tool to help students develop conceptual frameworks (Chittleborough, Treagust, Mamiala, & Mocerino, 2005; Spier-Dance, Mayer-Smith, Dance, & Khan, 2005). For example, using Rutherford’s solar system model of the structure of an atom to facilitate learning about atomic structure (Coll, France, & Taylor, 2005). Chittleborough et al. (2005) indicate that within the science classroom, models can take on a variety of forms such as: symbolic representations of scientific phenomena, equations, diagrams, analogies, three dimensional representations, pictures and simulations. They also go on to suggest that it is a helpful practise to categorize models into four types based on significant characteristics rather than trying to characterize each specific model separately. This notion yields four distinct types of models: mental model, teaching model, scientific model, and expressed model. Figure 2.1 outlines how these four models are related to the learner.

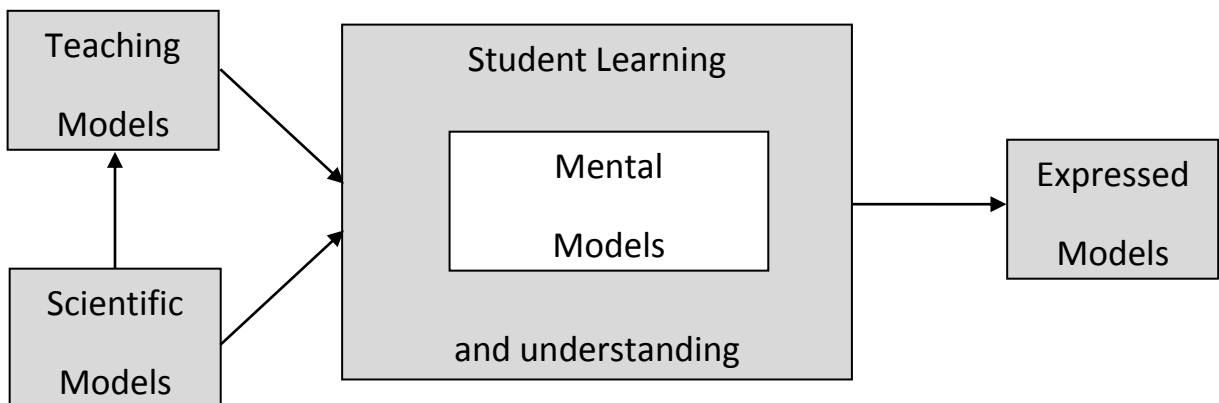


Figure 2.1: A theoretical framework of models in learning – relating the four types of models: scientific, teaching, mental and expressed (Adapted from Chittleborough et al., 2005, p. 197).

Mental models are physiological representations of ideas, concepts or phenomena that are upheld by the student and used to describe phenomena that cannot be directly experienced (Chittleborough et al., 2005; Coll et al., 2005). A scientific model is a model that has been critiqued by the scientific community and has been accepted as having some degree of value. The teaching model is a specifically constructed model to be used in the classroom to help the students with their conceptual change development. The expressed model is similar to the mental model of the students but is in an expressed form such as writing or speaking (Chittleborough et al., 2005). From the diagram above, it can be seen that the teaching model and scientific model provide a basis for the student to develop their own mental model, and it is important to note here that when the teaching model and the scientific model have discrepancies and do not align, alternative or misconceptions can be developed as the mental model of the student (Chittleborough et al., 2005).

After discussing learning that takes place around scientific phenomena, it is important to discuss the environments that the learner can be immersed in, and the learning that takes place in these different settings.

2.2.2 The Nature of Free-Choice Learning

Historically, researchers and educators have classed different learning environments as being either formal or informal; where a formal environment is referring to a classroom or a university setting, and an informal environment refers to education and learning that occurs outside of these parameters (Falk, 2005). Formal environments were seen as a place where the content is taught in a very organized fashion. The intentions of the teacher and the learner are to promote learning (Gerber et al., 2001) and the “instructional procedures vary from teacher-centred, with didactic transmission of knowledge, to highly student-centred, experimental, where knowledge is socially constructed” (Gerber et al., 2001, p. 535). It is also important to point out here, that within this environment the emphasis is placed on fulfilling the curricular goals, where there is little importance ascribed to “children’s prior knowledge, memories, and experiences outside the classroom” (Gerber et al., 2001, p. 536).

While it can be seen that a description and explanation of a formal learning environment can be argued, a clear definition of an informal environment is more difficult to ascertain. However there seem to be some points of commonality of informal environments. For example, Bamberger and Tal (2007) indicate that learning that takes place in the classroom occurs as a linear sequence from lesson to lesson, which rely on students prior knowledge, and the scientific concepts that were learned in the previous lesson. In an informal setting such as a museum, the learning that takes place is in small amounts of time spent at each exhibit, it “does not require continuity, and relies on curiosity, intrinsic motivation, choice, and control” (p. 77).

Discussions based on these historic terms amongst science education scholars have lead to the development of the term ‘free-choice learning’ (Bamberger & Tal, 2007; Falk, 2005; Tofield et al., 2003). This development stems from the fact that “there is no convincing evidence that the fundamental processes of learning differ solely as a function of the physical setting or the institution supporting the learning” (Falk, 2005, p. 271), and while it is fair to argue that the physical context of the learning will be a factor (one of many) that influences the learning –

as an isolated factor it is unlikely to affect and influence the learning (Falk, 2005). This point can be further augmented by highlighting two extreme cases. Firstly, it would be ridiculous to argue that taking a group of students to an interactive science centre to only have students sit whilst a teacher-directed pedagogical approach was taken, where the teacher lectured them on science is any different from running that same lecture, with the same pedagogical approach in the classroom (Falk, 2005). Secondly, at the other extreme of the spectrum, lies the argument that there are no real differences between carrying out an open ended voluntary inquiry based investigation in the classroom compared to carrying out that same investigation at an interactive science centre (Falk, 2005).

Free-choice learning then, can be regarded as a term that recognizes and acknowledges the unique characteristics and aspects of learning outside of a traditional ‘formal’ classroom setting. Some of the unique characteristics include: the notion that the student is free to choose what they will be learning; the learning that takes place is not sequential (Falk, 2005); the student is autonomous; and learning that takes place is not centred around, or subscribed to a set curricula but rather is a result of the students interest (Tofield et al., 2003). It also takes into account the socially constructed nature of learning, whereby the learning that takes place is influenced by the students interaction with others and their sociocultural and physical environment (Falk, 2005; Falk & Dierking, 2000). It is also important to note here that there is a vast array of different settings which lend themselves to free-choice learning (Dierking & Goldman, 2005; Falk, 2005; Tofield et al., 2003), such as interactive science centres which are increasingly being recognized as places where free-choice learning can occur (Stocklmayer & Gilbert, 2002).

2.2.3 The Development of Interactive Science Centres from Museums

Museums are an example of a setting that provides informal learning environments where visitors can exercise significant free-choice over what they may learn (Falk & Dierking, 2000), as opposed to formal learning environments

where the learner cannot exercise the same level of choice over what they might be learning. When observed in detail, museums are complex organizations. Although, if they are taken at face value, they can be simply thought of as a place or building whose purpose is to contain collections of objects (Alexander & Alexander, 2008). They are organizations that do not have an agenda based around producing a profit, but rather are seen as institutions that document societal development, where the public can view exhibitions and learn about developments that have been made over centuries (McManus, 1992).

The idea of a museum, or a place to house a collection of objects is not a new one (Miller, 1973), and its origin can be dated back to ancient times in Greece wherein the “third century BC, King Ptolemy the First, founded a place for the muses” (Otrell-Cass, 2001, p. 10). Since this origin, museums have undergone continuous evolution to get to what we view them as today: from cluttered collections of masterpieces that were exclusively private to their owners (Miller, 1973); through to a place that is open to the general public where visitors come to view exhibits that are on display, participate in programs, and possibly re-conceptualise a preconceived view in this free-choice learning environment (Falk & Dierking, 2000).

These initial museum collections however, were cluttered and were seen as being in a state of chaos rather than having an organized, systematic approach (Bennett, 1995). It wasn't until the seventeenth century that objects started to be categorized systematically and organized accordingly, such as coins and art pieces (Otrell-Cass, 2001), which has been referred to as the change from chaos to order (Bennett, 1995). In the eighteenth century, these objects and artefacts that were now systematically ordered were studied and researched (Otrell-Cass, 2001). As well as this important development, museums were also transitioning from being private collections of objects that belonged to the wealthy and powerful, to institutions that served the general public (Miller, 1973; Otrell-Cass, 2001).

Throughout the nineteenth century, the idea of categorizing and classifying objects, and then reordering them accordingly allowed for further museum development – the development of specialised museums (Bennett, 1995; Otrell-

Cass, 2001). These were museums that were now focused on a singular entity, for example, art, folk culture, or natural science (Otrell-Cass, 2001). During the twentieth century, there was an apparent rift between types of these specialised museums – art and culture were now being separated from museums of science and technology. This rift created an opportunity for science museums and science centres to develop, and in turn, the exhibits in these science centres would transform from objects with name tags into hands-on interactive exhibits – thus forming the interactive science centre (Otrell-Cass, 2001; Shortland, 1987).

The first interactive science centre, which was founded by Frank Oppenheimer, was opened in San Francisco in 1969 and it was called *Exploratorium* which was derived from the words exploration, and auditorium (Otrell-Cass, 2001; Shortland, 1987). It was postulated that students and visitors alike would learn more if there was a more hands-on approach to the exhibit (Otrell-Cass, 2001). After the development of Exploratorium, many more interactive science centres were developed during the 1970s in North America, France, Australia, and England, and many more were planned (Shortland, 1987). The exhibits in these interactive sciences centres were now less focused on the objects themselves and more on being a medium of facilitating concepts, ideas and phenomena (Otrell-Cass, 2001). Since the original development of interactive science centres in 1969, there have been many advances worldwide. The next section in this chapter outlines the development of these free-choice learning environments in New Zealand.

2.2.4 Interactive Science Centres in New Zealand

In New Zealand, museums developed into science centres in a way that echoed that of the rest of the world. They started by being a means to collect and display advances in science and technology to the public, something that has been apparent since the nineteenth century (Hodder, 2010). These museums also started to develop order within their collections, with the exception of “smaller regional museums and especially in local museums featuring technological processes relating to industries that developed in their area (e.g., mining at Waihi; timber at

Putaruru; coal-mining at Huntly)” (Hodder, 2010, p. 336). As these museums were still developing, there were only a few museums in New Zealand that were directly focused on science, and these were not considered to be interactive (Hodder, 2010). From the beginning of the twentieth century interactive science centres, where visitors had the opportunity to physically interact with the exhibits, began to evolve (Otrell-Cass, 2001).

The driving force behind developing science centres in New Zealand was based on the need to improve public understanding of science, and to develop and improve a scientifically literate community that would have a knowledge base to aid with informed decision making (Hodder, 2010; Otrell-Cass, 2001). Another reason for developing science centres was to try and increase the number of young New Zealanders moving into science careers, which was declining (Otrell-Cass, 2001). Discussions took place around the idea of promoting learning in science, and thus the idea of creating science centres and offering learning experiences in science outside the classroom were being considered and developed. With the development of these new learning centres, there was a shift in how scientific ideas could be communicated. As a result, the idea of developing a science centre with interactive exhibits where the visitor would be engaged, and participate, was coming of age (Otrell-Cass, 2001).

The first interactive science centre to be developed in New Zealand was the Museum of Transport and Technology (MOTAT), which was established in Auckland in 1988 (Otrell-Cass, 2001). As mentioned above, there was an increasing need to promote science, so money was contributed by the New Zealand Lottery Grants Board to help fund, and develop interactive science centres throughout New Zealand. The contribution from the New Zealand Lottery Grants Board provided enough funding to expand on interactive science centres in New Zealand, and ultimately build interactive science centres in all of the main city centres (Hodder, 2010; Otrell-Cass, 2001).

Along with MOTAT in Auckland, Wellington developed Capital Discovery which was an interactive science centre. Palmerston North also got a science centre that was part of the Manawatu Museum, Science Alive! was created and built in

Christchurch, and Discovery World was developed in Dunedin (as part of the Otago Museum). A small time after these interactive science centres were developed and built, Exscite was constructed in Hamilton (Hodder, 2010). As all these interactive science centres were in the main centres of New Zealand only, a mobile interactive science centre was established to take aspects from these interactive science centres to the smaller communities, although it initially only travelled around the South Island. At first this mobile interactive science centre was part of the Science Alive! centre in Christchurch, but later became its own organisation: The National Science-Technology Roadshow Trust, which held national tours (Hodder, 2010). There was another interactive science centre that was constructed after the Lottery Grant Board's funding had been used, and that was the Faraday Centre in Napier (Hodder, 2010). Below is a map of New Zealand detailing the position of each of the interactive science centres:

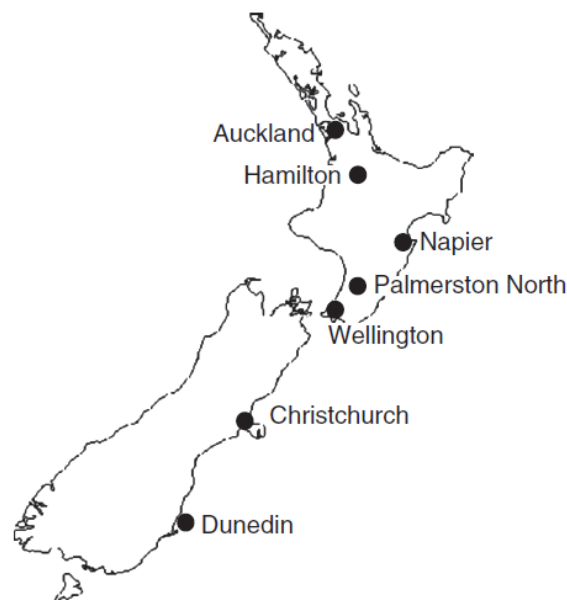


Figure 2.2: A map of New Zealand which shows the placement of all of the interactive science centres (From Hodder, 2010).

2.2.5 Summary of Free-Choice Learning

The first interactive science centre was built in San Francisco, it was called *Exploratorium*, and it was developed by Frank Oppenheimer. Since the development of this origin, there have been many more interactive science centres built around the world including New Zealand which now has seven of these learning centres as well as a mobile interactive science show. Interactive science centres are considered to be free-choice learning environments that have developed from museums over the past century, as opposed to more formal environments such as the regular classroom. In this environment, visitors are now given the opportunity to not only go and view collections and exhibits but are able to experience scientific phenomena first hand as they control parts of an exhibit.

As visitors take part in an interactive exhibit, it is postulated that this type of interaction is essentially a teaching model that can help conceptualise a scientific idea by developing (or changing an existing) mental model. This conceptualisation of a scientific idea as a mental model can then be expressed by the visitor, which will show that they understand the concepts being portrayed. This conceptualisation, or conceptual change, is the view of learning that many in the science education community have adopted.

2.3 The Nature of Science

2.3.1 Defining the Nature of Science

The NoS is a notion that “typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge” (Abd-El-Khalick & Lederman, 2000, p. 666). However, it is important to note here that there is no agreement on a specific definition of the NoS, as the concepts are still being debated between science philosophers, scientists and science educators (Abd-El-Khalick & Lederman, 2000; Hipkins, 2002; Hipkins, Barker, & Bolstad, 2005). Abd-El-Khalick and Lederman (2000) point out that this discrepancy should not be unexpected given the “multifaceted,

complex, and dynamic nature of the scientific endeavour” (p. 666). While there is this typical reference of the NoS, it is important to indicate and summarise the development of the NoS over the past century.

At the beginning of the 20th Century, to have an understanding of the NoS was the same as having an understanding of ‘The Scientific Method’ (Central Association for Science and Mathematics Teachers, 1907, as cited by Abd-El-Khalick & Lederman, 2000). During the 1960s the idea of ‘inquiry learning’ and the ‘process skills’ in science became the area of importance. Emphasis was placed on aspects of science such as observing reactions, interpreting experimental data, and designing and carrying out experiments (Abd-El-Khalick & Lederman, 2000). Later, in the 1970s, there was a very clear shift in the definition of the NoS in response to the research carried out at Ohio State University, which characterised scientific knowledge as:

...being tentative (subject to change), public (shared), replicable, probabilistic (predictions based on scientific knowledge are never absolute), humanistic (reflects human attempts to impose order on nature), historic (past knowledge should be judged in its historical contexts and should not be compared to contemporary conceptions), unique (has its own set of rules and values), holistic (internally consistent), and empirical (based on and/or derived from observations in the natural world).

(Ohio State University, 1974, as cited by Abd-El-Khalick & Lederman, 2000, p. 667).

During the 1980s the definition of the NoS was still undergoing development. It was evolving and starting to take into account psychological and sociological factors (Abd-El-Khalick & Lederman, 2000). Then, in 1982, the National Science Teacher Association indicated that “an adequate understanding of the NoS entails an understanding of the empirical and tentative nature of scientific knowledge, and an appreciation to the central role of theory and inquiry in science” (Abd-El-

Khalick & Lederman, 2000, p. 668). These ideas were advanced even further in the 1990s when the American Association for the Advancement of Science further defined understanding of the NoS by outlining three principles: first, the world should be viewed as understandable, but yet keeping in mind that the science cannot answer all questions; second, principles relate to the notion of scientific inquiry, in that although inquiries in science rely on logic and evidence, they are primarily driven by imagination and creativity; and third, there is an importance associated with understanding the social and political aspects that are involved with science (Abd-El-Khalick & Lederman, 2000). However, it is important to highlight the fact that there is no definitive meaning of the NoS and that this philosophical notion is as tentative as the concepts, knowledge and enterprise of science itself (Schwartz & Lederman, 2002).

2.3.2 The Nature of Science in the New Zealand Curriculum

While the definition of the NoS remains in need of further refinement, and there has been intensive research carried out about the NoS throughout the past 50 years (Abd-El-Khalick & Lederman, 2000). There has, however, been an aspect of the NoS that has remained relatively constant over the decades. This constant aspect is the belief that it is important students acquire an understanding of the NoS (Martín-Díaz, 2006). There have been many research publications over the years that have outlined the need for students to develop an understanding of what is meant by science, how people participate in it, and how it changes and develops over time. For example, Barker (2002) identifies that there is an urgent requirement for students to learn, understand, and appreciate the whole entity of science. Although the most important notion is that students should learn the link between science, technology, and society (Martín-Díaz, 2006).

The importance of learning about the NoS can be seen within the New Zealand Curriculum. The *Science in the New Zealand Curriculum* document (Ministry of Education, 1993) was a policy document to direct teachers in what needed to be taught at different levels in science. It was developed well over a decade ago and

it advocated for learning about the NoS via its integrated strands, entitled ‘Making Sense of the Nature of Science and its Relationship to Technology’ and ‘Developing Investigative Skills and Attitudes’. These integrating strands were intended to be taught in conjunction with one of the four contextual strands, and the NoS strand was concerned predominantly with “distinguishing between science and technology, although the latter had its own specific curriculum document by 1995” (Hipkins et al., 2005). At the time of this curriculum development, the notion of scientific literacy was also emerging. With that, curriculum writers intended that there would be clear links to the notion of scientific literacy. However, two out of the three achievement aims within the NoS strand were dedicated to addressing science/technology issues (Hipkins et al., 2005). In addition to these issues, the integrating strand also had considerable focus on fair testing, and did not explicitly identify what it meant by the NoS.

New Zealand has recently undergone a curriculum reform, and a new revised Science Curriculum document now places even more emphasis on learning about the NoS (Ministry of Education, 2007). Under the heading of the NoS, this new curriculum document states:

The nature of science strand is the overarching, unifying strand. Through it, students learn what science is and how scientists work. They develop the skills, attitudes, and values to build a foundation for understanding the world. They come to appreciate that while scientific knowledge is durable, it is also constantly re-evaluated in the light of new evidence. They learn how scientists carry out investigations, and they come to see science as a socially valuable knowledge system. They learn how science ideas are communicated and to make links between scientific knowledge and everyday decisions and actions.

(Ministry of Education, 2007, p. 28).

The New Zealand Curriculum document aims to teach these scientific qualities via four achievement aims: understanding about science, investigating in science, participating and contributing, and communicating in science (Ministry of Education, 2007). However, teaching the NoS is not simple, if for no other reason, because many teachers hold naïve views about the NoS and teach science in a way that suggests it is a formulaic process; in which a scientist always strictly adheres to the so-called ‘scientific method’ (Hume & Coll, 2008).

2.3.3 Teaching the Nature of Science

Teaching the ideals of the NoS in schools, and helping students develop a clear understanding around the NoS is something that has been discussed and debated over the last century (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), along with the development of a meaning for the NoS. However, there has been little research, and concepts have been left unexplored about teaching the NoS in classroom (Bartholomew, Osborne, & Ratcliffe, 2004). This is of importance because policy documents like the New Zealand Science Curriculum (Ministry of Education, 2007), have increased the need for learning about the NoS; yet there are still gaps “between the rhetoric of policy and classroom practise” (Bartholomew et al., 2004, p. 658). There are three key themes that the literature offers about improving NoS instruction in the classroom, which are: the teachers own views of the NoS (Abd-El-Khalick & Akerson, 2004; Akerson & Volrich, 2006; Lederman et al., 2002; Posnanski, 2010), using an implicit or explicit teaching approach (Akerson & Abd-El-Khalick, 2003; Posnanski, 2010; Schwartz, Lederman, & Crawford, 2004), and the idea that the science teacher needs to develop a ‘nature of science pedagogical content knowledge’ (Akerson & Volrich, 2006; Schwartz & Lederman, 2002).

Research on the instruction of the NoS in the classroom has consistently highlighted that teachers do not have an adequate understanding of the NoS themselves (Lederman et al., 2002). It is also highlighted that their views on the NoS are often not aligned with contemporary views and conceptions of the NoS

(Abd-El-Khalick & Akerson, 2004). With this dilemma in mind, it is not surprising that teachers who lack clear understanding of the NoS, or embrace naïve views on the NoS would not be able to adequately teach, and help their students develop clear ideas and views about the NoS (Akerson & Abd-El-Khalick, 2003). As Posnanski (2010) points out, the concepts of the NoS that students will obtain will be roughly in line with those of the teacher. Although, it has been postulated that this lack of understanding about the NoS that some science teachers have can be resurrected by offering professional development programmes that help them to develop a view about the NoS that is more aligned with views that are advocated for by research. During these professional development programmes teachers may also be able to learn strategies to teach the NoS to students (Posnanski, 2010).

Succinctly, the research outlines two approaches for teaching the NoS: an implicit approach, or an explicit one. These two approaches can be used whilst teaching the NoS to students (Abd-El-Khalick & Akerson, 2004), or be used as part of the professional development programmes that some science teachers require as outlined above (Posnanski, 2010). An implicit pedagogical approach to teaching students about the NoS stems from the idea of scientific inquiry, which is taken to mean the acquisition of scientific knowledge by way of a process that acknowledges the characteristics of science as an enterprise (Schwartz et al., 2004). This is what some science teachers would refer to as ‘doing science’ (Schwartz et al., 2004), and the NoS is portrayed as an underlying theme throughout the process. Essentially students learn aspects, and develop views of the NoS as a ‘natural consequence’ (Schwartz et al., 2004) or as a ‘by product’ as they carry out the investigation, employ a variety of science based skills, and engage in discussions (Abd-El-Khalick & Lederman, 2000; Posnanski, 2010). An example of learning the NoS via an inquiry process is highlighted by Lederman et al. (2002), with the development of hypotheses, and observing what happens. The related NoS aspects to these core skills are: realising and acknowledging the fact that hypotheses are formed using imagination and creativity, and realising and understanding that scientists do not often have direct access to observations of the

natural world. Rather, observations are constrained by perception (Lederman et al., 2002). It is also important to note here, that for students to develop informed views of the NoS, they also need to be able to distinguish between inference and observation. This requires an understanding that observations are measurable by the senses, or extension of the senses, and inferences rely on statements and frameworks that are not accessible or measurable by the senses (Lederman et al., 2002).

From this pedagogical approach stems the question of, if a student is engaged in a scientific inquiry, and is involved in using skills, and discussions, is that enough to learn about the NoS? The research strongly indicates that this process is not enough, and is not sufficient at teaching students about the NoS, and does not offer them a chance to develop their own informed views and conceptions (Schwartz et al., 2004). Thus, it can be seen that while an implicit pedagogical approach can teach students about the NoS, there is a crucial factor that needs to be addressed: the idea of explicit pedagogical approaches (Akerson & Abd-El-Khalick, 2003; Posnanski, 2010; Schwartz et al., 2004). Explicit pedagogical approaches are similar to implicit approaches; however, they now incorporate an added planned instructional section that outlines and discusses specific aspects of the NoS throughout the inquiry process. This pedagogical approach is designed to capture and draw the students' attention to aspects of the NoS "through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples" (Schwartz et al., 2004, p. 614). From the discussions above it can be seen that for a learner to acquire an informed view of the NoS then both an implicit and explicit pedagogical approach is required (Schwartz et al., 2004). Moss (2001) sums up this argument, by stating "understanding the relationship between explicit instruction and implicit messages of the nature of science is critical if we are to effectively teach the nature of science" (p. 789).

The third theme that was discussed in the literature is the idea of developing a 'nature of science pedagogical content knowledge' (Akerson & Volrich, 2006; Schwartz & Lederman, 2002). This stems from the notion of pedagogical content

knowledge (PCK) that was first introduced by Shulman (1987) as being an important quality for effective teaching. Succinctly, PCK is viewed as being a developing knowledge base that a teacher possess, and it consists of an blend of pedagogical knowledge, and content knowledge “that makes possible the transformation of disciplinary content into forms that are accessible to and attainable by students” (Akerson & Abd-El-Khalick, 2003, p. 1028). To include teaching about the NoS as well now, not just pure content, it can be seen that an effective PCK will now be at a point that intersects NoS knowledge, pedagogical knowledge, and content knowledge (Akerson & Abd-El-Khalick, 2003)(see Figure 2.3).

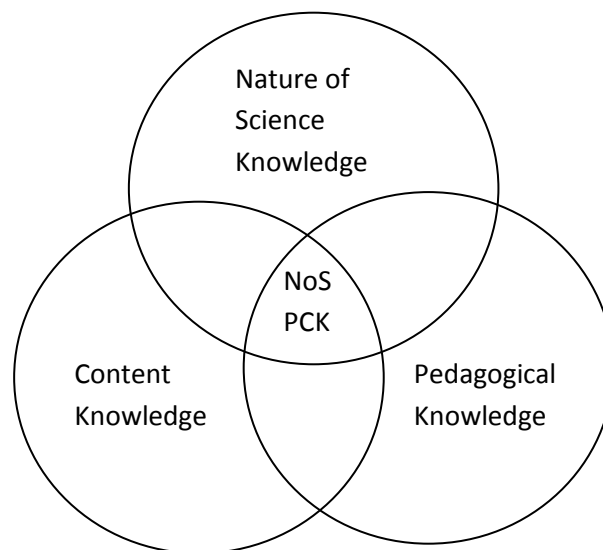


Figure 2.3: Nature of science pedagogical content knowledge, and its relationship to pedagogical knowledge, content knowledge, and the inclusion of knowledge about the NoS (Adapted from Schwartz & Lederman, 2002).

Figure 2.3 outlines the region where a teacher’s knowledge base should lie to be an effective teacher of the NoS, however to first enter into this area of knowledge development, the teacher needs to have an informed view and conception of what the NoS is (Akerson & Abd-El-Khalick, 2003). It must also be strongly noted here that to effectively teach the NoS to students, pedagogical knowledge alone, or

content knowledge alone will not be sufficient – it needs to be an amalgam of these two qualities (Schwartz & Lederman, 2002).

2.3.4 Summary of the Nature of Science

The NoS is a notion about science which has had a tentative definition over the past century. While the definition still requires further development, it can be seen that it does draw on common aspects which include acknowledging the way creativity and imagination have a role in science. It also includes aspects such as science being a human enterprise and whilst it answers questions about phenomena within the natural world, it cannot answer every question. There is also a need for the understanding of the social and political aspects of science.

Along with the development of a definition of the NoS, incorporating aspects of the NoS into policy documents is also evident. For example, the New Zealand Curriculum policy document has recently undergone a major reform, and the learning area of science has a strong emphasis on learning about aspects of the NoS. While this development has taken place, and there has been a lot of research carried out around the NoS and its meaning and definition, there has been little research done about teaching the NoS in the classroom – something of importance. If teachers are to implement these NoS aspects that have been outlined in their national policy documents, then it is clear that there needs to be research carried out around teaching the NoS.

While there has been little research around teaching the NoS, there are three themes that have been echoed throughout the literature about this concern. First, is the idea that ‘you can’t teach what you don’t know’ – thus, there is a need for science teachers to up-skill their own views and knowledge around the NoS in order to convey this information to their students. Second, a teacher can portray the NoS either implicitly, for example an inquiry based lesson where learning the NoS is a by-product, or explicitly, where the teacher would directly highlight aspects of the NoS to the students, whilst carrying out their investigation. The literature discussed above strongly advises that the use of one of these techniques

is not enough – both need to be used throughout the science course. The third theme that has been outlined in the literature is perhaps the most important one. This is the notion of developing a nature of science pedagogical content knowledge – or a NoS PCK. This is where the teacher draws on aspects from their content area, their pedagogical knowledge, and their knowledge of the NoS in order to have a base that allows them to effectively portray the NoS to their students. While it is noted here that teaching the NoS is difficult, it is postulated that one way for a teacher to effectively portray these crucial NoS aspects is to employ the use of an interactive science centre.

2.4 Learning at Interactive Science Centres

2.4.1 Views on Learning at Interactive Science Centres

Interactive science centres go further than just simply entertaining and astonishing their visitors for a small amount of time, rather they have exhibits that have been developed to engage visitors for an adequate amount of time so that learning can take place (Boisvert & Slez, 1995). If this requirement is met, and visitors engage with the exhibit in the desired way, then it is argued that interactive science centres provide an effective environment where students can learn about scientific concepts. This is done by undergoing knowledge construction, and developing and changing their conceptual ideas around these scientific concepts (Dagher, 1994; Gilbert & Stocklmayer, 2001). To discuss the learning that takes place during a visit to an interactive science centre, it is useful to have a theoretical framework to work with and refer to, for this the ‘contextual model of learning’ will be used.

Falk and Dierking (2000) introduced the contextual model of learning as “a device for organizing the complexities of learning within free-choice settings” (Falk & Storksdieck, 2005, p. 745). This model however; is better thought of as a large-scale framework which encompasses a range of key factors associated with learning in museums (Falk & Dierking, 2000; Falk & Storksdieck, 2005). Falk and Dierking (2000) indicate that while there are a large number of factors that

will influence direct and indirect learning in a museum setting, possibly in the thousands, their research highlighted eight important factors that are fundamental to learning in a museum environment. Figure 2.4 below shows the eight key factors, each of which are placed under a sub-heading.

Personal Context

1. Motivation and expectations
2. Prior knowledge, interest, and beliefs
3. Choice and control

Sociocultural Context

4. Within-group sociocultural mediation
5. Facilitated mediation by others

Physical Context

6. Advance organizers and orientation
7. Design
8. Reinforcing events and experiences outside the museum

Figure 2.4: Falk and Dierking's (2000, p. 137) contextual model of learning, which highlights the eight key factors when discussing learning in a museum environment.

The *personal context* fragment of the framework can be viewed as the “personal and genetic history that an individual carries with him/her into a learning situation” (Falk & Storksdieck, 2005, p. 745). Within this, important aspects that may influence what is learnt within a free-choice environment include: prior knowledge and interest, reasons for visiting the museum or science centre, and “the degree of choice and control over learning also affects visitor learning” (Falk & Storksdieck, 2005, p. 745). From this perspective, learning in a free-choice

environment can be seen as highly personal and will be influenced by the learners prior knowledge systems and frameworks (Falk & Storksdieck, 2005).

With the social nature that humans have, it can be expected that learning will be *socioculturally* situated (Falk & Storksdieck, 2005). Falk and Storksdieck (2005) indicate that in the past there has been little empirical knowledge in the area of researching learning in museums with relation to sociocultural surroundings and interactions, however; “considerable research now exists which shows that visitors to museums are strongly influenced by the interactions and collaborations they have with individuals within their own social group” (p. 746). With this research indicating the importance of interactions, data has arisen suggesting that a difference in visitor learning can be associated with quality interactions with those outside of that social peer group, for example museum staff, teachers, or other visiting groups (Falk & Storksdieck, 2005).

As well as the personal context, and the sociocultural context, the authors suggest that the learner will react to the *physical context* of the free-choice learning environment. This physical context refers to both the large scale physical properties; lighting, climate, and space, as well as the small scale physical properties; the exhibitions themselves, and the objects they are made up of (Falk & Storksdieck, 2005). Since interactive science centres can be regarded as a free-choice learning environment, the learner navigates their own path around the centre in a non-sequential way. Research has then shown that the successfulness of navigating through a complex three dimensional environment is correlated to what is learnt (Falk & Storksdieck, 2005). As well as being in this complex setting that the learner has to navigate through, the exhibits themselves will greatly influence the learning that takes place. Here it is important to outline and discuss the exhibits themselves, and how different types can promote learning.

2.4.2 Learning from Exhibits at Interactive Science Centres

The learning experience that takes place at an interactive science centre can be viewed as either coming from a convenient physical interactive teaching model

that portrays a real-world phenomenon, which Gilbert and Stocklmayer (2001) describe as being an ‘analogical model’. Or an interactive scientific model of a phenomenon that stems from the accepted scientific reasoning and justification around said phenomenon which Gilbert and Stocklmayer (2001) refer to as a ‘consensus model’. From these statements it can be seen that interactive exhibits are essentially either an exemplar which is an idealized model of real-world phenomena, or an analogy in the form of an analogical model with the purpose of representing some sort of scientific phenomenon (Stocklmayer & Gilbert, 2002). While it is important to have an understanding of interactive science centres as a whole, understanding about the nature of the exhibits themselves is also central to this discussion.

To discuss the different types of exhibits an interactive science centre offers it is useful to be able to make generalisations and categorize the exhibits accordingly. Stocklmayer and Gilbert (2002) offer a system of classifying different exhibits into four main groups: exhibits as exemplars of phenomenon, exhibits as showing only similarities between entities, exhibits showing similarities between both entities and relationships, and exhibits only showing similarities between relationships.

The first grouping of exhibits, as the title suggests are simply exhibits that “consist of exemplars of phenomena, that is, examples that demonstrate characteristic behaviour in the most efficient and effective manner” (Stocklmayer & Gilbert, 2002, p. 839). This first group of exhibits can be seen in traditional museums as being things such as different animals or a collection of plants. Within the walls of an interactive science centre, however, the most common example of this type of exhibit is one that details and shows the characteristics and behaviour of a material. Here the authors offer the example of an exhibit whereby visitors investigate the effect of polarised light by placing a polarising filter in front of a light source and observing its effect (Stocklmayer & Gilbert, 2002). Text about the scientific ideas usually accompany these exhibits, however the targeted learning, and the main purpose of this type of exhibit is to give the

visitors direct experience with the phenomena at hand (Stocklmayer & Gilbert, 2002).

The following three classifications of exhibits stem from the idea of having an analogical representation of scientific phenomena which explains the target phenomena (which it is assumed that the visitor or student knows little about) by using a ‘source’ idea (which is something the visitor is assumed to know more about) (Gilbert & Priest, 1997; Stocklmayer & Gilbert, 2002). A very simple example of an analogy (which is more suited to a classroom rather than a science centre, but is useful to help explain the ideas) is to teach students about the atomic structure of an atom by using an egg. It would be assumed that the students would know very little about atomic structure in terms of the nucleus and electrons (targeted idea), but may be able to understand it by using the idea of an egg and explain that the nucleus is the yoke, and the electrons travel around the egg shell (the source for representation). Also, these next three groups of exhibits are made up of models that are “produced by the mapping of a source onto a target, [which] consists of *entities* and *relationships between those entities*” (Stocklmayer & Gilbert, 2002, p. 839). Again the authors offer an example to explain their point about entities and relationships which consists of a concrete (physical, able to touch) model of an ionically bonded crystal (e.g., sodium chloride). The range of different atoms in the lattice are seen as the entities, and they are “held together by the balance of electrostatic attractions and repulsions operating between them” (p. 839) which are the relationships (Stocklmayer & Gilbert, 2002).

The second classification is made of exhibits and models that detail similarities drawn between entities, but not between relationships (Stocklmayer & Gilbert, 2002). The authors offer two exhibit examples to explain this. One of these is identical to an exhibit which is housed at the interactive science centre, Exscite, where this research project is based so it will be used. This is the example of earthquakes: how they occur, and their effects. Within this exhibit, visitors are required to sit on a platform inside of the wall, and are then required to push a button that makes the platform rock backwards and forwards. This is then used as an analogical that represents how an actual earthquake occurs and its power.

Typically there is some accompanying text, graphics, and diagrams which are intended to detail the relationship between the causes (forces under the earth) and the movement of the platform (the effect of what happens on earth), however the use of the exhibit does not require an understanding of these relationships (Stocklmayer & Gilbert, 2002). With this, Stocklmayer and Gilbert (2002) caution that the “lack of the explicit provision of a relationship analogue in such an exhibit inhibits the understanding that can be derived from it” (p. 840).

The third group of exhibits outlined by Stocklmayer and Gilbert (2002) consists of exhibits and models that are developed from analogies which have been drawn from both entities and the relationship that exists between the two entities. Again an example from the literature, and one that is common (perhaps not in an interactive science centre, but are frequently used for charity fundraisers), is the idea of a black hole. This exhibit is used to model the nature of a black hole, in that it has a gravitation force surrounding it which pulls objects into it. The model consists of a cone type structure where the visitor can drop an object at the top (such as a marble – or a coin in the fundraising one mentioned earlier), and the object then spirals down the cone into a hole to not be seen again. Here the cone structure represents the gravitational field, and the object disappearing into the hole at the bottom representing the relationship. The learning that is intended at this type of exhibit is that the visitor will learn about “causal mechanisms by means of which the targets behave as they do” (Stocklmayer & Gilbert, 2002, p. 840).

The last classification consists of exhibits and models that have similarities drawn between the relationships only. Stocklmayer and Gilbert (2002) offer an example to reiterate this thought, which consists of an exhibit called the ‘light harp’. This is made up of a series of small holes which have photo sensors in them, and above that there are light emitters. Visitors then interrupt the beam of light and a musical sound is heard (similar to that of a shop door chime). Visitors can then use this exhibit as if it was a harp to try and produce a melody. The user also has the option to change the type of music that is being emitted to correspond with different instruments. The purpose of this light harp is to demonstrate the

propagation of light waves; however the analogy between light and sound waves is not told to the visitor. This type of exhibit has the potential to provide explanations and analogical models about causal mechanisms based around complex phenomena (Stocklmayer & Gilbert, 2002).

While all of these exhibits promote learning around scientific ideas and concepts, research has indicated that simply using the visit alone as a stand-alone lesson may not provide the students with an adequate learning experience (Bamberger & Tal, 2008). This dilemma has brought about the idea that the learning can be facilitated and aided.

2.4.3 Facilitating the Learning Process

The literature has offered various ways to increase the learning potential of an interactive science centre, such as: careful preparation for the visit and considering the unique learning experience and opportunities at an interactive science centre rather than simply following similar processes and emulating what happens in a classroom (Griffin & Symington, 1997; Tal, Bamberger, & Morag, 2005); using pre- and post-visit activities, rather than using the visit as a stand-alone lesson (Anderson, Lucas, Ginns, & Dierking, 2000; Burtnyk & Combs, 2005; Davidson, Passmore, & Anderson, 2009); using worksheets while the students are making their visit (although this needs to be carefully orchestrated so it does not impinge greatly on their ability to be mobile and explore galleries freely) (Burtnyk & Combs, 2005; Kisiel, 2003; Price & Hein, 1991); and having someone with the students during their visit to interpret, and help make meaning of the exhibits (Ash, 2004; Gutwill & Allen, 2012).

When teachers embark on any type of learning outside of the classroom experience or a field trip, there is some preparation and procedures are carried out, but this preparation lacks a learning focus. The preparation that is done for an excursion requires the teacher to shift into a management role that focuses on small technical things such as chasing up students for fees and permission slips, designing a schedule for the trip, and issuing instructions to the students regarding

what they need to bring, wear and eat (Griffin & Symington, 1997; Tal et al., 2005). However, in a study carried out by Griffin and Symington (1997), they saw that if there was preparation done before a visit to an interactive science centre, the learning potential could be increased. With this conclusion the authors offer some guidelines about preparing for a visit to a science centre, which include: making sure that the content covered within the exhibits is applicable to what has been done in class, such as while studying horticulture, a visit to a dinosaur gallery would render not very useful; encourage students to ask questions about the exhibits; and develop and employ learner-centred approaches for when they are at the science centre, so the learning that is taking place is not just teacher directed (Griffin & Symington, 1997).

As well as preparing for the visit to an interactive science centre, researchers also suggest developing and using pre- and post-visit activities as a way of enhancing the learning opportunities (Anderson et al., 2000; Davidson et al., 2009). A study carried out by Anderson et al. (2000) investigated the importance of pre- and post-visit activities when taking a group of students to a science centre to learn about electricity and magnetism. Before the visit the students worked in groups constructing concept maps about what they knew in terms of electricity and magnetism, and then had to complete one on an individual level. After the visit to the interactive science centre, students then carried out post-activities which required them to again work together and select a couple of exhibits that appealed to them. Students constructed concept maps about what they knew again, thus producing their third concept map. Through the knowledge shifts that were apparent from the students' work (and also apparent in the semi-structured interviews), the authors were able to conclude that when visiting interactive science centres, or any centre with a free-choice nature, that "pre- and post-visit activities not only support the development of scientific conceptions, but also to detect and respond to alternative conceptions that may be produced or strengthened during a visit to an informal learning centre" (Anderson et al., 2000, p. 678).

Worksheets for the students to complete at the science centre during a visit have also been mentioned throughout the literature as a tool for enhancing the learning (Burtnyk & Combs, 2005; Kisiel, 2003; Mortensen & Smart, 2007; Stavrova & Urhahne, 2010). Worksheets are usually either supplied by the teacher, or by the centre that they are visiting, and have the goal and the potential to highlight important pieces of information about the exhibit that the students may otherwise gloss over and miss (Kisiel, 2003). Stavrova and Urhahne (2010) suggest that for a worksheet to be useful in this enhancing process they need to: include questions that directly refer to the exhibits themselves, use a variety of types of questions so students can understand them, and so they promote social interaction between their peers, and aren't so long that they dominate the entire visit, so the students are allowed free time to exercise choice in the centre.

If a carefully designed worksheet that contains strategic questions, clean and unambiguous information is developed and used, then learning in a free-choice environment can be enhanced (Kisiel, 2003; Mortensen & Smart, 2007; Stavrova & Urhahne, 2010). While this viewpoint is shared by a variety of authors, others have opposing viewpoints. For example, Price and Hein (1991) discuss their view on worksheets which is in direct contrast to the information detailed above. They caution to teachers and educators the negative effect worksheets can have, namely that they have the ability to “actually impede student learning by inhibiting true observation, preventing students from formulating their own questions, and causing students to focus on the narrowly described task to the exclusion of broader questions. Effective programmes use worksheets sparingly, if at all” (p. 515).

Throughout the visit, someone to interpret the exhibit to the students, highlight important information, and perhaps help them with their worksheets or activities becomes important (Ash, 2004). It could be assumed that the teacher takes on this important role in the learning process that is going to take at the science centres. However, once they arrive at the interactive science centre (or some other free-choice destination), the teacher is often required to make a shift into a management role. This shift occurs because whilst they are visiting the exhibits

because they are primarily responsible to sticking to their schedule, and dealing with time constraints, student needs, and logistical problems (Tal et al., 2005).

This shift that the teacher makes is necessary as they are accountable to a variety of individuals, such as the parents, the school, and the students. With this shift however, come limitations. Namely, the teacher is now unable to provide the learning support that is needed to really enhance the experience (Tal et al., 2005). Although even if the teacher did have the time, it has been suggested in the literature that in the contextual setting of an interactive science centre, teachers are no longer experts, but are well-intentioned novices that are drawing from their own learning experiences, and using these experiences to inform their practise (Griffin, 2004; Tal et al., 2005). With this comes the need for a person to be able to mediate the information that the exhibits are trying to portray to students (Ash, 2004).

Ash (2004) asks a very important question about this mediation job, which succinctly put is: ‘who has the right to be this person that forms an important relationship with the variety of learners that come visit the exhibits, and interprets the information?’ Ash then goes on to give her viewpoint of an answer to this question by indicating that the best person for that job is simply the person that has designed the gallery or exhibit. This solution seems as though it would be highly unmanageable, and it has been mentioned that with some professional development individuals such as teachers (if their role of managing the students can be lessened), museum staff, or parent chaperones may be able to help with this mediating role (Griffin, 2004; Tal et al., 2005).

So far this section has focused on the nature of learning at interactive science centres; the different types of exhibits that an interactive science centre may contain, and the analogical representations that exist within each one, including its entities and the relationships between those entities, whether they are made clear from the model, or whether it was provided with accompanying text. There has also been a focus on the variety of methods that can be used to enhance and push the learning that can occur at an interactive science centre. An understanding of exhibits and the learning that occurs at them is important, however this research

project is not focused on just learning at an interactive science centre, but the possibility of learning about the NoS at an interactive science centre.

2.4.4 Nature of Science at Interactive Science Centres

The NoS blends various aspects of science together; such as history, philosophies, and sociology, and as such forms a fundamental part of what *should* be taught to students (Pedretti, 2002). However, when science teachers have, and uphold views on the NoS that are more often than not inadequate and not aligned with contemporary views and conceptions of the NoS, the information they deliver has these same qualities (Abd-El-Khalick & Akerson, 2004; Lederman et al., 2002). These views that the teacher has, and uses to form a basis for what they teach, may set up a learning environment where the knowledge and ideals that the students develop echoes the teachers knowledge in terms of its inadequacy (Posnanski, 2010). This situation appears to be rather problematic in regards to giving the students false information, one possible solution suggested in the literature is the use of interactive science centres to represent aspects of the NoS (Rennie & Williams, 2002).

The idea of learning about the NoS at an interactive science centre stems back to 1969 when the first interactive science centre, *Exploratorium*, was developed by Frank Oppenheimer and opened (Davidsson, 2009). This is because Oppenheimer believed in, and argued for the public developing an understanding of science, and thought there should be an environment where visitors could learn about science by not only watching but actually using the scientific equipment. He also wanted this environment to provoke peoples curiosity, and to help them answer questions about science they might have (Davidsson, 2009). However, even though interactive science centres can make visitors think, and teach them new things about science, learning about the NoS in an interactive science centre can be problematic, as exhibits often do not have the NoS as a central theme, or not represent it at all (Davidsson, 2009; Davidsson & Jakobsson, 2007; Rennie & Williams, 2002).

A possible causal factor for this problem was argued in the literature, which was the criticism that learning about the NoS at an interactive science centre is difficult because the science being portrayed is as an issue free entity – described by Pedretti (2002) as showing the ‘wonders of science’. This view on interactive science centres means that the exhibits are developed in such a way where human accomplishments are represented in a way that portrays science as this straightforward unproblematic process (Davidsson & Jakobsson, 2007; Pedretti, 2002; Rennie & Williams, 2002).

The literature suggests that to make these interactive exhibits portray what Rennie and Williams (2002) refer to at the ‘real nature’ of science, interactive science centres need to incorporate important NoS aspects such as: “socio-scientific issues” (Davidsson, 2009, p. 199), controversial issues, the fact that scientific knowledge is tentative and can be wrong, and indicate a degree of uncertainty with their claims (Rennie & Williams, 2002, 2006). It is also argued that for students to be able to learn about the NoS in this environment, science must be shown as a cultural activity that is studied across a range of languages (Osborne, 2002), and that students should be given “opportunities to read science, discuss how ideas are supported and write scientific texts” (Davidsson, 2009, p. 201). If interactive exhibits are able to include controversial aspects, or give details on how the knowledge being presented was discovered, then students may be able to understand aspects of the inner workings and the NoS (Davidsson & Jakobsson, 2007). An example may be an exhibit depicting the structure of an atom. To satisfy the above requirements it may include information and models about previous ideas like J.J Thomson’s *plum pudding model* of an atom, Ernest Rutherford’s experiment with gold foil and how it discredited the ideas before him, and then onto our perception today. By doing this, it may set up an opportunity for students to discuss with their peers about how ideas in science have changed over the years, and where they might be heading.

2.4.5 Summary of Learning in an Interactive Science Centre

From a basic viewpoint, exhibits at interactive science centres are best described as analogical representations of scientific phenomena which aim to teach visitors by using an idea that the visitor should be able to ascribe to, and representing the scientific idea with it. By using an analogy, the exhibit has the potential to aid the visitor with the idea of conceptual change detailed above, thus has the potential to help people learn scientific ideas. However; while at an interactive science centre, neither the analogy nor the scientific idea being presented controls the entire learning process. For this idea, it is useful to subscribe Falk and Dierking's (2000) framework 'contextual model of learning' which takes personal, sociocultural, and physical contexts into account whilst learning in a free-choice environment. Meaning that the personal attributes (such as prior knowledge), how the visitor behaves socially in that setting (such as conversing with peers), and the physical atmosphere will all effect the learning process and the outcome of what is learnt.

Along with these attributes affecting the conceptual outcome, the literature has suggested that there are ways in which learning in a free-choice environment can be facilitated. Included in this argument are the uses of pre- and post-visit activities which help reinforce the content of the visit; using worksheets whilst at the centre which gives student some direction (although it has been argued to ensure the worksheet still allows the students to freely view exhibits); to include some open ended questions that require conversation with peers or adults; and the use of someone to accompany the visitors to give information about exhibits.

This research project is based not only on learning at interactive science centres, but around learning aspects of the NoS at an interactive science centre. While the literature indicates that this is a possibility, it also indicates that it can be difficult as NoS aspects are not always apparent when looking or engaging with an exhibit. It cautions that a reason for lack of NoS at an exhibit can stem from the fact that interactive science centres can fall into the category of just displaying human achievement, described as the 'wonders of science', as opposed to displaying science as a tentative, not always right or certain, human enterprise. Succinctly, by

employing some of the techniques outlined above, there is a great potential that interactive science centres may be able to teach aspects of the NoS to students.

2.5 Literature Review Summary

The literature read has indicated that there is a consistent view on learning in science that is used by the science education community. This view is that for someone to learn in science, they are required to go through some type of conceptual change process which will ultimately alter their original conception or mental model, and allow them to express the new idea. For this conceptual change process to occur, the person needs to have their original conception (or misconception in some cases) challenged to induce a state of dissatisfaction. Once challenged, and in this state where their original ideas will not fit the information, they are able to develop and rebuild their ideas, thus taking part in a conceptual change process. This process may be helped by the use of scientific models, or teaching models (which are influenced by scientific models), which set out to challenge ideas and information, and align conceptions with those that are accepted in the scientific world. It is also important here to indicate that this conceptual change process can happen in a variety of learning environments.

While there are many different learning environments, the literature offers two different categories to categorize learning environments: one is referred to as a formal environment, which encompasses any environment that follows a strict agenda for learning such as a classroom. The other is a more informal environment which is referred to as a free-choice learning environment as the person involved chooses what they learn. Notwithstanding, the literature has also cautioned that just because a learning environment is physically deemed a free-choice learning one, it can still be a formal environment if the students are required to follow strict instructions, and the lesson is still teacher directed.

There are many examples of free-choice environments, however this research is primarily focused on interactive science centres. Over time, interactive science centres evolved from the idea of a museum that house some type of collection,

traditionally art or natural history, into a visitor-centred learning environment where the visitor not only views some type of scientific phenomenon, but is able to be in control of the exhibit somehow. The first of this type of learning environment was *Exploratorium*, which was an interactive science centre, developed and built in San Francisco in 1969 by Frank Oppenheimer who believed that the public should have an understanding of science. It was thought that one way to achieve this goal was to create this type of hands-on learning environment. Now there are many of these interactive science centres situated around the world, including New Zealand which is home to seven of these centres, as well as a mobile interactive science show that visits smaller towns and cities around the country.

Interactive science centres have been critiqued for their uses, and for the most part are seen as a free-choice learning environment that enables students and visitors alike to take a hands-on approach at an exhibit and go through a conceptual change process. While there is evidence that suggests students learn science whilst visiting these environments, the key question this research project is interested in is ‘can students learn about the NoS at an interactive science centre?’ To discuss this question first though, there needs to be an understanding on the NoS, and its importance.

The definition of the NoS is a tentative one, and has been for a long time. Though, the literature has pointed out that we should expect an inexact definition that is under constant scrutiny since it is trying to define that nature of this entity called *science* that is also tentative and constantly changing. Although the explanation of the NoS is tentative, and requires further discussion and defining, there are some themes that some researchers and authors have agreed on. Themes include taking into account how psychological and social factors have influenced science, the empirical and tentative aspects of science, and recognising that science is a human enterprise that doesn’t know all of the answers. While the definition is still requiring further refinement though, the NoS has been recognised as an important teaching area and thus is cited in policy document in relation to teaching science.

The New Zealand Curriculum is a policy document that outlines what is required to be taught at the eight levels of formal education. This curriculum has recently undergone a major reform, and the science section now places a greater emphasis on the NoS than it had done previously. This new science curriculum aims to teach the NoS to students by using four subsets: understanding about science, investigating in science, participating and contributing, and communicating in science. With this new policy document, teachers are now required ensure that some of these aspects are present in their science lessons to try and portray the NoS. However, the literature has indicated that whilst this is the ideal situation, teaching the NoS to students is no easy undertaking.

It is argued that to teach students about the NoS, the teacher is not only required to have a developed pedagogical content knowledge (PCK), but a PCK that also incorporates aspects of the NoS, thus developing a ‘nature of science pedagogical content knowledge’ (NoS PCK). When a teacher has, or is developing this NoS PCK, they are able to teach the NoS in one of two ways: implicitly or explicitly. An implicit teaching approach to teaching the NoS essentially refers to a pedagogy whereby the NoS is learnt as a by-product. In this, the student carries out the lesson, for example a type of investigation or inquiry, and the NoS can be seen throughout as an underlying theme of science. Secondly is the idea of teaching the NoS explicitly to students which requires the teacher to have planned instructional pieces of the lesson that specifically outline and discuss aspects of the NoS. While these two approaches can be used independently, the literature suggests that to maximize student learning about the NoS, then these two approaches should be used in conjunction with each other. However, employing these strategies can still prove difficult for teachers and educators, which is why it has been postulated that the use of an interactive science centre may provide an environment where students can learn aspects of the NoS.

There have been many factors outlined that can shape the way a person learns at an interactive science centre – or any free-choice learning environment. While it is apparent to point out that the information contained within the exhibit may dictate what the visitor learns, there are also many other factors that are associated with

what is learnt. While taking all of these factors into account to describe learning is quite difficult, some of these factors have been categorized by Falk and Dierking (2000) into three subsets which indicate the key factors that can affect learning in these environments. The three subsets are: the personal aspects – what information, knowledge and attributes does the visitor have before visiting the centre, sociocultural aspects – how does the visitor interact with others whilst visiting the exhibits, and physical aspects – the actual physical atmosphere of the learning environment. It is argued that aspects that fit into these three subsets and the information of the exhibit will determine what is learnt whilst visiting. This describes learning as a whole in an interactive science centre, but it also needs to be clear how someone may learn from specific exhibits.

Most exhibits at an interactive science centre differ from one another, not only in content, but how they try to portray this content to its audience. As exhibits differ from one another, it can be difficult to discuss how each one promotes learning. However, Stocklmayer and Gilbert (2002) have identified a system that allows all types of exhibits to be categorised into four groups: exhibits as exemplars of phenomenon, exhibits as showing only similarities between entities, exhibits showing similarities between both entities and relationships, and exhibits only showing similarities between relationships. The first type is simply an exhibit that displays or represents some type of scientific phenomena, while the remaining three are exhibits that are analogical representations of scientific phenomena, meaning that they portray a scientific idea by using some type of analogy that is more familiar to the audience.

However, while a student is visiting an interactive science centre, the various factors identified above, or the types of exhibit are not the only aspects to take into consideration. With this, the literature has suggested various ways that the learning in this type of environment can be enhanced. These suggestions include using: pre- and post-activities – these are activities that the students and teacher would carry out about the topic that the interactive science centre is covering prior to visiting the centre, and then again some weeks later back at school to help reinforce the ideas; worksheets that give the students some direction, and promote

peer discussion, although it is important that the worksheet is such that it doesn't become teacher centred or dominate the trip leaving little room for free-choice learning; or having someone accompany the students during their trip to help interpret information and understand the point of exhibits. While it may be assumed that this last role is one of the teachers, whilst they are at the centre they transform from a facilitator of learning to a management role that is concerned with logistical and management issues, thus it may be useful to have another person there either for the learning, or to act as a manager.

So far interactive science centres, the NoS, and learning at interactive science centres have been discussed, but this still leaves the question of whether or not aspects of the NoS can be learnt at an interactive science centre. The literature has indicated that interactive science centres do not have the NoS as a central theme (if at all), and therefore it is hard to distil any aspects of the NoS out of exhibits. It is argued that interactive science centres are more concerned with displaying a version of science that only represents great human achievement – described as only showing the wonders of science. It is then suggested that exhibits at interactive science centres need to contain vital NoS information such as science's tentative nature, controversy over ideas, a degree of uncertainty about a claim, and indicate how scientific knowledge comes from a human enterprise and is a product of sociocultural interactions within the scientific community. With this comes the postulation that learning aspects of the NoS is possible at an interactive science centre, the exhibit may just need to shift its focus towards NoS ideas.

Chapter Three

Methodology

3.1 Introduction

This chapter outlines and explains the theoretical basis of educational research as a whole, and the theoretical underpinning of this research. It also details the practical nature of how this research has been carried out. Its layout is as follows: Section 3.2 presents the research questions that were used. Section 3.3 outlines and discusses the theoretical notion underpinning the nature of educational research. Section 3.4 outlines and discusses the three current paradigms of education research. Section 3.5 outlines and discusses the specific research design which includes: the methodology, where the theoretical arguments pertaining to educational research are used to develop a framework to carry out research and answer the research questions; detailed information about the chosen data gathering methods and how these methods fit within the research paradigm; a discussion on validity, reliability, and triangulation considerations; an outline of the participants that took part in the research; and information about ethical considerations. Section 3.6 describes the data gathering process in detail which includes specific details about the data gathering methods as well as information about how the research data was handled and how it was analysed.

3.2 Research Questions

1. What aspects of the nature of science can be represented in a science centre?
2. What aspects of the nature of science do students learn when these specific aspects are highlighted to them at an interactive science centre?

3.3 The Nature of Educational Research

The notion of educational research is concerned with the nature of the investigation and analysis in an educational setting, whereby a variety of qualitative and quantitative research methods are employed with the intention of

obtaining new knowledge about a certain behaviour. This knowledge can then be used to gain a better understanding and insight to a particular area of education and thus attempt to develop answers to specific problems or issues in education (Labaree, 2003; Lather, 1992). It is important to note here that during this analytical research process, knowledge is not always just ‘discovered’ as was perceived during the 1970s in educational research, rather this process allows for the generation and construction of knowledge (Donmoyer, 2006). For example, in an interview situation Kvale (1996) indicates that a construction site for knowledge is created based upon the collaboration and conversation that takes place allowing generation of new knowledge between the two parties.

The knowledge that is generated during this research process is of a special nature and to understand this concept it is useful to consider Labaree’s (2003) view, “if we think of knowledge as ranging from hard to soft and from pure to applied, educational knowledge is both very soft, and very applied” (p. 14). This type of knowledge is ‘soft’ due to the fact that educational researchers are often working in complex, large scale environments which results in causal claims that tend to be not valid, nor reliable (Labaree, 2003). Labaree (2003) further discusses that because of the soft nature of this knowledge, claims made in education “tend to be mushy, highly contingent, and heavily qualified, and the focus is frequently more on description and interpretation than causation” (p. 14). Similarly, this knowledge is applied, as it does not surface from theoretical base, rather “it arises in response to the needs defined by an institutional arena” (Labaree, 2003, p. 14).

This special type of knowledge, along with the complex issues such as “trying to understand social interactions embedded in institutional structures” (Labaree, 2003, p.14) that educational research is faced with, helps to explain the shift of research methods used by educational researchers. Historically, quantitative research methods were predominately used, which stem from a positivist paradigm approach. Due to the special type of knowledge, methods have shifted to qualitative research approaches, which stem the interpretive paradigm – as these methods are “well suited to the task of making sense of the socially complex, variable rich, and context-specific character of education” (Labaree,

2003, p. 14). However, quantitative methods methodology must not be overlooked; this style of data collection has a more definitive feel about it, and is often seen as being “more conducive to casual inference” (Labaree, 2003, p. 14). However, while carrying out this type of research, educational researchers are required to make assumptions and generalisations, and are required to eliminate variables before they are able to reach their elegant models – thus making them abstract, and not valid from a schools actual reality perspective (Labaree, 2003).

3.4 Current Paradigms in Educational Research

When discussing research methods and methodology it is important to outline and discuss the frameworks that set the parameters for the research. With this, the current educational research paradigms are discussed in detail. The section above briefly mentions two very different paradigms in educational research: a positivist and interpretive paradigm. It is important to note that there is a third research paradigm in educational research referred to as the critical paradigm of educational research. The first paradigm to be discussed here is the philosophical position referred to as the positivist paradigm. This philosophy has been a “recurrent theme in the history of western thought from the Ancient Greeks to the present day” (p. 9), although it is historically “associated with the 19th century philosopher, Auguste Comte”, who first coined the term (Cohen, Manion, & Morrison, 2007, p. 9). This philosophical paradigm stems from the empirical principles of the nature and inquiry of science (Scott & Morrison, 2005), in that the “social observations should be treated as entities in much the same way that physical scientists treat physical phenomena” (Johnson & Onwuegbuzie, 2004, p. 14), and explanations of the social phenomena are developed using this observation along with reasoning (Cohen et al., 2007). However, like any scientific theory put forward, there are many criticisms and opponents of positivism, mainly due to its “ontological and epistemological bases” (Cohen et al., 2007, p. 17).

There are a variety of discourses that the opponents and critics of positivism subscribe to, and although these various discourses uphold different epistemological viewpoints, “they are united by their common rejection of the belief that human behaviour is governed by general, universal laws and characterized by underlying regularities” (Cohen et al., 2007, p. 19). Anti-positivists argue that the social world of a human being can only really be understood from the standpoint of the individual, and that the behaviour that an educational researcher is trying to research can only be properly understood if the researcher shares the same frame of reference with the individual. If the researcher is within this frame of reference, they are able to understand the individuals’ interpretation of the world from an inside perspective, rather than an outside one (Cohen et al., 2007). With the arguments against positivist research methods a second educational research paradigm was developed, referred to as the interpretive paradigm.

This interpretive paradigm is characterized by a concern for the individual to which the research pertains, and the “central endeavour” in this interpretive paradigm is to “understand the subjective world of human experience” (Cohen et al., 2007, p. 21). Within this paradigm, the theories that are developed tend to be anti-positivist in nature due to the fact that theory is emergent, and arises from particular situations – meaning that theories must not proceed the research, but rather follow it (Cohen et al., 2007). During this developmental process, the aim of the researcher is to take these theories, which are particular to a person in a set time and place, and then make comparisons to a different time and place – “thus theory becomes sets of meanings which yield insight and understanding of people’s behaviour” (p. 22), and the understandings and meanings can be as diverse as the environment to which they were developed in (Cohen et al., 2007).

The third paradigm that is current and emerging in educational research is the paradigm of critical educational research. “This regards the two previous paradigms as presenting incomplete accounts of social behaviour by their neglect of the political and ideological contexts of much educational research” (Cohen et al., 2007, p. 26). While positivistic paradigms are concerned with technical

knowledge, and interpretive paradigms with hermeneutic knowledge - this paradigm subscribes to a “view of what behaviour in a social democracy *should* entail” (Cohen et al., 2007, p. 26). This paradigm is significant in educational research because it seeks to question and transform situations based upon the principle that behaviour is influenced by the equality and democratic characteristics of a society. This is in contrast to positivistic and interpretive paradigms which are of a technical nature and are trying to gain a better understanding of an issue (Cohen et al., 2007).

3.5 Research Design

3.5.1 Methodology

The nature of research into how effective an interactive science centre is at portraying aspects of the nature of science (NoS) to students is concerned with identifying and understanding what students are thinking when they are using exhibits at an interactive science centre and what knowledge they might take away with them about the NoS. For this process to happen questions must be developed and research methods must allow for the research to interpret student responses. For this research, two qualitative research methods were used to further understand human behaviour in an interactive science centre. Predominantly to investigate whether or not exhibits at the centre can effectively portray aspects of the NoS. Since this research is using qualitative research techniques, judgments will be made by interpreting the qualitative data, thus placing this project within an interpretive educational research paradigm. However, there needs to be some important considerations made, namely the fact that since the data obtained from qualitative research is of a ‘soft’ and different nature compared to quantitative ‘hard’ data, there needs to be a clear framework that the specific research methods fall within.

The specific methodology to shape the methods used throughout this research project is called the *illuminative evaluation* methodology which was developed by Parlett and Hamilton (1972), to have a sharper focus on interpreting the situation.

As this methodology is primarily based on interpreting data, it belongs in the interpretive paradigm and draws upon specific qualitative and quantitative data collection methods (Otrell-Cass, 2001). This technique is also relevant to this research as it focuses predominately on describing and interpreting data that is obtained, rather than focusing on the measurement and prediction of data (Otrell-Cass, 2001).

This illuminative evaluation is seen as an inquiry process whereby the different perspectives of all of the students are taken into account as not all of the students will be thinking the same way about certain things (Kelly, Woolfson, & Boyle, 2008). Throughout this research project, this methodology advocates taking the information obtained from all of the students and developing arguments that make connections between the learning environment that they were in and experiences that they had while they were visiting the interactive science centre.

3.5.2 Data Gathering Methods

Data that was collected from the students during this research project was done using two research methods: interviews and observations. The interviews, more specifically, semi-structured interviews were used as a tool to investigate students' views, beliefs and understanding around aspects of the NoS. These semi-structured interviews were comprised of set 'base' questions that had been developed with the research questions and the research framework in mind, and had the ability to deviate and ask further questions as students responded (Appendix C). Observations were seen as an important part of this research project as their purpose was to investigate and document the behaviour of the students as they visited the interactive science centre. In the following two sections an overview of each of these research methods is given along with discussions of their advantages and limitations for this research.

An interview is a powerful research tool for educational researchers (Cohen et al., 2007) and is required when the research questions require an in depth analysis of the participants responses (Desimone & Le Flock, 2004), rather than simply an

analysis of data that has been collected from surveys and questionnaires, which targets breadth, not depth (Cohen et al., 2007). From an outside observer, an interview simply consists of two people conversing and discussing a topic which is of interest to both of them. However, when attention is focused towards the dialect and body language that exists between the interviewer, and the interviewee, it is clear that the interview process is much more than a simple everyday conversation (Dyer, 1995). Rather, it can be seen as any interaction where “two or more people are brought into direct contact in order for at least one party to learn something from the other” (Brenner, Brown, & Canter, 1985, p. 3) and is a “flexible tool for data collection, enabling multi-sensory channels to be used: verbal, non-verbal, spoken and heard” (Cohen et al., 2007, p. 349). It is these unique qualities that have made interviews a very useful method for data generation in educational research (Brenner et al., 1985), and why interviews were chosen as a research method for this research project.

From the comparison of everyday conversations to interviews, Dyer (1995) suggests that there are a number of important common features amongst most interviews; but the interviews themselves also differ from each other, most notably in their structure. Here, Dyer (1995) outlines that there are two extremes when it comes to interview structure: structured and unstructured interviews (however, some authors divide the concept of interviews into many different types (Cohen et al., 2007)). A structured interview is taken to be an interview where the interviewer has determined the questions and procedures in advance of meeting the interviewee (Cohen et al., 2007; Dyer, 1995). Within this interview, the interviewer is left with little freedom in terms of modifying the questions (Cohen et al., 2007), and in its most extreme form the interviewer would simply read the questions to the interviewee and record the answers given (Dyer, 1995). In direct contrast there is the unstructured interview which when thinking of a continuum lies at the opposite end of the spectrum to the structured interview. In these situations the interviewer has a larger degree of flexibility and freedom available as instead of set questions, they have a topic to investigate (Cohen et al., 2007). During the interview the interviewer “decides what questions to ask from moment

to moment depending on the information volunteered by the informant” (Dyer, 1995, p. 59). Succinctly, unstructured interviews promote free interaction, opportunities for clarification and discussion (Bishop, 1997).

This research project focused on an interview style that is between the structured and unstructured interview referred to as the semi-structured interview, or focused interview (Frankfort-Nachmias and Nachmias, 1996). Here there is a set of interview questions that are developed by taking the research questions and the research framework into consideration. These questions are then used as a guide and allow the researcher control over the direction of the interview (Bernard, 2006). In the context of this particular research it is useful as the research participants were young students, and if they gave an interesting or unclear response the interviewer has the ability to investigate further by asking some probing questions before moving back to the question guide. It would also be useful if students did not understand the question, at which time a modified question could be used to breakdown the key idea that is being targeted.

It is also important here to indicate the key advantages and limitations of this research method. The principal advantage of using an interview research method compared to many other research procedures is the depth of information that it can ascertain (Desimone & Le Flock, 2004). By employing an interview process, it “allows *both* parties to explore the meaning of the questions and answers involved” (Brenner et al., 1985, p. 3). This in-depth investigation and analysis then, along with its collaboration and conversation, creates a construction site where new knowledge can be generated (Kvale, 1996). As well as being a method that allows in depth analysis, another important consideration for research and an advantage of interviews is the response rate. When carrying out research, researchers require a lot of data and evidence to be able to make any credible conclusions and to theorise about their research questions. Due to the nature of an interview, the fact that it is in depth, recorded information, it automatically has a high response rate (Cohen et al., 2007; Frankfort-Nachmias & Nachmias, 1996). This is compared to other research methods such as surveys and questionnaires,

which can sometimes be left blank giving rise to a poor response rate (Cohen et al., 2007).

Like all data collection methods, interviews have limitations. The most notable limitation is the reliability of the data (Dyer, 1995) due to the interviews occurring in a social environment that is a conversation between two parties, and bias results can be generated (Brenner et al., 1985). Here Dyer (1995) indicates that the researcher must then carefully consider the data when coding and interpreting to ensure there is a clear distinction between what the interviewee said, or what the interviewee implied. One suggestion for trying to overcome this problem is outlined as producing and using detailed transcripts of the accounts that took place throughout the interview process. However, while this is the ideal situation, this forms another limitation for interviews: an unavoidable cost. While all research methods will have a cost associated with them, interviews have higher costs in terms of money and time than other research methods (Cohen et al., 2007). For this research, there no was monetary cost as the participants were volunteers; however, there was a significant amount of time required not only for conducting the interviews but also for transcribing and coding the data, compared to other methods such as surveys.

Observations are a data gathering technique frequently used in educational research and on the surface may simply appear as a situation whereby the researcher views the participants. However, by taking a more critical stance on observations they can be seen as being a situation where there is an “opportunity to gather ‘live’ data from naturally occurring social situations” (Cohen et al., 2007, p. 396). Also, data gathered using observations gives specific information about how the participants interact within a certain contextual setting; this information may not be collected when using interviews (Cohen et al., 2007). Working within an interpretive paradigm using qualitative data gathering methods with this live gathering of data ensures that the researcher is able to make first-hand interpretations about the information obtained rather than having to rely on second-hand accounts (Cohen et al., 2007). However, similarly to interviews, observations can have a varying degree of structure and level of participation by

the researcher, and also have advantages and limitations as they are used within various settings.

Observations are flexible data gathering tools that can be used when gathering both quantitative and qualitative data (Menter, Elliot, Hulme, Lewin, & Lowden, 2011). This gives rise to the degree of structure employed for an observation. Structured observations allow the researcher to create a systematic approach which in turn allows for the generation of numerical data which can be used for highlighting patterns and trends (Cohen et al., 2007). Here it is suggested (e.g., Cohen et al., 2007; Menter et al., 2011) that the researcher design an observation schedule card whereby the researcher can enter a code such as a tick or number that discretely describes interactions for the duration of the observation. This can be compared to research where the data will be qualitative and the nature of the observation lies at the other end of the spectrum being unstructured.

Unstructured observations allow for the researcher to gather information on what they have seen and then allow for interpretations to be made that highlight the links between social interactions, conversations, and the contextual setting where the observation took place (Menter et al., 2011; Mulhall, 2003). Within this type of observation, it is outlined that there are two distinct roles of the researcher, namely the researcher either being a participant or a non-participant in the observation (Menter et al., 2011). Working as a participant researcher, the researcher is engaged with the participants during the observation process at the research site. This type of engagement allows for “salient issues, findings and theories to emerge as the information accumulates” (Menter et al., 2011, p. 167). This is compared to a non-participant researcher role whereby the researcher finds a position at the research site that – while distancing from the participants – is still able to view all interactions, and observe the participants interacting without engaging with them (Creswell, 2005).

This research project uses an unstructured observation approach where the researcher is a non-participant. As this research project was within the interpretive paradigm using qualitative data, information around the social and contextual

interactions with the participants were important to be able to make interpretations about behaviour. The non-participant researcher role was appropriate throughout this research project as young students were being observed and if the researcher was participating there would be a risk of generating a different set of data that was influenced too much by the researcher.

Again, similarly to interviews, observations have advantages and limitations when used as a data gathering tool. These advantages and limitations will be influenced by the specific observational methods used as well as the paradigm that has been subscribed to. The use of unstructured, researcher as a non-participant observation to obtain qualitative data in this research project has two key advantages. Firstly, the use of this type of observation is very useful at supplementing data that has been collected using interviews (Menter et al., 2011). The main data collection method used for this research project was semi-structured focus interviews so employing another data collection method that supplemented and collaborated with this was very important. Secondly, like interviews, in-depth information could be obtained about behaviour and social interactions between the participants which could then be used, as outlined above, in conjunction with interview data (Menter et al., 2011).

Notwithstanding the manageability concerns of implementing and carrying out observations, there are other important limitations of this data gathering method that need to be addressed. Again, these limitations stem predominately from a validity and reliability view point. Most noticeably, the problem arises from the question of whether or not what has being interpreted is true of the situation (Cohen et al., 2007). Here it is cautioned that by simply having someone new in an environment, especially when the participants know they are being observed, can influence how the participants behave and interact and thus affect the data (Cohen et al., 2007; Menter et al., 2011). One suggestion to overcome this problem is for the researcher to spend time with, and become accustomed with the participants prior to the research commencing (Menter et al., 2011), which is a technique that was used for this research project.

3.5.3 Validity, Reliability and Triangulation

Reliability is a key concern when designing an educational research project (Dyer, 1995; Lowe, 2007). While Dyer (1995) states that the research should be “capable of returning an accurate result despite the presence of factors which might influence the outcome in one direction or another” (p. 128), it is important to note that reliability has different meanings when applied to quantitative research methods and qualitative research methods (Cohen et al., 2007). Within the context of a quantitative research project, reliability refers to the idea that the results can be replicated. This notion is summed up by Cohen et al. (2007) who state “for research to be reliable it must demonstrate that if it were to be carried out on a similar group of respondents in a similar context (however defined), then similar results would be found” (p. 146). This is compared to when the research methods are qualitative, whereby reliability refers to increasing the accuracy, and minimising any differences between what occurred in the research setting, compared to what the researcher made note of (Cohen et al., 2007). Due to this research project using observation as a data gathering technique, it was important to document everything of importance during that phase of the research..

When discussing interviews as a data collection method, there are two important considerations identified in the literature that relate directly to this research project. First, is the notion of the participants feeling threatened in the interview situation (Cohen et al., 2007; Gadd, 2004). In this situation, there is a chance they will take a defensive stance and be less likely to ‘open up’ and share their ideas freely (Cohen et al., 2007; Gadd, 2004). This was of particular concern during the interview phases of this research due to the nature of the participants, year five and six students. It was decided that students would be grouped together and ice-breaker questions would be used to try and promote a comfortable environment. This is discussed further in Section 3.6.1.

Secondly, there is a reliability concern that stems from the language used within an interview as well as a possible mismatch between questions for different interviews (Cohen et al., 2007; Creswell, 2005). To increase the reliability of the

data, Creswell (2005) indicates that the questions be constructed so that they are quite clear and unambiguous. Similarly, Cohen et al. (2007) indicate that using a highly structured interview which has the same questions would reduce the mismatching problem. The use of clear language was important, and an initial version of the questions was piloted with a year six student prior to the pre-interviews to ensure clarity. It was also decided that while structured interviews have higher reliability than other interviews, a degree of flexibility was required in order to ask probing questions when students gave interesting responses. This allowed for more in-depth questioning which increases the level of validity of the research (Cohen et al., 2007).

Similarly to reliability, validity is also a key concern when designing and carrying out educational research because if the collected data is invalid, the entire research is in danger of becoming worthless (Cohen et al., 2007). Again, a general viewpoint on validity is offered by Dyer (1995) which states that the research must be “actually capable of providing the information which it claims to provide” (p. 127). However, like reliability, validity can have different specific meanings dealing with quantitative and qualitative data gathering methods (Cohen et al., 2007). For example, Cohen et al. (2007) indicate that when using quantitative data collection methods, validity is often concerned with controllability and objectivity. In contrast, validity in qualitative data collection methods is concerned with honesty, depth, and scope. Creswell (2005) indicates that validity has a central aim, which is to develop meaningful ideas and inferences about a sample group or population.

As the primary data collection method for this research project was interviews, it was decided that using a semi-structured method would be the most suitable. This allows the researcher to have a set of guiding base questions for the interview, while maintaining a degree of flexibility whereby the researcher is able to digress from the set questions to ask follow up questions. This style allows for the depth of data collection that is mentioned in the literature, therefore increasing the validity of the data.

The literature also strongly suggests the use of more than one data collection method to increase the level of validity which is referred to as triangulation. Creswell (2005) defines triangulation as being a “process of corroborating evidence from different individuals (e.g., a principal and a student), types of data (e.g., observational field notes and interviews), or methods of data collection (e.g., documents and interviews) in descriptions and themes in qualitative research” (p. 600). Triangulation requires the use of two or more data collection methods and then comparing the data that is obtained to identify similarities and anomalies. If the researcher is able to draw similar concepts from a variety of methods, then there is a greater confidence in the validity of the research (Cohen et al., 2007). The idea of triangulation was taken into account when designing this project. It was decided that combining the interviews with an observational visit would increase the validity of the research.

3.5.4 Participants

A research report in 2007 conducted by New Zealand’s National Education Monitoring Project (NEMP) indicated that there was a significant decrease in student interest in science as they transitioned from year four to eight. With this in mind, it was decided the targeted age group for this research project would be a class of year six students. Initially Exscite was contacted to see whether or not they already had any suitable bookings during the right time period, or if they knew of schools that were repeat visitors to Exscite and may be interested in this research project. Unfortunately this process yielded no success. However, through a network of teachers I was able to contact a teacher who showed some interest. After contacting the teacher initially by email, a meeting was set up to discuss the details with him and his principal. After the meeting, both parties expressed that they were interested in the project and gave their consent for the research to go ahead. From here, the students in his year five/six class were then given information packs and information about consent.

3.5.5 Ethical Considerations

The school principal, classroom teacher, parents, caregivers and students all received information about the research project and informed consent was obtained by all parties prior to any data being collected. Information sheets as well as informed consent letters can be found in Appendix A and B. Data that was collected was treated as confidential and was kept securely on a password protected computer. The names of any participants have been changed to pseudonyms to protect their identities. Prior to any data collection the research was approved by the University of Waikato Ethics Committee.

3.6 Research Process

The data collection for this research project consisted of a three phase approach:

1. Pre-interviews (semi-structured).
2. Observational visit.
3. Post-interviews (semi-structured).

Each of these phases was carried out over three consecutive weeks during the third term (September) of 2011. Both interview rounds were conducted at the participating school using the staff board room, while the observational visit took place at Exscite.

3.6.1 Semi-Structured Interviews

After meeting the students for the first time, I introduced myself and explained to them why I was there and that I was going to be asking them some questions. From here their teacher randomly split the class up into six focus groups that had approximately four students in each. Group by group, students accompanied me to the staff board room where the semi-structured interviews commenced. After greeting the students I explained my purpose again, talked to the students about being recorded and showed them the recording device. Some introductory

questions were also used as an ice-breaker to get students comfortable talking in front of me before starting the interview. Once the students seemed comfortable sharing their ideas the interview process began, which followed the guiding questions which can be found in Appendix C.

Using focus groups for the interviews rather than conducting one-on-one interviews proved to be useful for three reasons. First of all, running six semi-structured interviews is more cost effective and efficient than trying to carry out approximately 25 individual interviews. Secondly, interviews can be a daunting experience for anyone. From the perspective of these students then, it would be fair to think that going into an interview room with someone they have not met before, and who is going to ask questions and then record the answers would be an intimidating experience. By having the students grouped together with their classmates, it was anticipated that they would feel more comfortable. As mentioned earlier, this was done to increase the level of reliability in the data collected. Thirdly, in Chapter Two the social construction of knowledge for learning in science is outlined. From there it seems appropriate then to create an environment for the students that allowed for the social construction of knowledge and ideas. It was anticipated that students would be able to share their ideas with each other in more of a discussion rather than simply asking questions. With this important consideration, throughout the interview process questions would be asked to the whole group rather than to individual students, although there were allowances for this. Careful consideration was also put into the use of leading questions, in that they should be avoided. However, due to the level of understanding for some of the students, one of the methods was to ask the question in a different way and to perhaps use an example they would understand. Even though this may compromise some of the questions, some useful information can still be obtained.

3.6.3 Observational Visit

The observation visit took place with the students at Exscite and was done in two parts: general class observations and specific focus group observations. Here students were split into their original focus groups and given some general instructions around the visit, and my role and presence was outlined again. Two of the focus groups were chosen based on the information they had given in the pre-interview phase to be treatment groups. These groups were taken aside and it was explained to them that I would be observing them as they interacted with some of the exhibits. While they were interacting with the exhibits and each other, it was also asked if they could read and discuss some questions (Appendix D) based around the exhibits. It was also mentioned that their discussions would be audio recorded.

Upon entering the interactive science centre, general observational information was documented about the students' initial reactions and behaviour as a whole group. After further instructions, the students were allowed to explore the centre at their will whilst remaining in their groups. Again, some general observational notes were taken about the student group as a whole and how they interacted. Once this general observational phase had been completed, the treatment focus groups began interacting and discussing using the guidelines. During this phase where the two treatment groups were interacting with the exhibits an unstructured observational approach was used, whilst I also remained a non-participant and simply observed and took notes at a distance. (Some recorded data also required some verification due to noise during the observational visit, and this recorded information can also be used to generate further discussion during the post-interview phase of the data gathering process).

3.6.4 Data Handling and Analysis

Both rounds of interviews were audio recorded, as were the discussions during the observational visit. These recordings were transcribed by the researcher, and once completed the recordings were listened to again to identify any anomalies in the

transcripts. Observational data was documented by the researcher using a research diary. In accordance with ethical guidelines set out by the University of Waikato, all data was kept securely by the researcher.

Once all of the recordings had been transcribed, each transcription was read through several times with the intention of making some early links within the data, which was noted. From here, the data was thematically approached (Creswell, 2005). Several themes were identified which gave an opportunity to better organise the data. Once data was organised into themes, the data was then analysed further using codes that made links between various aspects of data within a certain theme.

Observational data was also analysed in a similar way, and themes from the observational visit were also related and linked to the data analysed from the interviews.

3.7 Summary

Section 3.2 of this chapter outlines the research questions for this research project, and Section 3.3 outlines and discusses the nature of educational research. Educational research is concerned with the philosophical notions of finding new information within an educational context. Here it is also outlined that there are two types of methods for gathering data: quantitative and qualitative. Quantitative methods generate numerical data that can be manipulated and analysed using a statistical approach which highlights patterns and trends. Conversely, qualitative methods generate information about behaviour and interactions that can be interpreted by the researcher. This leads into the discussion about the research framework which is outlined and discussed in Section 3.4.

There are three current paradigms that govern the framework for the research in educational research: positivist and interpretive paradigms, and the emerging paradigm of critical educational research. Firstly, the positivist approach stems from a scientific point of view, which advocates for treating information in an

educational setting in much the same way that information is treated by physical scientists. Anti-positivists argue that the researcher should be a part of the frame of reference for the research to understand the information to its full extent, thus advocating for a situation, whereby the researcher interprets situations within an educational environment. These arguments lead to the development of the second educational research paradigm, referred to as the interpretive paradigm. This research paradigm advocates for the researcher gathering data and then making interpretations that link not only pieces of the information gathered, but also links with the contextual setting of where the research was carried out. The interpretive paradigm was adhered to for this research project. Lastly, is the paradigm of critical educational research. This research paradigm is emerging in educational research and argues that the positivist and interpretive paradigms do not give enough information about social interactions as behaviour is influenced by political characteristics of a society.

Section 3.5 outlines and discusses the research design for this research project. Firstly, the methodology is discussed. The specific methodology used for this research project is called the illuminative evaluation methodology. This methodology falls within the interpretive paradigm and can draw from a range of quantitative and qualitative data gathering methods. Succinctly, it is an inquiry process that takes various perspectives into account, which allows links to be developed between the context of the interactive science centre and student experiences.

Once the specific methodology has been outlined it is important to discuss the particular data gathering methods that will be used for this research project. It was decided that interviews and observations would fit with the aims of this research project and within the chosen research paradigm and research methodology. Whilst there are many different types of interviews, for the specific aims of this research project it was decided that semi-structured focus group interviews would be the most appropriate. Similarly, there are different types of observations and it was decided that an unstructured observation where the researcher was a non-

participant would complement the data gathered from the semi-structured interviews.

When carrying out educational research it is important to consider how reliable and how valid the data that has been gathered actually is. The research indicated two concerns when discussing reliability of data gathered from interviews, which are: students not ‘opening up’ during the process and discusses their ideas, and the consistency of the questions. To increase the reliability of data for this research project a rapport between the research and participating students was established as well as using ice-breaker questions with the intention of making the students feel comfortable. For question consistency, a base set of questions were used for each interview, although the researcher did have a degree of flexibility and was able to digress from the base questions and ask follow up questions. For observational data collection methods, the literature indicates that there can be a reliability concern if some information is overlooked. To counteract this dilemma, during the observational visit detailed notes were taken to ensure nothing was disregarded.

Like reliability, validity is an important consideration. This notion discusses how valid or true the data that has been collected actually is, that is, does the data actually represent what it intended to. When employing qualitative data collection methods, the literature indicates that the key to ensuring validity pertains to the depth of data collection. As briefly mentioned earlier, the research had base questions but also had a degree of flexibility. This flexible style of interview allowed for the researcher to ask further probing questions when the students gave interesting or unclear answers.

This research project also observed the idea of triangulation to increase the validity of the data, whereby two or more data collection methods are used. This process then allows the research to compare the data that was gathered from the different methods and then draw similarities and identify anomalies. It is also suggested that if the data from different sources does produce ideas that are similar, then the researcher may feel more confident about the validity of the

research process. With the goal of increasing the validity of the data by using a triangulation method, interviews were used in conjunction with observational visits.

The participants used for this research project were a class of year five and six students along with their teacher. All of the parties involved, including parents and caregivers of the students, and the school principal, received detailed information about the research that was to be carried out as well as being provided with informed consent letters. All parties are kept anonymous throughout the research project.

Section 3.6 outlines the specific research process which includes how the data gathering methods were employed, and how the data was handled and analysed. The data was gathered using a three phase process. Firstly, the researcher conducted semi-structured interviews with groups of students with the intention that if they were in a group they would feel more comfortable and be more forthcoming with their ideas than if they were by themselves. During these pre-interviews the students were asked a series of guiding questions whilst having the freedom to discuss a topic or idea of interest further. The second phase was an observational visit to an interactive science centre, Exscite. Here there were some general observations made about the class as a whole and how they interacted within the interactive science centre context. There were also two focus groups used as treatment groups that discussed some questions whilst interacting with two exhibits. As they interacted with the exhibits they were also being observed by the researcher. On returning back to school, the students were involved in a second round of semi-structured interviews using their same focus groups. Students were again asked a series of guiding questions that were similar to those from the pre-interviews.

Original raw data that was obtained was kept secure by the researcher. Recorded data was then transcribed and the recordings listened to again to ensure accuracy. Once a set of clear and accurate transcripts were obtained, the researcher identified various themes throughout the information. These transcripts were then

organised based around the identified themes, and then further coded to make links between what students said and their observations. The information that was obtained is presented in the following findings section, Chapter Four, and the discussion of what these findings mean is in Chapter Five.

Chapter Four

Findings

4.1 Introduction

This chapter describes information obtained during the data collection phase of the research project. Firstly, the context of this research project is outlined in section 4.2. Secondly, information collected for the first research question: “What aspects of the nature of science can be represented in a science centre?” is outlined and discussed in sections 4.3, 4.4, and 4.5. Thirdly, information collected about the second research question: “What aspects of the nature of science do students learn when these specific aspects are highlighted to them at an interactive science centre?” was done using pre- and post-interview questions, as well as discussion questions for two of the focus groups. Questions throughout the interview processes were directed towards finding out what students initially knew about science, scientists and most importantly the use of (teaching) models in science. The information collected here was thematically analysed with several central themes deriving from the intervention questions themselves. Sections 4.6, 4.7, and 4.8 outline each theme and then discuss them further using information that has been obtained from the students that were part of the research.

4.2 Context: School and Exscite

The school that was used for this research project was an urban state integrated Catholic primary school with a decile rating of six. Decile ratings refer to the socioeconomic status of a school with one being the lowest, and 10 being the highest. The school is considered a full primary school and caters for students from a new entrant level through to year eight and had a roll of 456. From this school, one class was used for data collection in this research project. The class that participated had a roll of 27 and was made up of a mixture of girls and boys that ranged from years five to six (nine and 10 year olds). Their teacher, Homer (pseudonym), completed a Bachelor of Teaching (Primary) degree and during his last professional practice teaching placement was offered a job. Homer is now an experienced teacher in his ninth year of his career, teaching years five and six and also teaching the younger year four students for a period of time. Homer also has

an interest in science, studying physics at high school to year 13 level, as well as completing a science paper at university at a stage two level. While there is an interest in science, due to the government requirements (as set out by the New Zealand Curriculum document) and school administration requirements, some areas of learning had to be modified, or in some cases removed. Homer expressed that when these changes were made, science was often one of the first subjects to suffer to ensure there was adequate time for literacy and numeracy based learning. Upon talking to Homer and his principal about the research project, both parties expressed that they would like the class to be involved with the research that was to be carried out in conjunction with Exscite, an interactive science centre.

Exscite (a name derived from **Ex**plorations in **Science** and **T**echnology) is an interactive science centre in the Hamilton central business district which is adjoined to the Waikato Museum building. Exscite's original conception was in the early 1990's by a local body called the Waikato Science Centre Advisory which was made up of local scientists and educators who wanted to promote science education. During the time of conception and its now permanent location, Exscite was housed at a variety of temporary locations until permanent facility funding could be obtained. During the initial stages of developing Exscite as an interactive science centre, there were similar initiatives around New Zealand which were being encouraged by the Royal Society of New Zealand which envisioned setting up a network of science centres across the country whereby resources and knowledge could be shared. In 1993, some of the key people that were the driving force behind Exscite then went to form the Exscite Trust which advocated for council approval and funding to acquire a permanent facility for Exscite. In 1994, the Exscite Trust secured funding from the local council as well as the New Zealand Lotteries Board and they were granted a space for a permanent facility next to the existing Waikato Museum. Construction of the facility began soon after and Exscite was officially opened in its new permanent facility in January 1996.

Like many interactive science centres however, funding became an issue for Exscite. Hamilton City Council declined to fund Exscite's operational costs in

June of 1996, and Exscite's future was uncertain as it was threatened with closure. In the following month, July of 1996, Exscite advertised its closure. The next year would prove crucial to the survival of Exscite as the Trust entered into complicated negotiations with the Hamilton City Council. In August of 1997 the negotiations were completed and Exscite was granted funding enabling it to continue. After a difficult first few years, Exscite is now a successful interactive science centre with a mission statement that reads: *to promote and popularise science and technology to members of the general public through the use of interactive exhibitions and exciting and constantly changing education programmes*. With this mission statement in mind, Exscite has housed and developed many interactive science exhibits that have been used to educate a variety of people, with an evident focus on primary school children.

4.3 Interactive Exhibits Used for this Research

Exscite is home to a variety of interactive science exhibits; however, only two were used as a focus for this research project. The two exhibits that were used were chosen because they were able to highlight some aspects of the nature of science (NoS). During an early visit to Exscite, it was difficult to identify NoS aspects with many of the exhibits. It seemed that the majority echoed what the literature had warned about: exhibits are designed without the NoS in mind; rather they represent human achievement in science, which can be categorised as the 'wonders of science'. With this in mind, several exhibits were eliminated as these were unsuitable for this project. Upon realising this dilemma, a more critical selection process was undertaken about each exhibit of interest and were analysed. The notes of each exhibit were compared to the NoS achievement objectives outlined in the New Zealand Curriculum document, with an aim to identify any strong links from the exhibit to the NoS. From here, judgements were made about each exhibit and, after careful consideration, two exhibits were selected for this project, they were 'Harnessing the Potential', and 'The Grain Factory'.

Sections 4.4 and 4.5 include details about the two chosen interactive exhibits at Exscite that have been selected as they suit the requirements of this research project. Each sub-section contains a brief overview on how the exhibit works, ‘the big science idea’ which outlines the scientific concepts underpinning the exhibit, an interpretation of what the learning intentions should be and what its aim is, and how it links to the NoS. With the aim of making these sub-sections as clear as possible, photographs have also been included where appropriate. As this research project is predominately focused within the New Zealand education framework it is fitting to link the NoS aspects back to the Science in New Zealand Curriculum. As the target group is years five and six, the majority of the class will be operating within level three of the curriculum so I have made links to level three, nature of science:

Students will:

Understanding about science

- Appreciate that science is a way of explaining the world and that science knowledge changes over time.
- Identify ways in which scientists work together and provide evidence to support their ideas.

Investigating in science

- Build on prior experiences, working together to share and examine their own and others’ knowledge.
- Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations.

Communicating in science

- Begin to use a range of scientific symbols, conventions, and vocabulary.
- Engage with a range of science texts and begin to question the purposes for which these texts are constructed.

Participating and contributing

- Use their growing science knowledge when considering issues of concern to them.
- Explore various aspects of an issue and make decisions about possible actions.

(Ministry of Education, 2007)

4.4 Harnessing the Potential

4.4.1 Brief Overview

This interactive exhibit requires students to use a hand pump system that pumps water into a partially full elevated holding tank. Once the tank has reached a certain volume, the excess water overflows down a chute where a turbine is spun to create electrical energy and in turn, light up a model house.



4.4.2 The Big Science Idea

There is a plethora of scientific ideas within this exhibit. There are many good conceptual points about the physical world of science, and there are also some important underlying aspects of the NoS. Firstly, the physical ideas, and then the NoS links follow below: the point that the exhibit designers are trying to make is that energy can be transformed from one form to another. You start with chemical potential (i.e., your food), which transforms into kinetic (i.e., using the pump). As the water is pumped to a holding tank which is high, the water has to do work against gravity which in turn gains gravitational potential energy. The water then rushes down the chute, which transfers the water's gravitational potential energy into kinetic energy and then uses this energy to spin the turbine at the bottom. As the turbine spins with the water, it spins a coil of copper wire within a magnet which serves to transform the kinetic energy of the water into electrical energy to light up the house. It also gives a description of how a large-scale commercial

hydro-electric turbine functions in relation to the exhibit. Some of the specific terms that are used are of too higher level for level three students, but as part of the curriculum they should be able to understand different forms of energy and some energy transformations.

4.4.3 Included Information

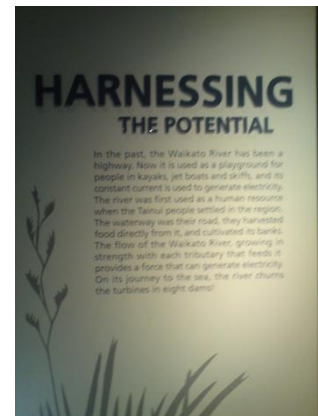
Below are some photographs of different pieces of information that accompany the actual exhibit.

1. Firstly, there is detailed information about the history of the Waikato River, and how it is important to this exhibit.

The information reads:

In the past, the Waikato River has been a highway. Now it is used as a playground for people in kayaks, jet boats and skiffs, and its constant current is used to generate electricity.

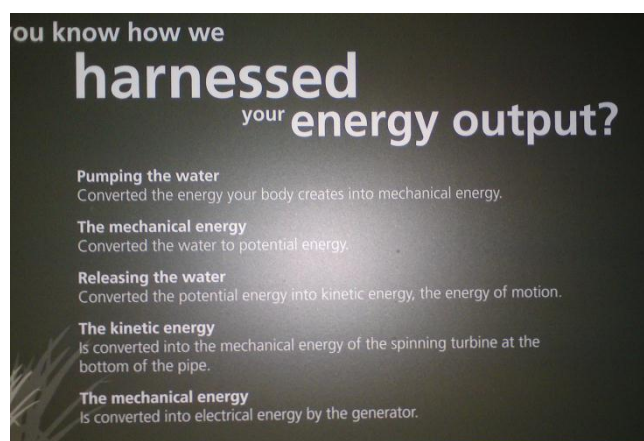
The river was first used as a human resource when the Tainui people settled in the region. The waterway was their road; they harvested food directly from it, and cultivated its banks. The flow of the Waikato River, growing in strength with each tributary that feeds it provides a force that can generate electricity. On its journey to sea, the river churns in eight dams!



2. Secondly, there is some information about what is meant by the whole idea of harnessing energy.

The information reads:

Do you know how we



harvested your energy output?

Pumping the Water

- Converted the energy your body creates into mechanical energy.

The Mechanical Energy

- Converted the water to potential energy.

The Kinetic Energy

- Is converted into the mechanical energy of the spinning turbine at the bottom of the pipe.

The Mechanical Energy

- Is converted into electrical energy by the generator.

- Underneath the sign about harvesting energy, there is another display that explains that this is a simplistic model of what is really going on in a hydro-electric dam.

The information reads:

Similar in Principle!

This simple model works on the same principles as a hydro-electric power station.

A hydro-electric power station uses the water stored in a dam. This is called potential energy. When the water flows down the penstock pipes towards the turbines, it has become kinetic energy, the energy of motion. The water turns the turbine to create electrical energy.



There is also some information on how the generator uses kinetic energy to generate electricity, but is too complex for the age this research is targeting as it talks about valence electrons and their movement.

4. Directly next to the crank handle there is some information about the whole aim of this exhibit.

The information reads:

Can you power up the national grid?

- Pull the lever back and forth to pump water to the holding tank.
- A valve will open to release the water to drive the turbines at the bottom.
- Power the national grid and watch as the power reaches Hamilton's house.



There is also a pictorial representation of this information on the exhibit itself.



5. Lastly there is a model house that lights up if there is enough electrical energy. It is called Hamilton's house and there is a story that accompanies it, in terms of what is using electricity in each of the rooms.



4.4.4 Learning Intentions

These learning intentions are an indication as to what students may learn after interacting with this exhibit. They are an interpretation based on my experience as a science teacher, information I was given by the science officer at Exscite, and as well as having an input from a museum host that I discussed the exhibits with.

For a class of year five six students, who are working within level three of the curriculum framework, after interacting with this exhibit I would anticipate that the students will:

- Understand that energy can be transformed into different forms.
- Outline the basics of a hydro-electric power system.

4.4.5 Nature of Science Links

There is a lot to be said about the NoS for this exhibit. To attempt to outline everything, I will break it into the NoS strands outlined by the NZ curriculum.

Understanding about science:

- Science is just one way of explaining the world. We cannot see energy, but we ‘know’ it is there, and energy transformation is an abstract concept.

Investigating in science:

- Exploration of prior knowledge sharing of experiences and identifying sources of evidence.
- The use of simple models to explain scientific phenomena. Exhibits are often seen as scientific teaching models as their purpose is to portray scientific ideas in such a way that the user can easily identify with, and make the connection between the teaching model and the *real* scientific phenomena that it is portraying. Succinctly, it is analogous to a scientific model to help students learn by helping them to develop a mental model or mental representation of what is

happening. This mental model then sets the student up to be able to express orally or written what they have learnt.

Communicating in science:

- Science often uses a range of conventions and specific vocabulary: potential energy, kinetic energy, chemical energy, electrical energy, energy transformations. The purpose of having terms and conventions that may have specific meanings in science is so scientists can discuss and collaborate on problems without having ambiguity. Misconceptions in science are often because of the confusion between the use of everyday language and science specific language.

Participating and contributing in science:

- This exhibit promotes the idea of using an existing natural resource as a renewable source of electrical energy. This idea may be able to be used by the teacher to generate a discussion about the issue of concern: renewable versus non-renewable energy. Students may then have an opportunity to act as scientists by participating and contributing to class discussions around this problem.

4.5 The Grain Factory

4.5.1 Brief Overview

The Grain Factory is a permanent (since Exscite's conception) interactive exhibit which challenges students to move grain around a complete cycle using a variety of different techniques which is made up of six different machines.



4.5.2 The Big Science Idea

Scientists can be problem solvers, and one problem that plagued humans was how to transfer commodities like water and grain either laterally (across), or vertically (upwards against gravity). This interactive exhibit consists of six different machines that show how we can overcome these problems, by shifting grain around in a circular fashion. Included is the use of an Archimedes Screw which was a scientific discovery centuries ago, but is still used today. This exhibit also employs the use of conveyer belts, where some grain is placed on the belt at one end and then the user cranks a handle to move the grain to the next machine. They also demonstrate a bucket and conveyer belt system, where buckets pick up the grain, and then move up hill with it to be deposited at the top. This whole exhibit is predominately physics based as it is concerned with aspects of mechanics and the machines also have labels next to them which explain not only what each part is, but what it is used for.

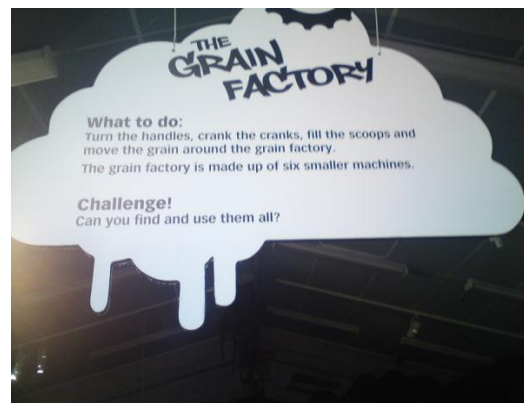
4.5.3 Included Information

This exhibit has a small display brief that hangs above the exhibit, as well as having some key words painted on the actual exhibit.

The brief display contained the following information:

What to do:

- Turn the handles, crank the cranks, fill the scoops and move the grain around the grain factory.
- The Grain Factory is made up of six smaller machines.



Challenge!

- Can you find and use them all?

Each of the six different machines has a key word associated with it:

1. Wedge (used to scoop the grain).
2. Screw – move grain from one place to another.
3. Pulley – makes it easier to pull the conveyer belt.
4. Cam – changes circular movement into straight (linear) movement.
5. Wheel and axel – together they work as rollers moving the conveyer belt.
6. Tilting hopper – (a container that tilts from side to side depending which side is heavier).

4.5.4 Learning Intentions

These learning intentions are an indication as to what I deduce the exhibit is aiming to teach students. They are an interpretation based on my experience as a science teacher, information I was given by the science officer at Exscite, and as well as having input from a museum host that I discussed the exhibits with.

For a class of year five and six students, who are working within level three of the curriculum framework, after interacting with this exhibit I would anticipate that they could:

- Highlight some specific key words that are used in mechanics.
- Discuss how we could use some of these mechanisms in a different way. (For example, using the screw or buckets to take water from a low point to a higher point).
- Discuss the idea that scientists are problem solvers, and how they work together.

4.5.5 Nature of Science Links

Understanding about science:

- Students may think about how important it is for scientists to work together and share ideas. A good way to use this exhibit to highlight this is to have a student move some grain around the entire exhibit by themselves, and then have them work in pairs or groups. After this activity, it may be shown that working together is superior to working alone.

Investigating in science:

- This exhibit is a physical teaching model for students to explore and interact with. It is a teaching model which has been specially crafted to be analogous to a scientific model to help students learn by helping them to develop a mental model or mental representation of what is happening. This mental model then sets the students up to be able to express orally or written what they have learnt.

Communicating in science:

- After interacting with this exhibit, students may be able to describe each of the six machines and what each part is used for. Students may also be able to explain how these machines have made some tasks easier and may be able to give their own example(s).

Participating and contributing in science:

- This exhibit does not put great emphasis on exploring issues to work towards a resolution, as they only have to 'crank the handles'. However, I do believe that that the students will still have to explore the exhibit and use each other's knowledge to reach the end result of the grain completing a cycle.

4.6 Interviews: Pre-Visit

Students were divided up into six roughly even focus groups by their teacher and then taken to a separate room for the first round of focus group interviews. The class has a roll of 27, but five students were away leaving an available 22 students. This was the first meeting with the students, and given their age it was understandable that they were nervous. The semi-structured interview procedure then began and they were asked a series of questions that were drawn from six key themes. This process was audio recorded. Each theme is outlined below with details of what the students said including excerpts from the transcriptions. All of the student names that are used for excerpts are pseudonyms.

4.6.1 Previous Science Experiences

After meeting with students and explaining who I was and why I was here working with them, the first question that was asked to them was about science they had previously done. To try and broaden the answers, questions extended beyond any science they had experienced at school to any science that they previously have done either at school or at home. It was clear that many of the students were initially nervous, but others were enthusiastic in sharing their ideas.

Student's initial responses to this question were surprising. Science is something that is clearly outlined in the New Zealand Curriculum document as an important learning area but many of the students claimed to have not done it before. In fact, out of the 22 students interviewed that morning only four students claimed to have participated in some sort of science before. From the six focus groups that were used, two groups claimed to have never done any kind of science previously.

Of those four students that talked about doing science, the experiences they had talked about were from at home or from previous school years. Two out of the four experiences were classic 'volcano demonstrations' whereby a paper-mache volcano was constructed leaving a jar or a similar vessel as the main vent of the volcano. Baking soda, vinegar and red food colouring are then added to the jar resulting in an effervescent experiment that overflows red foamy liquid.

Researcher: *Isabella, what can you tell me about some science you have done before?*

Isabella: *I made a volcano. You put vinegar and stuff in it.*

Researcher: *What happened?*

Isabella: *All that vinegar and stuff came out onto the dirt and made a mess.*

[Talking to Isabella about previous science experiences]

Another experience that was recalled was another example of an over represented experiment where the student puts mints into a bottle of cola. Similarly to the volcano experiment, a foamy liquid is ejected from the bottle, although in this case the reaction can shoot into the air.

Researcher: *Mike, have you done any science before?*

Mike: *When I was younger we did this Mentos thing. We made a Mentos bomb.*

Researcher: *What did you do to make it work?*

Mike: *We got a test tube and put the Mentos in the test tube then put paper on the top of it. We then opened the Pepsi bottle and held the test tube just above it. Then you took the paper away and the Mentos went down and you took the test tube away. Then it goes up, probably like two metres. It was like the volcano experiment. Three kids from our class got to do it and I was one of them. When I pulled my paper out though, sometimes it doesn't work and just fizzes all over you.*

[Talking to Mike about previous science experiences]

In the fourth experience that was mentioned, the student was unable to recall what they actually did, rather, that they had done some science.

Researcher: *Krystal, have you done any science at school or at home before?*

Krystal: *Last year we did. I can't really remember, but it had bottles and stuff.*

Researcher: *Can you explain what you did?*

Krystal: *I can't really remember, just remember doing it last year.*

[Talking to Krystal about previous science experiences]

Surprised by these findings, I discussed it with the class teacher, Homer, after finishing with the focus group interviews. Homer went on to explain to me that these results could be due to the fact that time is a very precious commodity when you are a teacher, and unfortunately science is one of the first subjects to be compromised or even removed from the day to day curriculum to ensure that there is enough time to focus on student literacy and numeracy. Due to these types of restraints, science is only done briefly during one term of the school year, and when it is done it is called 'topic'. This leads into another key point that Homer also mentioned which was often when students do science at school; they do not know that they are doing science because it is referred to as 'topic'. For example, a topic that they might do is the rocky shore, while this is indeed science, students may not pick up on that. Also, when discussing this phenomenon with Homer, he explained that his class had not started their topic study yet, but would come later in the year.

After talking to the student's about their previous science experience, the next question was based around how they saw scientists and what they believe scientists did.

4.6.2 Perception of Scientists

The question around how they perceived scientists yielded an array of results. While it is difficult to sum up a collective argument that is representative of the entire group of students that were interviewed, there was a common theme that scientists are hands on people that had an ultimate goal of finding out ‘stuff’. When questioned about how they find out new things, again the answers were varied but centred on scientists carrying out research in some kind of manner. While students were able to give a brief outline to their thoughts, they were unable to give many specifics about the work of a scientist, or any specific examples. Below are some excerpts of what students said during this question.

Researcher: *Izzy, are you able to tell me what you think a scientist does?*

Izzy: *They mix chemicals and make stuff.*

Researcher: *What else might they do?*

Izzy: *They research heaps of things and test things on animals and people to see what they might be allergic too.*

Researcher: *Anything else you can think of?*

Izzy: *Some scientists make medicine to help people get better.*

[Talking to Izzy about her perception of scientists]

Researcher: *Sarah, can you tell me what scientists do?*

Sarah: *Learn about what is happening in the Earth.*

Researcher: *What else do scientists do?*

Sarah: *They do experiments.*

Researcher: *How do they do experiments?*

Sarah: *Probably with an animal, they might research it or something.*

[Talking to Sarah about her perception of scientists]

Researcher: *Katie, are you able to tell me what a scientist does?*

Katie: *They figure out how things work, and make things.*

Researcher: *What sort of things do they figure out?*

Katie: *How things work.*

Researcher: *Are you able to give me an example?*

Katie: *No.*

[Talking to Katie about her perception of scientists]

One focus group was also able to relate the idea of research to what they had previously done in class. That is, using books and computers when they are faced with a question or problem.

Researcher: *Choin Wain, what do you think scientists do?*

Choin Wain: *They find out stuff.*

Researcher: *How do they find out stuff?*

Choin Wain: *They experiment and do research.*

Researcher: *How do they do their research?*

Choin Wain: *With books and did research on the computer, the usual stuff.*

Researcher: *What's the usual stuff?*

Choin Wain: *What we usually do. Go on a computer, on the internet, but if you don't have the internet then use books and things.*

[Talking to Choin Wain about his perception of a scientist]

During the discussion on how students perceived scientists, one interesting point was brought up, which was about different types of scientists. However, it was not something that was identified by all groups, possibly because it was not a direct question.

4.6.3 Different Types of Scientists

When discussing their perception of a scientist, two out of the six focus groups discussed the idea that the term 'scientist' is quite a general term, and under that heading there are in fact many different types of scientists. Below are the examples of typical excerpts from each of the groups in regards to the notion of different types of scientists.

Researcher: *Chris, can you tell me what scientists do?*

Chris: *Well there are different types of scientists. Like volcanologists that study volcanoes, and geologists that try and figure out what type of chemicals there are in the world. Lots of stuff.*

[Talking with Chris about different types of scientists]

Researcher: *Michael, are you able to tell me what a scientist does?*

Michael: *Aren't there lots of different types of scientists?*

Researcher: *There are lots of types, what different types do you think there are?*

Michael: *Ones that look at space stuff.*

Fred: *Medical ones.*

Harry: *Ones that look at marine animals.*

Karl: *Ones that study moon rocks.*

Michael: *Aren't the ones that study Earth called geologists
or something?*

Harry: *They can study plants and that.*

[Talking with a focus group about different types of scientists]

After discussing perceptions of scientists and roles of scientists with students, the next part of the research was to ascertain whether or not they had seen scientists.

4.6.4 Science in the Media

This theme has been derived from the questions whereby students were asked if they had seen a scientist or not. Similarly to the first question in the interview process, the question was posed in a broad style. Rather than limiting students to real life examples, they were asked about whether or not they had seen scientists in books, on television programmes, movies – where ever they could give an example.

Most of the students had not seen a scientist in real life, but when asked about books and television examples they could all share something. Examples that students were able to discuss included Albert Einstein, cartoon characters, Discovery channel and the news. Excerpts of what some students said about scientists and science they had seen before in the media are outlined below.

Researcher: *Have you ever seen a scientist in real life, in a
book, or on television?*

Bob: *Does Albert Einstein count?*

Researcher: *Of course! Where have you seen Einstein?*

Bob: *On television.*

Choing: *I've seen him in a book.*

[Talking to a focus group about where they had seen scientists]

Researcher: *Have you ever seen a scientist in real life, in a book, or on television?*

Acasia: *Do movies count?*

Researcher: *Yes.*

Acasia: *Back to the future, as the bell rings, Phineas and Ferb. There was also this movie but I can't remember its name, the guy could blow bubbles from his fingers.*

Daisy: *Oh, that's inspector gadget.*

[Talking to a focus group about where they had seen scientists]

Researcher: *Have you ever seen a scientist in real life, in a book, or on television?*

Michael: *Yes.*

Researcher: *Where have you seen one Michael?*

Michael: *I went to this space thing out around by the zoo, and there was this scientist there and he was talking about the moon and stuff.*

Researcher: *Okay, what did you learn from him?*

Michael: *It was a quite a long time ago so I can't really remember.*

Researcher: *Okay, have any more of you seen scientists?*

Karl: *I have seen one on television.*

Researcher: *What programme?*

Karl: *On like channel 70 I think.*

Fred: *That's Discovery.*

Harry: *One News sometimes has them too.*

[Talking to a focus group about where they had seen scientists]

This question marked approximately halfway through the interview process. Now that some of their basic knowledge about scientists and their work had been ascertained, questions that required them to think more scientifically and analytically were to follow.

4.6.5 Scientific Theory Development – How Ideas Change

This theme of the research was made up by three different questions. Firstly, it was introduced to students by asking them if they thought that scientists always agreed with each other. All students answered 'no'. Many of which then went on to discuss that it comes down to differing opinions and that they had to prove their ideas to other scientists for others to accept it. It was also mentioned by a few students that different opinions could be sorted out by using a voting system.

Researcher: *If there are two scientists, do they always agree with each other?*

Alex: *No.*

Researcher: *Why do you say no, Alex?*

Alex: *Because they always have different opinions.*

Researcher: *Okay, what do you think about that, Chris?*

Chris: *I'm going to have to go with Alex, and put different theories.*

Researcher: *Okay, what do you think about that, Mike? Scientists not always agreeing with each other.*

Mike: *Not always, sometimes they do, but not always.*

Researcher: *If they don't agree with each other, what do they do, Mike?*

Mike: *They work it out again.*

Researcher: *How do they do that?*

Mike: *Well, they do everything they did again to make sure it is right, except they now work together.*

[A focus group discussing how scientists do not always agree with each other]

Secondly, after initially discussing the idea with students that scientists do not always agree, the next interview question then lead into how scientific knowledge is created. Here, the students were asked what makes scientists change their ideas. This question was met with varying responses. Students alluded to the fact that if ideas are challenging each other, then the research needs to be conducted again – this time in conjunction with each other. Two of the focus groups also mentioned that to change someone's idea, you must first prove it wrong, and then prove the other idea to be correct. As mentioned earlier, voting was mentioned by some students as a way to decide which scientific theory would become the accepted one.

Researcher: *If a scientist has an idea, how might that idea change over time, Izzy?*

Izzy: *They might find some new things.*

Researcher: *How will they find new things?*

Izzy: They might research it a lot. They might have an idea in their head from the start, but then it will start to change as they research it more.

[Talking to Izzy about what makes a scientist change their idea]

Thirdly, after exploring perceptions of scientists not agreeing with each other and changing their ideas over time, the students were asked about how scientific knowledge could be created if there was something that was completely new to scientists. This question was a tricky one for the students to understand, perhaps it was too complex for their age, but with some gentle probing and the use of examples, students were forthcoming with their ideas.

Student responses to this question were quite varied. A few students were still unsure of the question and were unable to give a response; however, most of the other students were able to give an interesting insight. Of the students that gave responses, some were as simple as ‘examine this new thing’, while others talked in depth about sample collection for further research using special instruments such as microscopes.

Researcher: Isabella, if there is something that is a brand new thing that no one had ever seen before, what do scientists do?

Isabella: They see things about it, want to know more about it, and find out stuff.

Researcher: How do they find out stuff?

Isabella: In their labs.

Researcher: What is in their labs?

Isabella: There are chemicals, liquids, poison, and machines like the one you look through to make everything look bigger.

Researcher: *Do you know what it is called?*

Isabella: *A microscope. They might use it to recognise that things are dangerous.*

[Isabella discussing what scientists do when faced with something new]

From talking to the students about scientific theory development, the interview moved to the last, but possibly most important piece of discussion: the use of models to represent ideas.

4.6.6 Models – Uses and Purpose

This area of science was explored by asking the students what they knew about models, and in the situation where the question confused them, an example of a model was given to the students so they could still discuss its purpose and use. This was the last question for the focus group discussion with each group of students, and by this time they had been involved in the focus group setting for an average of six minutes so were now very comfortable sharing and discussing their ideas with each other.

To begin with, students were asked outright whether they knew what a model was, from these answers it was gauged whether or not they may need an example to help them further understand the point of this overall theme. Initial answers from students were naïve, in that out of the six focus groups four of them immediately thought of people that model clothes. Using this as a basis however, it was easy to relate the idea of a supermodel to how that fits in with a real person, and then to relate this to another example to get them thinking. However, some students were able to make a clear connection early on about what a model was and how it related to the ‘real thing’. Below are two excerpts that detail a typical conversation during this question.

Researcher: *Izzy, do you know what a model is?*

Izzy: *A supermodel on a run way, and a model that stands in stores made out of wood.*

Researcher: *You are on the right track, a model in a store is similar to a real person, and it is just modelling them. Now sometimes you can get other models like model cars, model cars are just 'models' of a big car.*

Izzy: *Like those toy cars in a glass case that might be special to you so you put it on a shelf.*

Researcher: *Yeah, so it's a model of a bigger thing.*

[Talking to Izzy about her perception of models]

Researcher: *If I asked you what a model is, would you know what it is?*

Chris: *Like a racing car?*

Researcher: *It could be a racing car.*

Chris: *Stuff that you can collect, like you can get a model Ferrari, but it doesn't need to be big or work.*

Researcher: *Okay, so how does a model Ferrari relate to a real Ferrari?*

Chris: *It looks alike, and it is made out of the same parts, just a smaller version. The parts don't work.*

[Talking to Chris about his perception of models]

Whether students came up with answer about models that displayed an adequate understanding of models in this science context, or an example was used to help

their understanding, the next phase of this research was the same. This was to then talk to the students about the fact that scientists sometimes use models, and to then ask the students about their thoughts on why scientists might do this. Answers to this question were quite varied, although a central theme emerged of using models for testing purposes. Here students highlighted that often it is too dangerous or just simply impractical to run tests on ‘things’ without first using models. Below are a range of excerpts from this question from the students.

Researcher: *Now why do you think scientists sometimes use models?*

Izzy: *To test things, and do experiments on.*

Isabella: *Sometimes you will put them into a machine and see what happens, if it blows up, or gets squashed.*

Izzy: *If they have a new entrance class, and they are teaching science in class, they might have these things that you can open up and will have these things called the veins and stuff.*

Isabella: *Like the frog experiment, where you open up a frog to see what’s inside of it.*

[Talking to Izzy and Isabella about why scientists might use models]

Researcher: *So sometimes scientists use models as well for different things, why do you think they might use models?*

Alex: *To help figure out what they are studying.*

Researcher: *What do you mean by that?*

Alex: *Well... if a volcano erupts, you can’t just go up to the volcano, and ask, “Hey, how did you erupt?” You have to make a model exactly the same and*

figure out why it erupted. It could have been an earthquake there.

Mike: *They make smaller models so they can see how it works.*

[Talking to Alex and Mike about why scientists might use models]

Researcher: *Now sometimes scientists use models, why?*

Bob: *To test them.*

Researcher: *Test what?*

Bob: *To show other people, but they don't work, because one person might push a wrong button, and it might go boom!*

Researcher: *Anything else to add about models?*

Bob: *Well, they use dummies as test things.*

Choin Wain: *Yeah for car crashes, for air bags and car seats.*

[Talking to Bob and Choin Wain about why scientists might use models]

Researcher: *Now sometimes scientists use models, why do you think they would do that?*

Michael: *To make sure the experiment was safe.*

Researcher: *Make sure it is safe? What do you mean?*

Michael: *Make sure it is safe so if a real human was looking at it, they would probably use a fake plastic thing, to see if it was safe for a real human to do it.*

Researcher: *Any other reasons?*

Harry: *They get stuff, and then they make a model of it to test it so they don't damage the first one - the real one, yeah.*

[Talking to Michael and Harry about why scientists might use models]

Once this question was finished the students were dismissed back to class and as they left I talked to them about their field trip the following week which they were most excited about. The information that was obtained from these pre-interview focus groups formed a basis in which two focus groups could be identified as being able to clearly express their ideas so when the class was at the interactive science centre these two groups would be the main focus for this research.

4.7 Observational Visit

The observational visit followed one week after the pre-interviews. The class arrived with their teacher, Wendy (pseudonym) as Homer was absent to begin with, but would join the class later on when he was able to, and two parents. As the class arrived students were first given an opportunity to have their morning tea outside of the interactive science centre, and once finished students were split back into their original focus groups, although there was one student absent, and two more new students that were absent during the original focus group interviews. These two students just worked in with other focus groups.

Before entering the interactive science centre, the research was again explained to the students. Initially they were to stay within their focus groups until sufficient data had been collected, then they would be free to explore before departing for school. Two of the focus groups were also identified as being treatment groups for the observational visit phase of the research. These groups were taken aside and it was explained to them that they would have a short worksheet (Appendix D) to complete about two exhibits to begin with, and to complete this worksheet all they had to do was read the question and then discuss it as a group. The students were

encouraged to first explore the exhibit, read information and try different things and then begin the worksheet. They were also told that while they were discussing the questions they would also be recording themselves.

Upon entering the interactive science centre, the students were clearly excited by this new environment and wanted to explore anything and everything immediately. The students were sat down by Wendy who issued them with the typical school field trip instructions, such as 'school rules still apply'. Their attention was then shifted and they were once again reminded about the importance of staying in their groups for the beginning of the session. The two treatment focus groups were again brought aside as the other students began rushing off excitedly to explore the centre. The other students were very enthusiastic about their visit and often forgot to look at or read any of the accompanying information. Some of the parent helpers, as well as Wendy, pointed some of the information out at times, but the students were more interested in exploring the interactive parts of the science centre. Due to only having one recording device, the two treatment groups had to go one after another.

The questions that the treatment groups had with them could be split into three main themes: firstly there was the Harnessing the Potential exhibit, followed secondly by The Grain Factory exhibit, the two exhibits targeted in this research. The third theme which was overarching between both target exhibits was the idea of models. Below each of these themes is outlined, discussed, and has direct excerpts from the recordings made by the students. It is important to note here that the interactive science centre became very loud with excited students moving about, so some of the audio recordings were hard to hear. With this, when I met with the students again I had them clarify any pieces that were unclear.

4.7.1 The Grain Factory

Due to physical layout of the interactive science centre, this exhibit was used first. The layout of the interactive science centre is a two-storey building with exhibits positioned against the side walls with few smaller mobile exhibits, such as 'Build

a Bridge from Blocks' that were in a more central location. Along with these exhibits around the walls, was The Grain Factory exhibit, which is an eye-catching, brightly coloured machine that is centred right in the middle of the room as you enter. This was the exhibit that all of the students wanted to explore first. From observing the students they were very excited and drawn towards all of the parts that moved rather than reading the attached information for the exhibit. Students worked together, shared their ideas, shouted to each other and eventually got the point of this exhibit – move grain from place to place using the different machines. Once the focus group students had reached this point they then started to look at the worksheet and audio record their discussions. The questions that were asked have elements that not only pertain to The Grain Factory, but also to models. The questions on the nature of models are detailed in the following section.

Students were initially asked questions that had them critically think about what it was they were doing, such as what had they learnt from the exhibit and what jobs can this exhibit do? Student responses to this question were brief. It seemed that they were not able to think in a way whereby they could see this 'machine' being used outside of the setting in which it was presented to them. Rather, it was viewed as this was 'it' and if it was used for another job the same setup would be used. Students were unable to distinguish that this exhibit was made up from a few different machines that could be used separately for other functions. Succinctly, they could only understand the concepts that were straight forward and obvious to them, but did not understand the key science and technological concepts that were underpinning the design. Below are excerpts from the focus groups that indicate this way of thinking.

Luke: [reading from worksheet] *What sort of jobs can this model do?*

Michael: *It can take grain from one part of the machine to the other.*

Harry: *It could probably sort out corn.*

Luke: *It takes grain up, and then puts it down there so it can be sorted.*

Karl: *Yeah, you could probably put some washing thing over there to so it washes it.*

Fred: *It's like a non-stop cycle, it just keeps going.*

Luke: *It probably takes six or something men to do this job.*

Michael: *So that's the first question.*

[A treatment group discussing and exploring The Grain Factory]

Kate: [reading from worksheet] *What sort of jobs can this model do?*

Izzy: *It can like, sort out all of the seeds, all the seeds that can be used.*

[A treatment group discussing and exploring The Grain Factory]

Secondly, the students were asked about what they had learnt from using this exhibit. Again, students had naïve views and were unable to articulate some of the key scientific and technological ideas that were being displayed. Similarly, the answers that students gave were very brief; the excerpts from this question follow.

Luke: [reading from worksheet] *What did you learn from The Grain Factory?*

Michael: *I learnt that it can probably clean grain, and sort corn.*

[A treatment group discussing what they had learnt from The Grain Factory]

Kate: [reading from worksheet] *What did you learn from The Grain Factory?*

Izzy: I learnt that there are a lot of ways of.... Building muscles and keeping you fit.

[A treatment group discussing what they had learnt from The Grain Factory]

The worksheet then had questions on it that linked the grain factory to models which is the core of this research project. The findings from those questions are detailed below in Section 4.7.3. Once students had finished at The Grain Factory, they were then asked to find their way to the next exhibit, Harnessing the Potential, and follow the same process: explore, and then answer some questions.

4.7.2 Harnessing the Potential

This exhibit is tucked away on the lower level of the interactive science centre. It is part of an exhibition that displays an array of information about the Waikato River in Hamilton. The information includes the variety of different fish and other aquatic life that lives in the river. This Harnessing the Potential exhibit (along with another exhibit that is a stationary fitness bicycle connected in way that lights up a map of Hamilton when used), displays information about the use of the Waikato River as an electrical power source. Similarly to the first exhibit the students used, they were excited to be using this equipment.

Students explored this exhibit, taking turns at cranking the hand up, and eventually watched the water flow down the chute and spin the turbine to create electrical energy. Once students had finished their initial exploration, they began to discuss the questions. The first question that was required was similar to that of The Grain Factory; here the students were asked what this exhibit can do. Out of the two treatment groups, it appeared that one of the groups began to start understanding some of the underlying science concepts that this exhibit was attempting to portray: energy conversions. The other treatment group also talked briefly about some of the science concepts but not to the level of the first group. Below are the excerpts from this question.

Michael: [reading from worksheet] *Explore the exhibit and talk about what the exhibit can do.*

Luke: *It can power up houses.*

Michael: *This one puts the energy your body creates into mechanical energy, and it can create enough energy to light up a house.*

Harry: *So the energy your body creates turns into mechanical energy, and then...*

Fred: *The water goes up there, and then it makes this spin which lights up the house.*

Luke: *When it hits the ideal water level, the water starts flowing faster.*

[Treatment group discussing what the Harnessing the Potential exhibit can do]

Izzy: [reading from worksheet] *Explore the exhibit and talk about what the exhibit can do.*

Isabella: *One type of energy can be transformed into another type.*

Kate: *It keeps you going, and once you hit the second line it will power up, and you will see this really cool thing. It's actually quite fun, especially when you have to get the water level and the house lights up.*

[Treatment group discussing what the Harnessing the Potential exhibit can do]

Again, once the students had finished this initial question, they were asked about what they had learnt from using this exhibit. Similarly to The Grain Factory question, the responses that students gave to this question were quite vague and brief. Below are the excerpts from each treatment group.

Michael: [reading from worksheet] *What can people learn from coming to an exhibition and 'playing' with models like this one?*

Luke: *They can learn how energy can be made, and learn how a small pump of water can make energy.*

Harry: *And machines like this one can make the world a better place.*

[Treatment group discussing what they had learnt from Harnessing the Potential]

Izzy: [reading from worksheet] *What can people learn from coming to an exhibition and 'playing' with models like this one?*

Isabella: *They can learn what it does and it can build your muscles and yeah...*

[Treatment group discussing what they had learnt from Harnessing the Potential]

Once students had finished these initial questions, the worksheet went on to ask them further critical questions about the concept of models. The student responses are detailed below in Section 4.7.3.

4.7.3 Understanding Models

The notion of viewing exhibits as models and then understanding what the model is trying to portray in terms of scientific and technological concepts is central to this research project. During the observational visit to the interactive science centre students were asked some simple questions to have them begin their thought process and were then asked to relate these exhibits that they were using to the idea of a model, what it may be used for and how scientists might use them.

On the worksheet that the students were using it was highlighted to them that the exhibits they were using can be called models. This part of the research had two main themes. To begin with, students were asked if they had used models before. The responses for this question indicated that most of them had not used models before, with one person from the two groups explaining that she had used one before, but could not quite remember what it was called or its function – just a vague description. Below are some excerpts for this question. During the audio recording for the second group, there was a lot of loud noise so the information was verified during an interview process.

Luke: [reading from worksheet] *Have you used other models before? If you have, what were they about?*

Fred: *No I haven't used one before, have you, Michael?*

Michael: *Nah.*

Luke: *Have any of you?*

Harry: *Nah.*

[Treatment group discussing previous use of models]

Researcher: *So have any of you used models before?*

Kate: *Yeah.*

Researcher: *Okay, so what models have you used?*

Kate: *The water machine thing.*

Researcher: *Oh, before you went to Exscite, had you used other models?*

Kate: *Yes, but it wasn't like that, well it was kind of like that.*

Researcher: *Okay, can you try and describe it to me?*

Kate: *It had lots of handles and stuff like that, but we were using those cereal things... cereal food and it made it bigger.*

Izzy: *I've used one before; does it count if it was in a museum?*

Researcher: *Yeah.*

Izzy: *It's in the mediaeval part. You spin a handle and it makes those things go around. Like those hard metal ball things.*

[Verification of 'using models before' – post visit]

The next phase of this research area was to have the students discuss their ideas on why they think scientists may be interested in using models and how they might use them. This question was designed to try and get the students to really think critically about what a model was, and what it could be used for. Rather than seeing these interactive exhibits as teaching models that represent some scientific concepts, the students viewed them as being the 'real thing'. For example, the Harnessing the Potential exhibit is a simple analogous representation for a hydro-electric dam, with the intention the users would be able to realise and understand this relationship. The students however, were unable to form the link that is required and gave vague and shallow answers. Below are some excerpts of this question from both treatment groups.

Michael: [reading from worksheet] *Why do you think it is useful for people like scientists or engineers to use models like this one?*

Luke: *You get water quicker.*

Harry: *You don't waste energy.*

Fred: *You can create power.*

Harry: *Doesn't waste money.*

Michael: *Shows another way to make power.*

Luke: *Like instead of nuclear power, like that one in Japan that exploded pollutes the world. They are very dangerous.*

Fred: *And if you use this machine, it doesn't waste anything. No time, no money.*

[Treatment group discussing a scientist's use for a model]

Researcher: *Can you tell me what you meant by 'no waste'?*

Fred: *Like it doesn't waste energy.*

Luke: *It doesn't waste any power or money.*

Researcher: *How does it not waste power or money?*

Luke: *Because you just buy the pump and yeah.*

Michael: *Because it puts your energy into electricity, and changes your energy into electricity.*

Harry: *Because its water, there can't be any less water in the world so it would just keep getting water.*

Michael: *It would waste your time.*

[Verification of what was meant by 'no waste' – post visit]

Izzy: *Why do you think it is useful for scientists and engineers to use models like this one?*

Kate: *It gives it more energy for the town, and keeps you strong and healthy.*

[Treatment group discussing a scientist's use for a model]

Researcher: *You said it gives more energy for the town, what did you mean by that?*

Kate: *I think it's helpful, like testing to see if it can power a lot of houses, and it's hard work.*

Researcher: *Okay, so why is it helpful?*

Izzy: *Because where you are doing it, it goes up and makes power. You have to keep going. It's like the windmill, like how the air goes around, but instead its water. The water hits the spoons and then makes them spin which lights up the house. Spinning makes the power go.*

Researcher: *Where else do you think you could use that idea?*

Kate: *In a factory, it would be much faster I think, put things to good use, instead of just pouring water.*

Isabella: *You could probably use it at like beach houses or something because there is lots of water.*

Researcher: *What would it power?*

Kate: *Well you just work it every time until it gets to the point, and then just do it again.*

Researcher: *So someone has to keep pumping it?*

Izzy: *Take turns with your family but if you are by yourself, good luck.*

Researcher: *Do you think you could get something else to power it? Like wind making the windmill go around?*

Kate: *Make the fridge go, power the whole house, not just the lights.*

Isabella: *Or just make a windmill and spin it really hard,
and then once it stops try and find your way around
the house.*

[Verification of what was meant by ‘more energy for the town’ – post visit]

This section concluded the observational visit at the interactive science centre. Once students had returned the recording device along with any other additional material they were free to explore the centre. Students were clearly excited to be going back to being with their friends and exploring the many exhibits that the centre has to offer. One week after the observation visit, the students had another round of semi-structured interviews where they remained in their original focus groups and were asked a set of questions that were similar to the first round of interviews.

4.8 Interviews: Post-Visit

One week after the observational visit had been carried out, the students were interviewed again. For this process, the students continued to work in their original focus groups with the two new students who were absent during the first round of interviews remaining in the focus groups that they had joined at Exscite. By this time in the research, the students were relatively forthcoming and comfortable sharing and discussing their ideas about science. The questions that were used in this phase of the research were designed using the themes of the questions from the first round of interviews. This was done to gauge whether or not students had learnt new things about science and scientists over the period where they were involved in a visit to an interactive science centre. However, these post-interview questions did not include a question about scientists in the media because its primary function was used as an introduction into the work of scientists for the pre-interviews rather than gaining important information from the students.

This second round of interviews was also used as an opportunity to have students verify information that they gave during the observational visit that was either vague or unclear, or inaudible. Originally the first question was an approach to understand science the students may have previously done at school or at home, it was then altered during the post-interviews to try and find out what they had learnt at Exscite, or what they could remember.

4.8.1 Science Experiences at Exscite

To begin the interview process the students were simply asked what they learnt at Exscite and what were the things that they could remember. The responses to this question were surprising. Exscite is home to a plentiful range of different interactive science exhibits; however, many of the students were unable to provide information about what they had actually done at the centre. With this in mind, there was one interactive exhibit that each focus group discussed during this question which was an exhibit that was designed to show the sheer power of an earthquake. For this exhibit, the user takes a seat inside a small room which is a cavity in the wall. Once a button is pushed the seats shake vigorously for a short period of time. It was also evident during the visit that this exhibit was popular with the class as throughout the entire visit the exhibit was in use and was surrounded by eager students.

During this question, some groups also briefly alluded to other exhibits; however, could really only identify and describe the exhibit rather than explain it. These included 'The Grain Factory' and the 'Harnessing the Potential' exhibits which were used as a focus during this research, as well as a brief mention of: 'Slap Wall', where users slap coloured discs on a wall with the idea of testing and learning about their reflexes; 'Mario Karts', where users simulate driving and learn about the science involved with steering, accelerating and braking; 'Rowing Power', where users are invited to try a rowing machine with the intent of learning about the physical power required to row; and the 'Skipping Machine', where users skip using a skipping rope that is driven mechanically with the

intention of learning about gravity. Below are some transcript excerpts that detail some of the responses from the students to this question.

Researcher: *Can you tell me, what are some of the things you learnt at Exscite?*

Chris: *Well I learnt how powerful an earthquake can be.*

Mike: *Yeah.*

Researcher: *How did you learn that?*

Chris: [engaging with 'Earthquake House'] *We were lying down on the seats with pillows, and then we fell off onto the floor.*

Tony: *And squashed people.*

Alex: *Yeah, Choin Wain was lying on the floor and we squashed him.*

Researcher: *Okay, so what other things can you remember doing or learning about at Exscite?*

Chris: *Well I lit up Hamilton.*

Mike: *So did I.*

Alex: *And I rowed 1500m on the rowing machine.*

[Talking to Alex, Chris, Mike and Tony about their Exscite experience]

Researcher: *Can you tell me, what are some of the things you learnt at Exscite?*

Bob: *The Slap Wall was cool, yeah.*

Researcher: *Can you remember what that was teaching, or what it was about?*

Bob: *I know, it made your hands hurt.*

Choing: *Exercise!*

Choin Wain: *Sense.*

Choing: *Fast reflexes, and it made your hands hurt.*

[Talking to Bob, Choing and Choin Wain about their Exscite experiences]

Researcher: *Can you tell me, what are some of the things you learnt at Exscite?*

Izzy: *I learnt a lot of stuff from a lot of things.*

Isabella: *I learnt that power can be used different ways and really fast.*

Izzy: *Yeah, I learnt that human energy can power a whole city.*

Kate: *And that an earthquake is very dangerous.*

[Talking to Izzy, Isabella and Kate about their Exscite experiences]

From this question the interview questions shifted back to align with the previous interview questions. Following this question about student experiences while they visited Exscite, students were asked about their perception of scientists.

4.8.2 Perceptions of Scientists

Here students were asked about their perceptions of scientists. Their initial answers from the pre-interviews were the basis for a starting point as well as alluding them to the fact they had just returned from a field trip to an interactive science centre. Many of the students were able to add information to their previous ideas. New information included describing how scientists might conduct experiments and how research may be carried out. There was also new information relating to how scientists invent new things with the goal of making

things easier for people. Similarly to the first round of interviews, some of the students pointed out that the term 'scientist' is quite broad and that there are many different types. Again only two groups discussed these ideas so it has been included with this section about perceptions of a scientist. The information that was obtained during this question is varied from each focus group meaning that it was hard to make generalisations that include all of the ideas. With this in mind, excerpts from most of the focus groups have been included below.

Researcher: *In the first interview you talked about the fact that there are different types of scientists, and that scientists found out stuff. What can you tell me about what scientists do after visiting Exscite?*

Chris: *Different scientists measure different things.*

Researcher: *What types of scientists are there?*

Chris: *Volcanologists, geologists, meteorologists.*

Researcher: *Okay, from visiting Exscite what can you say about how scientists find out stuff?*

Alex: *With their little machines.*

Mike: *And measuring and weighing.*

Tony: *And using their brains.*

Researcher: *What types of little machines are there?*

Alex: *The things where you put the little chemicals in them and then they say...*

Chris: *You mean a microscope?*

Mike: *And they use test tubes.*

Tony: *Those aren't machines, they are just plastic bottles.*

Mike: *They still use them.*

[Talking to Mike, Tony, Chris and Alex about the perception of scientists]

Researcher: *After visiting Exscite, can you tell me what scientists do? Last time you said that they invent stuff.*

Bob: *They experiment and stuff.*

Researcher: *What do you mean by 'stuff'?*

Bob: *Um...*

Researcher: *You can describe it to me. What do you think he meant Choin Wain?*

Choin Wain: *Well I think he meant experiment, so really he's researching it and reading books and using the computer.*

[Talking to Bob and Choin Wain about their perception of scientists]

Researcher: *After visiting Exscite can you tell me what scientists do? Last time you told me that they figure out how things work, what else can you tell me?*

Daisy: *Um...*

Researcher: *What do you think scientists do?*

Katie: *They make things work easier.*

Researcher: *Why would they want to make things easier?*

Katie: *So other people can use them easier.*

Acasia: *They discover things.*

Researcher: *What type of things do they discover?*

Acasia: *How things work, why they work.*

[Talking to Daisy, Katie and Acasia about their perception of a scientist]

Researcher: *After visiting Exscite, can you tell me what scientists do? Last time you talked about how there are different types of scientists.*

Michael: *They figure out ways to make things better for the Earth.*

Harry: *Like making medicines and Mythbusters.*

Researcher: *Even though there are different types of scientists, do you think some scientists have things in common?*

Luke: *Yip, a lot of them do.*

Researcher: *What sorts of things do you think they have in common? For example what would a marine biologist have in common with an astronaut?*

Luke: *They try and...*

Fred: *They both float.*

Researcher: *What about what they do?*

Michael: *They find out stuff.*

Fred: *Wear special suits.*

Luke: *Search for things that no one else has seen before.*

Harry: *And then they tell the rest of the world.*

Michael: *Search places that not many people search.*

[Talking to Michael, Harry, Luke and Fred about their perception of scientists]

Once students had shared their ideas about how they perceived scientists they were then asked to discuss their ideas surrounding theory development. Again, these questions were linked to their responses in the first round of interviews.

4.8.3 Scientific Theory Development – How Ideas Change

This section of the interview is vital to this research project, as scientific theory development, along with carrying out investigation and scientist's working together, forms a crucial part of the NoS. Again, because this section of the research is lengthy, it was put to the students using different questions with the aim of avoiding confusion and obtaining quality information. Essentially, students were asked questions that broke this overarching question into three parts centred around the general theme of developing scientific theories, and this was done firstly using questions of the following nature: how scientists 'find out stuff'; whether or not scientists agree with each other's ideas; and what scientists might do when they are faced with a challenging situation that they have not encountered before.

During these questions students often gave short answers but were able to discuss ideas with their peers and were able to develop their ideas further when given a context for the question, or relating the question to the Exscite visit. Students responded to these questions positively with a majority of the entire group giving responses and discussing ideas about how scientists work to develop new information. Notably, the responses included using specialized equipment and the importance of working together. Below are some typical excerpts from various focus groups outlining their ideas about how scientists may initially come up with ideas.

Researcher: *How do scientists find out stuff? How do they discover things?*

Katie: *By working together and looking for information.*

Researcher: *Where do they look for information?*

Katie: *Everywhere.*

Daisy: *On the stuff they were looking at, or on the internet.*

Researcher: *Okay, what are some other ways that scientists find out stuff?*

Acasia: *They make plans.*

Researcher: *What do you mean by the make plans, Acasia?*

Acasia: *They work out steps on how they are going to do it.*

[Talking to Daisy, Acasia and Katie about finding out new information]

Researcher: *How do scientists find out stuff? How do they discover things?*

Michael: *They do it with special technology.*

Harry: *They use machines.*

Karl: *Yeah, but how do they make machines to build other machines?*

Michael: *Well, they build machines.*

[Talking with Michael, Harry and Karl about finding out new information]

Researcher: *How do scientists find out stuff? How do they discover things?*

Kate: *They test things.*

Izzy: *They test stuff, and if it doesn't work they remake it and then test it until it works.*

[Talking to Kate and Izzy about finding out new information]

Researcher: *How do scientists find out stuff? How do they discover things?*

Liz: *They research it.*

Researcher: *How do they research it?*

Liz: *Maybe on the computer.*

Researcher: *When you were at Exscite, how did you find out new things?*

Krystal: *We tried it out to see if we knew what to do.*

Researcher: *Do you think scientists may do something similar? How might they do it?*

Krystal: *They might test it.*

Researcher: *How do they test it?*

Krystal: *With special equipment.*

[Talking to Liz and Krystal about finding out new information]

After the students had discussed this question, similarly to the pre-interviews, this one progressed to asking the students about the dilemma that scientists may face when their ideas do not align, and what can be done. The responses and ideas that students gave during the post-interviews appeared to be more in-depth and thought-out than previous ones. Again, there was a clear answer from the students that scientists did not necessarily always agree with each other, and students indicated what might need to be done in order to have scientists agree about ideas. One common argument from the students was advocating that for a scientist's theory or idea about a certain phenomenon to be validated, the scientist was required to be able to prove their point and have sufficient evidence. Below are some typical excerpts outlining this second part of the overall interview question.

Researcher: *Now when scientists find out new stuff, do they always agree with each other?*

Michael: *No.*

Researcher: *What do they do if they don't?*

Michael: *They probably do something that they do agree on.*

Harry: *They just have their own ideas, and see who has the best idea, with more evidence to make their statement right.*

Fred: *Yeah, more evidence so everyone else agrees.*

Researcher: *But how they find more evidence?*

Karl: *By research.*

Harry: *They try different things.*

Fred: *They experiment.*

Harry: *They experiment different things.*

Michael: *That's how different scientists around the world figure out different things.*

Researcher: *If a scientist had an idea about how something works, how would someone change their idea?*

Harry: *They would show evidence.*

Karl: *Make better things.*

Fred: *Give better ideas.*

Michael: *Just guessing in the first part, but then take it apart.*

Harry: *Yeah, break it up.*

Karl: *Yeah, take it apart and have a look inside.*

Harry: *Or like research, and find out how it was made.*

[Talking to a focus group about challenging and changing scientific ideas]

Researcher: *Last time you guys talked a little bit about scientists not always agreeing with each other. What*

can you tell me about what happens if they don't agree with each other?

Mike: *They argue about it.*

Chris: *One of them will go and work it out again and say what was wrong, or I was right.*

Alex: *But it could also be because they were using different machines and stuff like that.*

Researcher: *So if they use different machines, and they get different answers, what do they need to do?*

Tony: *They need to figure out what they did wrong.*

Mike: *They need to use both machines.*

Researcher: *What do you mean by both machines, Mike?*

Mike: *Make them the same.*

Chris: *Like use one machine, and then use the other one, so you can combine the answers to make one answer.*

Researcher: *Okay, so what do you think will make a scientist change their ideas? What might make them change the way they think?*

Tony: *By thinking it through again.*

Researcher: *Any other ideas?*

Mike: *Trying different machines.*

[Talking to a focus group about challenging and changing scientific ideas]

From discussing these ideas with the students, the interview then progressed onto the final part of this question – asking the students about what scientists do when faced with a new challenge. Like the pre-interviews, this proved to be a difficult concept for some students to make sense of the question and then give an answer.

Again, gentle probing combined with the use of a contextual example they could understand, or relating the question to their Exscite visit proved useful. Student responses to this question were of a similar nature: the scientist(s) needed to find out information. Students indicated that to do this they needed to do research by either asking someone who does know, or using books and the internet. These answers appeared to mirror their ideas from the previous interview whereby they were relating the ideas of ‘not knowing’ and needing to do ‘research’ to what they do in the classroom (i.e., read books, ask people and use the internet). Below are some typical excerpts from this question.

Researcher: *If a scientist doesn't understand something, what do they do?*

Kate: *Research it.*

Isabella: *Try and find...*

Izzy: *Try to work it out.*

Kate: *Try and make it better.*

Researcher: *How do they research it?*

Izzy: *On the computer.*

Isabella: *If it is like a new product or something, or disease, they get the disease with gloves on and poke around and that.*

Izzy: *How do they research it if it wasn't invented yet?*

Researcher: *How do you think they do that?*

Izzy: *They try and work it out themselves and they write their mistakes on a piece of paper and try not to do them again.*

Kate: *Find someone to work it out for them, or to help them. Maybe another scientist knows a lot about that thing and they can help them.*

Isabella: *There's a scientist for everything, like food.*

[Talking to a focus group about scientists not knowing something]

Researcher: *If a scientist doesn't understand something, what do they do?*

Katie: *They keep working on it.*

Researcher: *How do they keep working on it?*

Katie: *They keep learning stuff about it, looking at different ways on how it could work.*

Researcher: *How do they learn new things about it?*

Daisy: *Find it out.*

Researcher: *How do they find it out?*

Daisy: *By the internet, or by someone who knows.*

Acasia: *By the person who is working on it.*

Researcher: *Why do you think it is important to find out new stuff?*

Katie: *If they didn't, they wouldn't know anything about it.*

Daisy: *We wouldn't have as much stuff, we wouldn't have computers, we wouldn't know how to make them.*

[Talking to a focus group about scientists not knowing something]

Once this question had been responded to, and discussed by the students the interview then progressed onto another important, and sometimes difficult to understand section about models which is detailed below.

4.8.4 Models – Uses and Purpose

Like the section above, this aspect is key when learning about the NoS as it is directly related to understanding complex scientific ideas and phenomena by portraying the ideas in a fashion that is manageable to understand for users. Many of the interactive exhibits that Exscite has can be regarded as physical teaching models, which provide students with an opportunity to explore and investigate a scientific concept. For this question in the research, it was reiterated to the students that the exhibits they used at Exscite are made primarily of these things called models, and then the students were asked why they thought this may be the case, and what they might be used for.

When discussing the idea of models during the pre-interviews, many of the students were confused and didn't quite understand the question. Some students, when hearing the word model, immediately thought of fashion models. However, after some gentle probing and using some examples such as model cars they were able to share some ideas. During these post-interviews, students had clearer ideas on models and all of the focus groups were able to relate to them and were able to give a relevant scientific purpose for having models. Responses included information such as the fact that models can be used for teaching purposes rather than have the 'real thing' and can be used to run tests on. Below are some typical excerpts from these focus group discussions.

Researcher: *At Exscite, many of the exhibits are called models. Why do you think they use these models?*

Chris: *To show us how things work.*

Mike: *And to show us how powerful things are.*

Tony: *But I didn't understand Mario Karts.*

Researcher: *What do you mean by 'they show us how things work?'*

Chris: *They had this grain machine there and it had different working parts. It showed us how the grain*

would come in and fill up and tip over either onto a conveyer belt or a...

Mike: *Elevator?*

Chris: *Might be, it's a conveyer belt that goes up.*

Researcher: *So are there other reasons why scientists would use these models?*

Alex: *To figure out information. To get more knowledge about the thing you are studying, for example, the earthquake machine.*

Researcher: *What does the earthquake machine do?*

Tony: *It shakes.*

Researcher: *Is it a model?*

Tony: *Yeah, a working one.*

Researcher: *Why do you say it is a working model?*

Tony: *Because it shakes which is what an earthquake does, but it doesn't make pieces fall and crush you and doesn't have a table in the middle to hide under.*

Chris: *It can show you how strong an earthquake can be.*

Mike: *It says that angry is 6 and raged is 5.*

Chris: *So they could figure out what a 7 or 8 would be.*

[Talking to a focus group about the use and purpose of models at Exscite]

Researcher: *At Exscite, many of the exhibits are called models. Why do you think they use these models?*

Bob: *To experiment with and test.*

Choing: *To see what they look like.*

Choin Wain: *To test them and see if they work.*

[Talking to a focus group about the use and purpose of models at Exscite]

Researcher: *At Exscite, many of the exhibits are called models. Why do you think they use these models?*

Daisy: *To see if it works when it is small.*

Katie: *How to make it when it's bigger.*

Acasia: *If it has the right proportions it should work when it's bigger.*

Katie: *Testing it.*

Researcher: *Are there any other reasons why you think scientists might use models?*

Katie: *To study.*

Daisy: *To show people what it might look like when it's bigger.*

Acasia: *To show what people have done.*

[Talking to a focus group about the use and purpose of models at Exscite]

Researcher: *At Exscite, many of the exhibits are called models. Why do you think they use these models?*

Michael: *Because if they use the real thing, and they do the wrong thing you might blow up.*

Harry: *Yeah, they are used to practise on.*

Researcher: *So used for practise?*

Fred: *Yeah, because if something is too big, they can use a smaller model.*

Karl: *Like Mario Karts, you look and think like you are driving but you are not actually driving.*

Researcher: *Okay, in the first interview some of you talked about testing models. What can you tell me about testing models?*

Harry: *They make one that's like it, but smaller, to test it out and see if it really works.*

Michael: *It's like the car crashing ads. They would have a real car and fake person to test it.*

[Talking to a focus group about the use and purpose of models at Exscite]

This question concluded the post-interviews with all of the students. The following section summarises all of the key points outlined in this chapter.

4.9 Summary

This chapter has presented the findings obtained from the data collection methods during this research project using the methodology outlined earlier in Chapter Three. Section 4.2 presents detailed information about the participants that took part in the data collection phases of the research project, as well as a detailed contextual description of Exscite. The participants were a class of year five and six students along with their classroom teacher. These students took part in the three phase research process involving pre- and post-interviews as well as an observational visit to Exscite, the interactive science centre that was used as a basis for this research project. Exscite has a variety of interactive science exhibits with the intention of fulfilling their mission statement that reads: *to promote and popularise science and technology to members of the general public through the use of interactive exhibitions and exciting and constantly changing education programmes.* While Exscite has many interactive exhibits, this research project focused predominately on two of them.

Section 4.3 outlines some information about the selection of the two interactive exhibits for this research project and the NoS links to the New Zealand Science Curriculum for year five and six students. Section 4.4 describes and discusses one of the interactive exhibits, titled *Harnessing the Potential*. This exhibit consists of a hand pump used to elevate a body of water which at a certain height flows through a chute. The flowing water is then used to power a generator which transforms the kinetic energy into electrical energy and then illuminates a model house. The NoS link that was apparent with this exhibit was the portrayal of models in science. It was intended that students would be able to make the link between using a physical analogical model and the scientific idea that it was being portrayed, which in this instance was energy transformations, the use of hydroelectric power dams, and the science associated with hydroelectric power generation. There is also other minor NoS links such as considering issues of importance (e.g., global and national energy concerns) which forms part of the participating and contributing strand; or the use of specific scientific vocabulary which is part of the communicating in science strand.

Section 4.5 describes and discusses the second interactive exhibit used for this research project which is called *The Grain Factory*. This exhibit is quite large and very central to the centre, and has been at Exscite for the last two decades. It is made up of six small interconnecting machines with the goal of shifting grain around from place to place. Again, this exhibit is a physical model to help students develop an understanding about the science behind how the machines work. Similarly to the previous exhibit, there is other minor NoS links such as appreciating the idea of working together, which is part of the understanding about science strand; or again, learning about specific terminology related to some of the machines. Both exhibits were used during the observational phase of the research, as well as some general notes about student behaviour as they were engaged at the exhibit.

Section 4.6 presents and outlines data that was obtained during the pre-interview phase of the research. Here, students were involved in a semi-structured, focus group interview process where they were asked a series of questions derived from

a set of base questions which can be found in Appendix C. Student responses to these questions were quite varied, from students who were unable to answer questions through to students that gave detailed information about volcanologists, for example. It was clear during this phase that many of the students had naïve views about science, possibly due to their lack of scientific experiences which they indicated. Students also gave interesting answers about theory development in science and many students were confused and misunderstood the questions about the purpose and uses of models. After this first phase of the research had been completed, the second phase was the observational visit.

Section 4.7 presents and outlines data that was obtained during the observational visit to Exscite. General notes were made about the students' initial reaction and behaviour at the interactive science centre. On arriving at Exscite, it was clear that the students were excited about this new environment. When allowed, students explored the various interactive exhibits with enthusiasm, often not reading the information cards that accompanied the exhibits but rather finding the interactive part and then engaging with them. Two of the focus groups from the first phase of the research were taken aside and given some specific information about their tasks. They were asked to visit the two targeted exhibits first before moving off to the others. While they were engaging with these exhibits the students were given a questionnaire to discuss (while audio recording themselves). These students gave short, naïve answers about the questions, which predominately focused on the purpose and use of models. Students were unable to make the links between these models and the scientific concepts that the models were representing.

Section 4.8 presents and outlines data that was obtained during the final post-interview phase of the research project. Upon returning from Exscite, students were asked a set of questions that were similar to that of the first round of interviews. During these questions, students were able to give more detailed accounts about science, and were able to give more meaningful answers about the purpose and uses of models. During the questions around models, students indicated that there are many uses for models such as using them to teach and using them to run tests on. As students indicated they had an increased level of

understanding about models, it was also apparent that they were able to make some links between a physical analogical model and the scientific phenomena that a model represents.

This chapter organised and presented the data in a coherent way which outlines key themes present throughout the research, with the intention of developing arguments that will help answer the research questions. There were several key themes that emerged from the data when analysing and comparing information obtained from the students between pre- and post-interviews, as well as the observational visit. This data and the emergent key themes are discussed in the following discussion chapter and the research questions answered.

Chapter Five

Discussion

5.1 Introduction

This chapter takes the research questions that were presented in Chapter Three and critically discusses them with reference to the findings presented in Chapter Four. The structure of this chapter stems primarily from the research questions and the themes drawn from the findings.

Section 5.2 addresses the first research question: ‘what aspects of the nature of science can be represented in a science centre?’ This question is answered by analysing the two exhibits focused on in this research project. Section 5.3 addresses the second research question: ‘what aspects of the nature of science do students learn when these specific aspects are highlighted to them at an interactive science centre?’ This section leads with an overarching statement that answers the question and is then supported by five key areas: Section 5.3.1 discusses the students’ perceptions of science and scientists; Section 5.3.2 discusses the students’ ideas about scientific theory development; Section 5.3.3 discusses student ideas about models; Section 5.3.4 discusses the student behaviour that was observed at Exscite; and Section 5.3.5 discusses how the treatment groups compared to the other students. Section 5.4 offers a summary of the critical discussions that answers the research questions.

5.2 Exscite’s Potential to Portray Aspects of the Nature of Science

This section serves to answer the first research question ‘what aspects of the nature of science (NoS) can be represented in a science centre?’ Researchers have claimed that interactive science centres and the exhibits that they contain have the potential to teach students about the NoS (e.g., Davidsson, 2009; Osborne, 2002; Rennie & Williams, 2002, 2006). However, many interactive exhibits may be designed to represent what can be referred to as ‘the wonder of science’ which highlights science as being a free entity rather than trying to portray science as a tentative and creative human enterprise (Davidsson & Jakobsson, 2007; Pedretti, 2002; Rennie & Williams, 2002). For an interactive exhibit to highlight and teach

students aspects of the NoS, it must incorporate NoS aspects and use these themes as a central point when designing the exhibit.

When visiting Exscite, it was clear that many of their exhibits were designed to engage primary school children and allow them fun interactive hands-on experiences. Although the exhibits were generally eye-catching and appealing structures that had been strategically placed around a two-storey room, Peacock and Pratt (2011) caution that this type of layout at a free-choice learning environment, where something is predominately eye-catching (e.g., The Grain Factory exhibit), can distract learners from the learning that is actually being targeted. All of the exhibits also had some accompanying text (see Chapter Four for examples) that attempted to explain the ‘big science idea’ underpinning the exhibit. Text and diagrams at the exhibits showed the students what to do and some exhibits also included a challenge. Whilst exhibits were appealing to the students and represented an area of science, NoS aspects were generally unclear. As the literature indicated, the NoS is not often the central idea when designing and constructing an exhibit and was the case at Exscite. This is probably because many of the exhibits at Exscite were constructed before the NoS became an important consideration in the new curriculum document.

Exscite houses many interactive exhibits, and while NoS links were unclear for individual exhibits, together they appeared to show some aspects of the NoS. Throughout the various exhibits, students were presented with a challenge, for example they had to light up the house when using Harnessing the Potential. To meet this challenge, and figure out what to do, students had an opportunity to act as scientists; hence they were implicitly involved in some aspects of NoS. For example, when engaging with Harnessing the Potential, students were required to read some information about how the exhibit functioned (but often overlooked the posters detailing energy). Once they had an initial idea of how this exhibit may function, their ideas required testing. When implementing their ideas and using this exhibit, some students were immediately successful, whilst others had to share ideas and discuss what they may have done wrong, and how to improve on their mistakes.

While Excite has many exhibits, this project focused primarily on two of the interactive exhibits (Harnessing the Potential and The Grain Factory). These were chosen primarily because they appeared to clearly highlight important aspects of the NoS strand in the New Zealand Science Curriculum. Since this project involved year five and six students, aspects of the NoS that the exhibits portrayed were related to the NoS strand at level three of the New Zealand Science Curriculum (Ministry of Education, 2007).

The New Zealand Science Curriculum divides the NoS strand into four different learning objectives: understanding about science, investigating in science, communicating in science, and participating and contributing in science (Ministry of Education, 2007). It was apparent that there were stronger links to some learning objectives for the different exhibits. The aspect of the NoS that was most predominant in both of these exhibits, as well as many other exhibits at Exscite, was the use of models to portray a scientific idea. This aspect forms part of the investigating in science strand outlined by the New Zealand Curriculum, where students are encouraged to explore models to help them develop an explanation of what is happening.

This idea of using a model in science is of significance in science. The two focus exhibits can be classed as analogical models (Gilbert & Stocklmayer, 2001) as they have taken an area of science (and technology) and created working mechanisms that illustrate the targeted science ideas. The importance of these analogical models is discussed by Chittleborough et al. (2005) who indicate that these physical teaching models help students to improve their understanding by allowing them to develop mental models about the scientific idea underpinning the teaching model (Figure 2.1). When students have an adequate understanding, or a well-developed mental model, they are then able to express their knowledge. For example students may be able to verbally or graphically represent their understanding.

There was also evidence of other NoS aspects that be can related to the NoS learning objectives within these exhibits, but their links were not as strong. One key feature of the Harnessing the Potential exhibit was to explain the concept of

energy by illustrating various forms of energy. Information at the exhibit explained that energy is something that we cannot see nor touch. These energy explanations form an important part of understanding about science, that is, appreciating the way in which science explains certain phenomena.

There was also a significant amount of technical information and scientific vocabulary associated with this exhibit, such as kinetic energy, gravitational potential energy, and light energy. This use of specific scientific language and conventions to explain scientific phenomena forms an important part of communicating in science. As explained in Chapter Four, these words and phrases were on the accompanying posters, and for maximum effect it, required the students to interact with the exhibit as well as read the information which was rarely done, as discussed below in Section 5.3.4.

Along with information about the specific terminology used, there were also details about the use of hydro-electric power. This information highlighted the principles behind how a power station works, as well as detailing some examples along the Waikato River. It was intended that this showcase an example of renewable energy to the students to help them better understand the idea of renewable versus non-renewable energy sources. While this exhibit may not explicitly offer an opportunity for students to be engaged under the participating and contributing heading, it can be used as a basis to develop further discussion. For example, the teacher could use some of the underlying information from this exhibit relating to renewable energy, such as environmental concerns, to generate a class discussion where students would be able to actively participate and contribute to the discussion.

While The Grain Factory exhibit did not place a large emphasis on science, rather an application of scientific principles, there were some aspects of the NoS that could be related back to the New Zealand Science Curriculum. The first point about the NoS with this exhibit, other than models, is the notion of working together. By working individually on The Grain Factory, the students would not be able to complete the task of shifting the grain in a continuous way. Rather, it

required six students to work the various machines simultaneously, possibly showing students the advantages of working collaboratively.

Again, the learning area about communicating in science was touched on with this exhibit. On different parts of the exhibit, there were some words to communicate some of the scientific ideas to the students, and like the other exhibit, students were required to read these terms as well as engage with the exhibit itself.

The participating and contributing strand as outlined by the New Zealand Science Curriculum is underpinned by the idea of there being an issue of concern or a problem to be addressed and students using their knowledge to overcome this issue or solve the problem. Here, it could be argued that there is a weak link whereby the issue the students are presented with may be the challenge of shifting grain around. They then have to share their ideas and use each other's knowledge to figure out what to do. This was evident as whilst the students were engaged with this exhibit there was a lot of communication between students about what to do.

These exhibits showed potential to teach students aspects about the NoS, but perhaps not as standalone entities. For example, the Harnessing the Potential exhibit had interesting pieces of information that related the exhibit to key aspects of the NoS. However, this is seen as more of a package that required the students to not only engage with the exhibit, but to also read (and understand) the accompanying information. While students excitedly engaged with the exhibits, the written information was often overlooked unless they were specifically asked to read it.

5.3 Aspects of the Nature of Science that Students' Learnt

This section addresses the second research question which was 'what aspects of the nature of science do students learn when these specific aspects are highlighted to them at an interactive science centre?' This study investigated two main aspects of the NoS: the notion of using models in science which is an important aspect in the investigating in science learning objective; and students' perceptions about

how scientists worked and how they generated new scientific information and theories, which is primarily focused within the understanding about science learning objective.

The initial ideas the students had about both models and how scientific knowledge appeared to be naïve and unclear. However, after visiting Exscite, their responses about these two aspects of the NoS appeared to be more sophisticated and well thought out. The following five subsections outline and discuss important points that lead to this conclusion.

5.3.1 Students' Perceptions of Science and Scientists

The majority of students were uncertain when it came to discussing science. Initially, most of the students were unable to give any information about any previous science experiences they had encountered. Of the 22 students interviewed, only four of the students were able to recollect some demonstration type activities such as a baking soda and vinegar volcano, whilst the others claimed to have never done science before. Through the investigation, it became clear that even though science is clearly stated in the New Zealand Curriculum, for the students in this study at least, it had been a subject without priority. Often learning about science is compromised to make allowances for teaching subjects that are regarded as being of higher importance such as mathematics and English, a point highlighted by Gough (2008) who indicated that a crucial limitation that teachers in the primary sector face whilst trying to teach science is time. Gough (2008) sums up this point by stating that teachers often “have difficulty finding a place for science in what they perceive as an already overcrowded curriculum” (p. 9). Tilgner (1990) reported that, when primary teachers do have opportunities to teach science, they are more concerned with providing scientific facts than involving the students in a scientific process. Another problem may be that when students were engaged in science, they were not told that explicitly. Rather, students were engaged in something called ‘topic’ which was carried out over one of the four terms.

Notwithstanding the above, there were two students that were able to give comprehensive information about scientists. However, it was clear that these students that had an interest in science had developed it outside of school. For instance one student giving detailed information about Earth Sciences such as highlighting the work of volcanologists and geologists. But this was not representative of the group.

Upon returning from the visit to Exscite, it was apparent that students had identified that the environment they had been in was influenced by science. Although, when questioned about what things they had learnt whilst at the science centre, students were unable to give detailed information. It was expected that after students had engaged with this array of interactive science exhibits they may be able to give some information about some of the science ideas they had been exposed to. However, many students were only able to recount small details about some of their Exscite experience. During the post-interview, all of the focus groups gave information about interactive exhibits where they had fun, such as the earthquake generator, or the Mario-Kart exhibit, but were unable to discuss the science behind the exhibits. This is similar to what Peacock and Pratt (2011) found when visiting a tropical forest with students. Here, the students were meant to be learning about tropical plants. However, Peacock and Pratt observed that the students were more interested and distracted by the actual domes that housed the plants and the tractor that took them into the domes than the tropical plants.

During discussion about the work of scientists, students initially gave a response that is typical of how scientists are often portrayed, such as, finding out new information by carrying out experiments. This finding is concordant with a study by Buldu (2006) about young students' perceptions of scientists which found that many students perceived scientists as being people concerned with researching, experimenting, and inventing things.

When discussing whether or not they had ever seen a scientist, many of the students were able to give information, but again their ideas seemed consistent with the usual stereotypes portrayed in the media. For the most part, the people that students identified as being scientists were similar to the findings by many

researchers that employed the ‘draw a scientist test’ (DAST) developed by Chambers (1983) (see discussion by: Archer et al., 2010; Finson et al, 1995; Huber & Burton 1995). Primary school students consistently had the perception that a scientist was a white older male, with an electrified hair style, who wore a white lab coat and safety glasses, and mixed or dealt with chemicals.

Then, during the post-interview process, students were asked more about the role of a scientist rather than what they looked like. With these questions, the students were able to add more information to their previous explanations of what scientists did. When the students visited Exscite, they were told that the exhibits were interactive science exhibits, and hence when they were engaged with the exhibits they saw themselves engaged as scientists. With this, students were able to give more comprehensive pieces of information. Previously, students indicated that scientists were predominately associated with researching and ‘figuring things out’. Now, students were able to add to these arguments by giving some detailed information about how scientists’ may carry out research, for example: working together, using specialised equipment, and finding evidence to support a claim.

These findings are akin to the findings by McNeill (2011) in her study about how primary aged students viewed scientific ideas. It was seen here that initial responses indicated that there could be disagreement amongst scientists about an idea. Then after working on a science based unit of work, their responses about how scientists may work through issues became clearer and more sophisticated. Similarly, the idea of evidence used to generate arguments became apparent after the students had been working within a scientific project (McNeill, 2011).

Overall, the students initially had limited knowledge when discussing science and scientists. However, when students were exposed explicitly to a scientific environment it was clear that they were able to build on their previous ideas. Rather than simply giving vague and naïve responses, many of the students were now including detailed and comprehensive information as part of their responses, such as how scientists may work (together) and the purpose of their work.

After talking with the students about science as a whole and the work of scientists, the interview questions shifted to incorporate a sharper focus on the NoS.

5.3.2 Students' Ideas about Scientific Theory Development

Students were asked to give details around how they thought scientists may derive new information, and how this information may be validated and used. These questions were included because the NoS learning area in the New Zealand Science Curriculum specifically highlights that students should have an understanding about the tentative NoS, how ideas change over time, and how the different contributions from various scientists contribute to theory development.

During the pre-interviews, all of the students interviewed said that scientists do not always agree with each other. At this point, most students were unable to develop ideas further. However, there were five students that went on to explain what may happen when this problem arises. Explanations here included ideas such as introducing a voting system whereby scientists can choose what they perceive as being the best idea, or having the scientists repeat the work they had previously completed in conjunction with another scientist who may have a conflicting idea.

During the post-interview interviews, students gave very similar responses to this question. However, nearly all of the students were now able to add to the discussion. Initially the answers to this question were quite short and vague, with some students having difficulty expanding on their own ideas. After returning from Exscite, students who were initially unsure and were unable to add to the discussion were now able to give more comprehensive information such as in order to prove one theory incorrect there needs to be sufficient evidence that challenges that theory. Again, these findings were similar to McNeill (2011), which discussed the level of understanding and improvement to the quality of answers after working on a scientific unit.

Related to asking the students about scientists agreeing with each other, the students were also asked about how ideas in science can change over time. During the pre-interviews, nearly all of the students indicated that ideas in science are in

fact tentative and subject to change. They also said that these ideas may change when new information about a certain topic is apparent, that is, previous ideas may be challenged by further research.

Discussing how scientists find out new information proved to be the most interesting discussion within this area of the NoS, but it also proved to be difficult. During the pre-interview interviews, this question appeared to initially confuse students so some further probing questions were used, along with using some examples. Whilst their initial responses were quite varied, approximately a third of the students interviewed were able to contribute to the discussion. These students had ideas that followed a similar theme: find things out about it. These results were similar to those found by Murphy, Murphy, and Kilfeather, (2011) in their study of investigating how primary aged students viewed science. Similarly, there was a common response from students about how scientists found things out. Before visiting Exscite, there were also four students that mentioned using tools such as a microscope, but this was not common within the group.

Again, during the post-interview interviews, students offered more comprehensive answers that appeared to be well thought out and developed. Students still indicated that whatever this new problem or phenomena was, the scientists needed to research it. However, after visiting Exscite, the students were able to give more detailed information about how to go about doing this research, such as using specialised equipment. The notion of perseverance was also discussed where students identified that scientists may have to try various approaches to find out new information, such as, asking someone who may be able to give an insight. Once the discussions around developing theories and finding out new information had taken place, the questions moved towards asking students about the uses and purpose of models.

5.3.3 Student Ideas about Models

Upon asking the students about what they thought a model was, it was clear they were unsure what was meant by the question. Many of the focus groups

immediately thought of a fashion model who models clothes. Chittleborough et al. (2005) stated that “students’ appreciation of models in science has been shown to be limited and naïve” (p. 195) and these authors suggest that this may be because, although models are regularly used as a teaching tool, their purpose and function is often not well explained.

However, by using fashion models as a starting point, as well as other examples, such as a model car versus an actual car, the idea of a model was discussed with the children. This was then used as a basis to ask the students about the purpose and uses of a model.

Once students had an idea about what a model was, they were able to give some information about the whole point of having models. Students suggested that a model is there to represent something, and the other key idea that was apparent was the use of models for running tests. Students also indicated that sometimes it can be impractical to carry out tests or research on the real thing due to safety concerns, such as a volcano, whereby a model of the landscape and geological landforms would be more suitable.

While the answers that students gave during the pre-interview interviews showed an understanding about the use and purposes of models, after visiting Exscite their answers became more comprehensive and developed. To begin this question in the post-interview interviews, it was highlighted to students that many of the interactive exhibits they had used the previous week were in fact models. Students were then asked why they thought these exhibits may be called models.

In Chapter Four, there are many excerpts of what students said during this question to highlight the in-depth and varied answers that were given. Students were able to indicate that the purpose of having models at Exscite was to represent something else, and they were there for a variety of reasons. Key reasons that the students identified included: showing other people the working parts of something; carrying out tests; and for studying. This was similar to the results found by Chittleborough et al. (2005) that detail the different perceptions that students had about scientific models as their understandings increased.

Many students also showed an increased understanding of what was meant by the term model.

Overall, the students had some initial ideas about what models were and were able to provide a brief description of what they were for. However, to get this information the students required examples and further questions.

After the visit to Exscite, and when it was indicated to the students that many of the interactive exhibits were models, they were able to give answers that were more thought out than previous ideas.

5.3.4 Student Behaviour at Exscite

It is important to outline here how the students as a whole were engaged with the interactive exhibits when they visited Exscite. It was clear that the students were excited about the opportunity of partaking in a field trip experience. This is reiterated by the study conducted by Varley, Murphy, and Veale (2008) who concluded that primary students had a clear and strong interest in science, particularly when in a hands-on environment. Researchers such as Griffin and Symington (1997) and Tal et al. (2005) warned, however, about the danger of the classroom teacher abandoning the purpose of the visit and taking up a role that was more focused on keeping the students on track, following school rules, and other logistical aspects of the trip. Unavoidably, this is what happened during the Exscite visit. The literature indicates that the teacher needs to take facilitator role during a visit to an interactive science centre, such as encouraging thoughtful discussion amongst the students (Ash, 2004; Gutwill & Allen, 2012). However, the students were given limited scientific information about Exscite from their teacher who instead focused on telling them how to behave and where to meet at certain times.

DeWitt and Storksdieck (2008) note that environments such as an interactive science centre can be a novel place for students. It is then important realise that if the novelty of being in such an environment is too great, the students can become distracted and quality learning may be compromised. This could be seen as an

issue as the students were excited to be in this environment with their peers, although they were able to still follow instructions. Students were asked to remain in their focus groups for the beginning of the visit for ease of data collection of the two treatment groups.

Of the many interactive exhibits that Exscite offered, the students predominately targeted the larger, eye-catching, exhibits first. Once students had done what they thought they needed to at an exhibit, they then moved onto the next one. The idea of physical layout being of importance when considering the learning in a free-choice learning environment was discussed in Chapter Two using Falk and Dierking's (2000) contextual model of learning. Here it is argued that properties such as lighting, climate, and space, can affect the learning that takes place (Falk & Storksdieck, 2005). Also, in this environment, the students navigate themselves around the centre in a non-sequential way. This is of importance here, as data has indicated that the success of navigating through a complex three dimensional environment is correlated to what is learnt (Falk & Storksdieck, 2005).

It was intended that, because the students were year five and six, that they would read the information before proceeding with the exhibit. It became apparent very early on that this was not the case. Students were more interested in turning handles, pressing buttons, and exploring anything that moved. This may be due to the novelty of the science centre which is indicated earlier in this section. Students only read the information when a teacher or parent helper (two parents were present during the visit to ensure correct adult to ratios) indicated that this information was available. Again, this point further reinforces the idea of having people with the specific purpose of promoting and facilitating learning (Ash, 2004; Gutwill & Allen, 2012). However, when the students read this information, it seemed as though they only did so because they had to, rather than working to take any quality learning away from it.

The literature (e.g., Ash, 2004; Gutwill & Allen, 2012) also suggested if the teacher is unable to act in a facilitator role in a free-choice learning environment, then having another person there whose task is to facilitate learning can be effective. Exscite does offer a science education service where the science officer

at Exscite facilitates the learning by running seminars with the students and teaching them specific information about each of the exhibits. For this research project however, the exhibits themselves were targeted so the science officer was not present during the visit.

5.3.5 Treatment Groups

There were two treatment groups used for this research project. From the pre-interview phase of the data collection, two groups were identified that were comfortable sharing ideas about science and in particular models. During the visit to Exscite, these groups were taken aside and given slightly different instructions.

Again, it was clear that, like the other students, these students were very excited. Since these students were asked to complete a small task before being able to continue freely exploring the various exhibits, it was clear that they were distracted and keen to join the others. This is likely why their answers to the discussion questions were quite short, containing unclear and vague information. Where it was unclear what students meant, the students from that focus group were asked for some additional information during the post-interview interviews.

While this study sought to examine the effectiveness of the exhibits as a standalone entity in teaching aspects of the NoS, the literature reviewed in Chapter Two, indicated that giving the students worksheets with the intention of them answering questions whilst they are at the exhibit can be a good way of enhancing their learning (Griffin & Symington, 1997; Tal et al., 2005).

A worksheet (Appendix D) was employed with these treatment groups when they engaged with the two exhibits *Harnessing the Potential* and *The Grain Factory*. During the visit, these students would have to answer some short discussion questions as they engaged with the two targeted exhibits. The students were encouraged to first use the exhibit, see what it does, and then answer the questions whilst audio recording themselves.

Worksheets have been strongly advocated by some writers (e.g., Burtnyk & Combs, 2005; Kisiel, 2003), although others have cautioned that they not be so

detailed that they distract the students from the learning that could be taking place whilst interacting with the exhibits (e.g., Price & Hein, 1991).

From using a simple worksheet as they engaged with the exhibits, students appeared to have a clearer understanding about what was going on within the exhibit. These students were also able to give a more detailed recollection of what they encountered from Exscite, especially when discussing the exhibits that had been targeted.

All the students showed an increase in their understanding about models from the visit to Exscite and the treatment groups' understandings of models were similar to that of the other students. Whilst they were able to give information about models, they were not able to make the link between the physical model that they were using and the phenomena that was being represented.

For example, using the exhibit *Harnessing the Potential*, students were able to give information about different applications of using a hand pump to create electricity but failed to make important links between the water flowing down the chute to spin the turbine and a river or wind powering a turbine. This exhibit contains detailed information about its purpose and goals (discussed in Chapter 4.4) however, due to the students not reading the information thoroughly, learning opportunities were missed. If the students had gained a more detailed understanding of what the model was trying to portray, then they should have been able to make the link between generators rotating to create electricity. Then using this link to say that this type of knowledge may be applied somewhere else, for example in a wind farm.

Overall, the students involved in the two treatment groups showed that they had learnt and remembered more about the actual exhibits than the other students. However, providing specific questions about the use of models was not explicit enough for these students. Even after providing these students with further discussion questions around the models, they were still unable to realise and discuss the link between the physical analogical model and the phenomena that was represented.

5.4 Summary

The use of Exscite to portray and teach aspects of the NoS was the focus of this study. As the literature cautioned (e.g., Davidsson, 2009; Davidsson & Jakobsson, 2007; Rennie & Williams, 2002), it was clear the NoS aspects are difficult to identify within interactive science exhibits. This is possibly due to the exhibit developers have various agendas and design hands on exhibits that detail ‘wonders of science’ rather than the NoS (Pedretti, 2002). While this was the case, after careful consideration of the exhibits, and looking for more than simply the face value of the exhibits, some NoS aspects became apparent. From all of the exhibits that Exscite contains, two exhibits were chosen that portrayed detailed information about the purpose and use of models. Exhibits also indicated that science is a human enterprise, that is, scientific knowledge is of a special nature such as being tentative and coming from human activities.

Also of importance to this study was whether or not students could learn some of these NoS aspects that had been identified. It was determined that students could learn aspects of the NoS at an interactive science centre as indicated by: student perceptions of science and scientists; scientific theory development; the purpose and use of models in science; student behaviour at Exscite; and how the two treatment groups compared to the other students.

During the initial stages of this study, it was clear that the students had not experienced much science. The likely causal factor for this was curriculum requirements set out by the school and government (Gough, 2008). It was also clear that some impressions had been made on the students giving rise to how they perceived science and how scientists work (Buldu, 2006; Finson et al., 1995). These perceptions were concordant with other findings from various researchers such as Archer et al. (2010), Finson et al. (1995), and Huber & Burton (1995). After visiting Exscite, students were able to give responses to these questions now that showed an increased and more sophisticated level of understanding. These results were similar to McNeill (2011) who also found an increased level of understanding around student perception after working through a science based unit.

Similarly, when questioned about aspects of scientific theory, students' initial responses were naïve and unclear. Although, there was a common theme amongst the students that scientists worked to find things out. This result was akin to Murphy et al. (2011) who also found this to be a common theme when researching student perceptions of scientists. After visiting Excite however, students were able to add to their original ideas by now discussing how scientists may work. Discussions now included the notion of perseverance and that the scientists may have to try various approaches to find out new information, such as, asking someone who may be able give an insight.

Discussing models proved to be a difficult task initially for the students. This was due to the students having ideas that were often naïve and unclear when it came to models. Chittleborough et al. (2005) then explain that this is often the case as even though models are frequently used whilst teaching, their purpose and function is rarely explicitly explained to the students. After visiting Exscite, students now appeared to be aware about what a model was and why it may be used, such as: sophisticated responses indicating their role in the scientific process; showing other people the working parts of something; carrying out tests; and for studying. These results were analogous to those found by Chittleborough et al. (2005) who also saw that students who were exposed to models, showed an increase in their knowledge about purposes and uses of models.

In their contextual model of learning, Falk and Dierking (2000), indicate that the physical layout of an interactive science centre will contribute to the learning. This layout also predominately governed how the students explored this environment. Students were noticeably excited as soon as they entered Exscite. This is described by DeWitt and Storcksdieck (2008) as being because they are now entering a novel environment. Once they were allowed to explore the exhibits, students moved quickly to towards the eye-catching exhibits. It is also important to note here that whilst in this novel environment, they are prone to become distracted by the actual exhibits, rather than focusing on what the exhibits are trying to portray. This point was reiterated by Peacock and Pratt (2011) who obtained similar results when taking students to a free-choice learning

environment. Whilst interacting with the exhibits, students were reluctant to read any of the information that was available, unless it was specifically pointed out to them, thus reinforcing the idea of having a person to help facilitate the learning available (Ash, 2004).

When visiting Exscite, there were two treatment groups that had some questions to discuss centred on the two chosen exhibits. It was intended that by having these students think critically and discuss the exhibits, they would be able to make important links about the purpose and use of models. However, like their peers, they were also in this novel environment (DeWitt & Storksdieck, 2008), and were keen to explore with their friends. With this, their responses to the discussion questions were short and vague. Upon returning from Exscite, when questioned about what they had learnt, their responses were similar to their peers. These treatment groups showed that they could remember more specific things from Exscite, but were still unable to make the links that what they were interacting with was a model and what it was representing.

Chapter Six
Conclusion and
Implications

6.1 Conclusion

This research project was based on the idea that free-choice learning environments, such as interactive science centres, may have the ability to teach students some aspects about the nature of science (NoS). However, since the NoS is not a central theme for developing interactive exhibits, NoS aspects were difficult to identify. Nonetheless, some aspects were identified and the two exhibits that displayed these aspects clearly, were chosen as a focal point for data collection.

While these exhibits had potential to teach some aspects of the NoS, it became clear that it was intended that the learning would come from a mixture of the students interacting with the exhibits as well as reading the information. However, in this new environment, students were interested in the hands-on interactive parts of the exhibits rather than the information cards that accompanied them. The only times the students read from any information cards was when a teacher or parent guided them to it. From this, it is clear that to increase the teaching potential of these exhibits the use of a learning facilitator would be beneficial, such as the science education officer at Exscite.

Upon meeting with the students, it was clear they were quite unsure about the whole area of science, and this was evident throughout their unclear and naïve answers when questioned about their previous scientific experiences. Again, when questioned about aspects from the NoS, their answers reflected their lack of experience within science. The data collected after the visit to Exscite indicated, however, that the students had learnt new information about aspects of the NoS. This is evident through the level of detail in the answers that students were able to give during the post-visit interview phase of the data collection.

These results then, and the conclusions drawn from them, indicate that there is a link between interactive science centres and students learning about NoS. However, while interactive exhibits showed potential to teach about the NoS, they were not effective as stand-alone entities, rather there needed to be a combination between the exhibits themselves and the information supplied. Then, the use of

facilitators, such as an education officer, to highlight important pieces of information, and hence be a part of the learning process may be beneficial and enhance the learning potential at an interactive science centre.

6.2 Implications

6.2.1 Implications for Teachers

Throughout the literature, there was a common theme stating that teaching about the NoS can be a difficult task. The data gathered throughout this study suggests that using an interactive science centre may be beneficial for teaching students about the NoS and has led to two suggestions for teachers to enhance the learning that might occur:

- Field trips to any free-choice learning environments are novel experiences for many students. It is important though, that this experience is not just left as a stand-alone activity. Pre- and post-activities should be developed and implemented that incorporate aspects of the NoS. It is also important to highlight the point that pre- and post-activities, as well as the actual site visit, should be somehow linked.
- Whilst at a free-choice learning environment, teachers often have to abandon their teaching role and revert to a managerial position to look after the students and ensure the trip runs smoothly. While this is a necessity, there is also a need for a person to help the students understand; hence they facilitate the learning process. Making use of a science education officer or equivalent during the visit may be beneficial for the learning.

By adhering to these suggestions, teachers may be able to use the interactive science centres as an effective teaching tool for teaching aspects of the NoS.

6.2.2 Implications for Interactive Science Centres

While use of interactive science centres can be an effective teaching tool for teaching students science and about the NoS, many interactive exhibits have been designed without considering the NoS, rather focusing on the ‘wonders of science’. While students enjoy interacting with these exhibits, they can view these as being novel and distracting which will be problematic. While engaged with these novel exhibits, students may be distracted from the targeted idea and hence they may not learn as much as anticipated. To teach students about the NoS, there needs to be a larger focus on NoS. Many of the exhibits that are currently at Exscite were designed and constructed before there was this focus on the NoS within science education. Thus, there needs to be a way to readjust or update exhibits to incorporate some aspects of the NoS.

From this study, there are three clear ways to increase the awareness about the NoS:

- While there is information accompanying the exhibits about the science behind the exhibit, perhaps information that explicitly details the NoS associated with each of the exhibits may also be beneficial.
- Teachers need to explicitly discuss the NoS aspects of the exhibits with the students. For example, reiterating what a model is to students, how it works, what it is, and why it is used by scientists. For this though, teachers may need to be supplied with supplementary information regarding the NoS within exhibits. However, as they are often unable to be in the facilitator role, the science education officer, or equivalent, may be able to explain this information to the students as they interact with the exhibits.
- Many of the exhibits were created before the NoS was a key part of science education, thus indicating the importance of updating exhibits. Here exhibits could be redesigned, or new exhibits may be designed and constructed to help teach aspects of the NoS.

By adhering to these suggestions the level of understanding about the NoS obtained from an interactive science centre may be increased. To accomplish this

second point, information about the NoS in regards to exhibits should be made available to teachers.

6.3 Future Research

Two suggestions for future research at Exscite, or other interactive science centres are as follows:

- This study, as well as the literature, indicated that using pre- and post-activities, in addition to worksheets when visiting a free-choice learning environment can be effective (e.g., Anderson, Lucas, Ginns, & Dierking, 2000; Burtnyk & Combs, 2005; Davidson et al., 2009; Price & Hein, 1991). With that in mind, it would be helpful to research the use of specific tools, such as worksheets, that target learning about the NoS when visiting Exscite. While Exscite does have some worksheets available, they are more focused on the students finding parts of the centre rather than thinking about the NoS. These activities would need to be clearly developed using information from Exscite as well as information from the current science topic the students may be completing. Teachers would then be able to implement these activities which would enhance the learning. An example here could be when a teacher is completing a unit on electricity and power, information about renewable energy could be used before experiencing *Harnessing the Potential*. Data may then be collected before and after each of the activities, including the visit. This would allow for an effective tool to offer teachers and others when using Exscite as a teaching tool for the NoS.

- Throughout this research project it was reiterated that interactive science exhibits are often designed and developed to showcase wonders of science, rather than illustrating the NoS (Davidsson, 2009; Davidsson & Jakobsson, 2007; Rennie & Williams, 2002; Pedretti 2002). It would be interesting to design and construct a series of exhibits aimed at portraying

particular aspects of the NoS, such as incorporating controversial issues, the fact that scientific knowledge is tentative and can be wrong, socio-scientific issues, and indicating a degree of uncertainty with their claims. An example of this could be an exhibition based around the concept of global warming. Here there may be a combination of exhibits that display information and also allow students to act as scientists and investigate changes, such as an exhibit where users have to investigate environmental temperature and investigate the effects on the earth. Research could then be conducted that investigates the effectiveness of these purposely designed exhibits to enhance understanding of the NoS.

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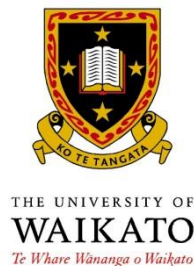
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Appendices

Appendix A – Information Letters

Centre for Science and
Technology Education Research
The University of Waikato
Private bad 3105
Hamilton, New Zealand



Date

Dear [Principal]

Information about the research project:

Learning Aspects of the Nature of Science at an Interactive Science Centre

My name is Jared Carpendale and I am a chemistry, physics, and science teacher at Hamilton Boys' High School and a research student at the Centre for Science and Technology Education Research, University of Waikato. I am very passionate about science education, in particular learning about science in and out of classroom environments such as an interactive science centre, zoo, museum, etc., and am currently doing my Master of Education degree in this field.

For my research I am investigating whether or not an interactive science centre has the potential to teach students about aspects of the nature of science, including: using a range of scientific symbols, conventions, and vocabulary; using their growing science knowledge when considering issues of concern to them; building on prior experiences, working together to share and examine their own and others' knowledge. This research will be in part conducted at Exscite, the interactive science centre at the Waikato Museum who are supporting this study. If you consent to taking part in this study I would ask that the class I am going to be working with visit Exscite once during term three.

The research will take place during term three of 2011, and will be conducted in three stages. During phase one I would like to visit the class from your school and ask students to take part in a focus group discussion (groups of between 3-5 students) where they will be asked an open ended question around the nature of science, which will be audio

recorded. From those discussions I will select two groups who I would like to observe during a visit to Exscite during phase two of this study. The two selected groups will receive worksheets with some prompts that I would like them to discuss as they are interacting with two selected exhibits. I would like to observe the selected focus group students, record their conversations and take photographs. Any photographs taken will have blurred faces to ensure no student can be identified. Phase three will occur after the visit. I would like to meet with the class once more and involve them again in focus group discussions similar to the phase one discussions which will also be audio recorded.

As well as providing you, the teacher, the students and the parents with this information, I am happy to explain the purpose of this study during my initial visit and would also like to offer you a meeting after the research has been conducted and analysed to share my findings. I am also planning to send your school a short summary of the research findings on completion of my thesis.

I hope that this investigation will help to better understand whether a visit to a science museum can help to support teaching aspects about the nature of science and whether the prompts used during the visit are supporting this focus.

Please note that this research will follow the University of Waikato Human Research Ethics Regulations. This involves the following points:

- Your consent to participate in this research will be obtained only after you have received all the information about it. If convenient I am happy to make myself available for a meeting for parents and caregivers prior to obtaining their consent where they can ask any questions about the research.
- If your permission is given to proceed, I will obtain informed consent from the teacher of the class, the students and their parents/caregivers before proceeding further with the research.
- You will not be obliged to agree for your school to participate if you are not comfortable doing so.
- You can withdraw your school's participation at any stage during the data collection phase of the research.
- All students who bring back informed consent forms from their parents and caregivers will take part in the focus group discussions. It is expected that there will be approximately six focus groups.

-
- Your school and students' privacy and confidentiality will be respected. They will not be identified by name or by any other information that can lead to their identity being known. All the reports and publications will use pseudonyms.
 - The time involved for a class in your school in this research is two focus group discussion sessions, where each focus group will take no longer than 10 minutes, plus the actual visit to the interactive science centre. These discussions will be audio recorded.
 - If a conflict does arise in the course of the research, the first person to address is the researcher, Jared Carpendale (jared.carpendale@gmail.com), and then if the next step is needed, you can contact Dr Kathrin Otrell-Cass (kathrino@waikato.ac.nz) who is the supervisor of this research project.

When we meet I will discuss informed consent, and give you informed consent forms for you to take away and read, and then sign and return if you are willing to let your school participate and are satisfied with all of the research aspects.

Thank you for your cooperation.

Jared Carpendale

jared.carpendale@gmail.com; Phone 027 294 2434

**Centre for Science and
Technology Education Research**
The University of Waikato
Private bad 3105
Hamilton, New Zealand



Date

Dear [Teacher]

Information about the research project:

Learning Aspects of the Nature of Science at an Interactive Science Centre

My name is Jared Carpendale and I am a chemistry, physics, and science teacher at Hamilton Boys' High School and a research student at the Centre for Science and Technology Education Research, University of Waikato. I am very passionate about science education, in particular learning about science in and out of classroom environments such as an interactive science centre, zoo, museum, etc., and am currently doing my Master of Education degree in this field.

For my research I am investigating whether or not an interactive science centre has the potential to teach students about aspects of the nature of science, including: using a range of scientific symbols, conventions, and vocabulary; using their growing science knowledge when considering issues of concern to them; building on prior experiences, working together to share and examine their own and others' knowledge. This research will be in parts conducted at Exscite, the interactive science centre at the Waikato Museum who are supporting this study. If you and your class consent to taking part in this study I would ask you to visit Exscite once during term three.

The research will take place during term three of 2011, and will be conducted in three stages. During phase one I would like to visit your class and ask students to take part in a focus group discussion (groups of between 3-5 students) where they will be asked an open ended question around the nature of science, which will be audio recorded. From those discussions I will select two groups who I would like to observe during a visit to

Excite during phase two of this study. The two selected groups will receive worksheets with some prompts that I would like them to discuss as they are interacting with two selected exhibits. I would like to observe the selected focus group students, record their conversations and take photographs. Any photographs taken will have blurred faces to ensure no student can be identified. Phase three will occur after the visit. I would like to meet with your class once more and involve them again in focus group discussions similar to the phase one discussions which will also be audio recorded.

As well as providing you, the students and the parents with this information, I am happy to explain the purpose of this study during my initial visit and would also like to offer you a meeting after the research has been conducted and analysed to share my findings. I am also planning to send you and the school a short summary of the research findings on completion of my thesis.

I hope that this investigation will help to better understand whether a visit to a science museum can help to support teaching aspects about the nature of science and whether the prompts used during the visit are supporting this focus.

Please note that this research will follow the University of Waikato Human Research Ethics Regulations. This involves the following points:

- Your consent to participate in this research will be obtained only after you have received all the information about it, and your principal has given consent. After I have your permission and consent, I will ask for consent from the parents and caregivers of the students.
- Only students that have ethical consent will be invited to partake in the focus group discussions, and it is expected that there will be approximately six focus groups.
- You will not be obliged to agree for you or your class to participate if you are not comfortable doing so.
- If students are not participating in the research project, it will not affect their experiences at Excite.
- You can withdraw your class' participation at any stage during the data collection phase of the research.

-
- Your privacy and confidentiality will be respected. You will not be identified by name or by any other information that can lead to their identity being known. All the reports and publications will use pseudonyms.
 - The time involved for your class in this research is two focus group discussion sessions, where each focus group will take no longer than 10 minutes, plus the actual visit to the interactive science centre. These discussions will be audio recorded.
 - If a conflict does arise in the course of the research, the first person to address is the researcher, Jared Carpendale (jared.carpendale@gmail.com), and then if the next step is needed, you can contact Dr Kathrin Otrell-Cass (kathrino@waikato.ac.nz) who is the supervisor of this research project.

When we meet, I will discuss informed consent and give you an informed consent form to take away and read, and then sign and return if you are willing to let your class participate and are satisfied with all of the research aspects. If you are willing to participate, I will come and collect your informed consent form, and give you the forms for the students to take home. I have also asked that parents and caregivers complete the form and return to you. I will collect the forms during my first visit in your class.

Thank you for your cooperation.

Jared Carpendale
jared.carpendale@gmail.com; Phone 027 294 2434

**Centre for Science and
Technology Education Research**
The University of Waikato
Private bad 3105
Hamilton, New Zealand



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Date

Dear parents/caregivers.

Information about the research project:

Learning Aspects of the Nature of Science at an Interactive Science Centre

My name is Jared Carpendale and I am a chemistry, physics, and science teacher at Hamilton Boys' High School and a research student at the Centre for Science and Technology Education Research, University of Waikato. I am very passionate about science education, in particular learning about science in and out of classroom environments such as an interactive science centre, zoo, museum, etc., and am currently doing my Master of Education degree in this field.

For my research I am investigating whether or not an interactive science centre has the potential to teach students aspects about the nature of science, including: using a range of scientific symbols, conventions, and vocabulary; using their growing science knowledge when considering issues of concern to them; building on prior experiences, working together to share and examine their own and others' knowledge. This research will be in parts conducted at Exscite, the interactive science centre at the Waikato Museum who are supporting this study. If you consent for your child to take part in this study, they will be asked to visit Exscite once during term three with the rest of the class.

The research will take place during term three of 2011, and will be conducted in three stages. During phase one I would like to visit your child's class and ask students to take part in a focus group discussion (groups of between 3-5 students) where they will be asked an open ended question around the nature of science, which will be audio recorded.

From those discussions I will select two groups who I would like to observe during a visit to Exscite during phase two of this study. The two selected groups will receive worksheets with some prompts that I would like them to discuss as they are interacting with two selected exhibits. I would like to observe the selected focus group students, record their conversations and take photographs. Any photographs taken will have blurred faces to ensure no student can be identified. Phase three will occur after the visit. I would like to meet with your child's class once more and involve them again in focus group discussions similar to the phase one discussions which will also be audio recorded.

I hope that this investigation will help to better understand whether a visit to a science museum can help to support teaching aspects about the nature of science and whether the prompts used during the visit are supporting this focus.

Please note that this research will follow the University of Waikato Human Research Ethics Regulations. This involves the following points:

- Your consent to allow your child to participate in this research will be obtained only after the principal of the school, and the classroom teacher has consented. Also, only after you and your child have received all the information about it. You will not be obliged to agree for your child to participate if you are not comfortable doing so.
- Only children who have ethical consent will be invited to take part in the focus group phase of the research. It is expected that there will be approximately six groups.
- You can withdraw your child's participation at any stage during the data collection phase of the research.
- If your child is not participating in the research project, it will not affect the experiences that they will have at Exscite.
- Your child's privacy and confidentiality will be respected. They will not be identified by name or by any other information that can lead to their identity being known. All the reports and publications will use pseudonyms.
- The time involved for your child's class in this research is two focus group discussion sessions, where each focus group will take no longer than 10 minutes, plus the actual visit to the interactive science centre. The discussions will be audio recorded.

- If a conflict does arise in the course of the research, the first person to address is the researcher, Jared Carpendale (jared.carpendale@gmail.com), and then if the next step is needed, you can contact Dr Kathrin Otrell-Cass (kathrino@waikato.ac.nz) who is the supervisor of this research project.

Please read informed consent forms carefully and then sign and return to the class teacher if you are willing to let your child participate and are satisfied with all of the research aspects.

Thank you for your cooperation.

Jared Carpendale

jared.carpendale@gmail.com; Phone 027 294 2434

**Centre for Science and
Technology Education Research**
The University of Waikato
Private bad 3105
Hamilton, New Zealand



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Date

Dear Students,

Information about the research project:

Learning Aspects of the Nature of Science at an Interactive Science Centre

My name is Jared Carpendale and I am a science teacher at Hamilton Boys' High School and a research student at the Centre for Science and Technology Education Research, University of Waikato. I am currently doing research on what students like you, might learn about science at Exscite – an interactive science centre.

For this research I will be spending time in your class with you and your teacher, and you will be invited to discuss with me and other students in your class what you may already know about science. After talking about what you know about science, I will join your class on a visit to Exscite. During this visit, I will be there to take a few notes, and might take some photographs of you using the equipment.

I will not use your real name and not show your face in the photos I will take.

You don't have to answer any of my questions if you don't want to.

If want to ask me more questions, you or your parents can contact me via email, jared.carpendale@gmail.com, or phone, 027 294 2434.

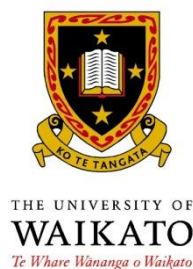
I am sure working with you and your class will help me learn how to teach science in a better way.

Thank you!

Jared Carpendale

Appendix B – Informed Consent Letters

Centre for Science and
Technology Education Research
The University of Waikato
Private bad 3105
Hamilton, New Zealand



Date

Dear [Principal]

Informed consent for the research project – Principal

Learning Aspects of the Nature of Science at an Interactive Science Centre

I have read the attached information letter about this research project.

I understand that:

1. My school's participation in the project is purely voluntary.
2. You are asking that my school takes part in this research project during class time as specified in the accompanying letter.
3. I have the right to withdraw my school at any time during the data collection phase of the research, the classroom teacher has the right to withdraw the class at any time during the data collection phase of the research, and the students have the right to withdraw the class at any time during the data collection phase of the research. No participant that has withdrawn will be identified, and any data collected from a child that has

been withdrawn will not be not be used for the analysis, and no further data will be collected.

4. All data collected from my school will be kept confidential and securely stored.
5. My school, classroom teacher, and students will not be identified in transcribed excerpts of the discussions or photographs.
6. Data obtained during this research project will be analysed and used in writing a thesis for a Master of Education degree at the University of Waikato. Some of the work may also be presented at conferences, or used in educational journals. All data will be reported anonymously so that confidentiality of the participants is maintained.
7. All data will be reported anonymously using pseudonyms so that confidentiality of my school and other participants is maintained.
8. I can direct any questions or concerns to researcher Jared Carpendale (jared.carpendale@gmail.com, Tel. 027 294 2434), or to the supervisor Dr Kathrin Otrell-Cass (kathrino@waikato.ac.nz, Tel. 07 8384512).

I give consent for my school to be involved in the research project under the conditions set out above.

Name of School: _____ Date: _____

Name of Principal: _____

Principal Signature: _____

**Centre for Science and
Technology Education Research**
The University of Waikato
Private bad 3105
Hamilton, New Zealand



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Date

Dear [Teacher]

Informed consent for the research project – Classroom Teacher

Learning Aspects of the Nature of Science at an Interactive Science Centre

I have read the attached information letter about this research project.

I understand that:

1. My class' participation in the project is purely voluntary.
2. You are asking that my class takes part in this research project during class time as specified in the accompanying letter.
3. I have the right to withdraw my class at any time during the data collection phase of the research, and the students and parents have the right to withdraw at any time during the data collection phase also. This means that any data collected from a child that has with withdrawn will be destroyed and no further data will be collected.
4. All data collected from my class will be kept confidential and securely stored.

5. My class will not be identified in transcribed excerpts of the discussions or photographs.
6. Data obtained during this research project will be analysed and used in writing a thesis for a Master of Education degree at the University of Waikato. Some of the work may also be presented at conferences, or used in educational journals. All data will be reported anonymously so that confidentiality of the participants is maintained.
7. All data will be reported anonymously using pseudonyms so that confidentiality of my class and other participants is maintained.
8. I can direct any questions or concerns to researcher Jared Carpendale (email jared.carpendale@gmail.com, Tel. 027 294 2434).

I give consent for my class to be involved in the research project under the conditions set out above.

Name of School: _____ Date: _____

Name of Teacher: _____

Teacher Signature: _____

Centre for Science and
Technology Education Research
The University of Waikato
Private bad 3105
Hamilton, New Zealand



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Date

Dear parents/caregivers.

Informed consent for the research project – Parent/Caregiver

Learning Aspects of the Nature of Science at an Interactive Science Centre

I have read the attached information letter about this research project.

I understand that:

1. My child's participation in the project is purely voluntary.
2. You are asking that my child takes part in this research project during class time as specified in the accompanying letter.
3. I have the right to withdraw my child at any time during the data collection phase, and my child has the right to withdraw at any time during the data collection phase. This means that any data collected from my child after the withdrawal will be destroyed and no further data will be collected from my child.
4. If your child is withdrawn from the research they will still take part in normal school activities, however no data will be collected.

5. All data collected from my child will be kept confidential and securely stored.
6. My child will not be identified in transcribed excerpts of the discussions or photographs.
7. Data obtained during this research project will be analysed and used in writing a thesis for a Master of Education degree at the University of Waikato. Some of the work may also be presented at conferences, or used in educational journals. All data will be reported anonymously so that confidentiality of the participants is maintained.
8. All data will be reported anonymously using pseudonyms so that confidentiality of my child and other participants is maintained.
9. I can direct any questions or concerns to researcher Jared Carpendale (email jared.carpendale@gmail.com, Tel. 027 294 2434).

I give consent for my child to be involved in the research project under the conditions set out above.

Please complete this form and return to the classroom teacher.

Date: _____

Name of Student: _____

Student Signature: _____

Name of Parent: _____

Parent Signature: _____

Appendix C – Focus Group Discussion Questions

These are a series of discussion questions that have been developed by using ‘Taking into Account Students’ Thinking’ (Bell, 1993) and the New Zealand Curriculum document (Ministry of Education, 2007). They are open ended questions that have been designed to provoke discussions amongst the students firstly around school science and then some specific aspects of the nature of science.

These questions are designed to be a standard base between each focus group; however, they will be conducted in an informal interview style to ensure student ideas can be probed and developed further.

Firstly, to get the students comfortable with the situation, there will be some general questions about their day and whether they understand why they are being asked questions. It will also be made clear that this is not a test.

1. Tell me about if you have done any science at school/home/anywhere else? Can you give any examples?
2. Can you tell me about what scientists do?
3. Have you ever seen a scientist? (maybe on T.V., or in books, or in real life)
4. How do scientists do their investigations? (How do they find out stuff?)
5. Do you think scientists always agree with each other? (What do they do if they disagree?)
6. What do you think makes scientists change their ideas?

7. What do scientists do when they do not understand something? How? Why?

8. Sometimes scientists use models; can you tell me why you think they do this? (May need to explain to students that a model is a smaller representation that shows how something works).

Appendix D – Exhibit Discussion Questions

Worksheet

Could you please find with your group an exhibit called the Grain Factory. Have one person in your group to read each question and another person to hold the recorder. Make sure the recorder is working, and ask if you think it's not.

Start by saying your first names.

Please read the questions below and talk about them while you are exploring the exhibit.

The Grain Factory

The Grain Factory exhibit is a model. This means that it allows you to explore how things work. This model shows you how different machines can be used for different jobs.

Now explore and talk about.

1. What sort of jobs can this model do?
Why do you think is it useful to use models like the Grain Factory?
Have you used other models before, if you have, what were they about?
2. Why do you think scientists use models like this one, and what can they learn from it?
3. What did you learn from the Grain Factory?

Please find the exhibit called ‘Harnessing the Potential’

Harnessing the Potential

Harnessing the Potential is a model that is used to show how one type of energy can be changed into other types of energy.

1. Explore the exhibit and talk about what the exhibit can do and show (explain it to each other).
2. What can people learn from coming to an exhibition and ‘playing’ with models like this one?
3. Why do you think it is useful for people like scientists or engineers to use models like this one?

