# EARTH SCIENCE IN NEW ZEALAND SCIENCE CENTRES – LEARNING ASPECTS THROUGH A SIMULATION BASED EXPERIENCE

A thesis submitted in
fulfilment of the requirements
for the degree
of
Doctor of Philosophy
at the
University of Waikato

By
KATHRIN MARIE OTREL-CASS

UNIVERSITY OF WAIKATO
2001

## ABSTRACT

This study investigated how simulations at the New Zealand earth science exhibition *Earthworks* could teach geological concepts. The introduction of a geoscience component in the New Zealand science curriculum, the development of science-technology centres and a funding opportunity provided the incentive for the development of *Earthworks*, which exhibits linked to the themes of the New Zealand science curriculum. For the designers of *Earthworks,* the exhibition was a challenge to provide an opportunity for both students and their teachers. This study looked at students' interactions at the science centre and portrayed them as objectively as possible, including externally contributing factors. Therefore, information such as the ideas that the designers tried to portray through the exhibits or the attitude of the teachers towards earth sciences was just as important as how the students experienced the simulations.

Although the literature provides discussion and definitions about learning in science centres, generally there has been less about the learning and teaching aspects of earth sciences in such settings. The aim of this study was to tie together many of the previous findings and apply them to the hypothesis that earth sciences can be taught effectively when they are supported by a simulation. This proposition was assessed by using a variety of methods: (1) analysis of observations of 118 students and 8 adult visitors to the earth science exhibition *Earthworks*; (2) content analysis of focus group interviews with 47 students and 37 teachers; (3) analysis of pre-questionnaires conducted with 156 teachers, 26 of which replied in a post questionnaire round; and (4) a document analysis that examined three documents.

Findings of the investigation gave rise to five conclusions about the impact of earth science simulations at science centres: (1) it was discovered that a theoretical framework assists designers in conceptualisation and teachers in the implementation of the program; (2) several factors were identified that enhance the ability of a simulation to effectively communicate earth science concepts like: clear communication of concepts, clear demonstration of spatial and causal processes, the opportunity for the participant to make hypotheses and test them and a clear statement of the role of the participant. (3) The results of the study further showed that students would usually try to find a meaning for something they saw and make a judgement as to whether it is worth while pursuing. (4) The recognition of a concept displayed by using a simulation appears to happen in a similar sequence to that of learning to read. (5) The findings from this study suggest that the motivation for reading a label on a given exhibit is driven more by the agenda of the visitor than by any other factor such as readability.

A central conclusion is that simulations have the potential to provide a useful tool for it to teach earth science concepts in the environment of a science centre, however it is vital for the success of such a learning tool to be carefully planned and tested before use.

## ACKNOWLEDGEMENTS

During the course of this study, I have received support from many people, all of whom I wish to thank here. Alister Jones (University of Waikato) my chief supervisor, who I thank for taking the project on late in the progress and his invaluable suggestions, advice and encouragement. Many thanks to Peter Hodder (Waikato Polytechnic) my supervisor, without whom this project would never have started, for his continued support, enthusiasm and endurance to the end. Thank you to Janet Burns (Massey University) for her early input to the project. To all the staff at EXSCITE especially David Wright and Jenny McFarlane and to Stuart Schwartz and Peter Milllward at the Science Centre and Manawatu Museum for providing access to the exhibition at the venues, thank you. I would like to thank all the teachers and students who supported the research by freely giving their time for interviews and filling out questionnaires.

Although I have been working and living off-campus, colleagues and friends at the department of Earth Sciences have always made me feel welcome and provided major support and friendship. In particular I would like to thank Penny Cooke, Barbara Hobden, Richard Chapman, Arne Pallentin, Jayanthi Jayawardane, Peter Kamp, Roger Briggs, Sydney Wright, Elaine Norton and in memory, Jeannette Gillespie.

Thanks to my family and friends in New Zealand and Austria for their support and understanding throughout my time at the University. Grandma, now you can finally show me your 'operation'. Special thanks to my children, Lucy and Kim for putting up with such a busy mum. Having been told that thesis writing is the number one cause of marital breakdown, I am most thankful to my loving and supporting husband and always patient IT aid, Andrew for proving this theory wrong.

This thesis is dedicated to my Mother – *Danke fűr all die Liebe und Unterstűtzung!*

## PREFACE

Back in my hometown, Salzburg, there is a museum of natural history – *Das Haus der Natur.* As a child I loved to go there being overwhelmed by the entrance hall, showing gliding Pterosaurs, giant squid and an Iguanadon. Up on the third floor there was a small room, being R18 rated, featuring the genetic horrors of life saved in formaldehyde. As a child it was naturally a 'dare' to enter and for me museums became places that featured amazing curiosities.

When I was in my early teens I went on a school trip to the *Deutsche Museum* in Munich. This experience was an eye opener for me and sparked an interest in science and museums that has lasted until today.

When I heard about the *Earthworks* project and the opportunity to conduct research in this area, it was the natural progression of this long interest that influenced me to proceed with this work.

**CONTENTS**

## FIGURES

# TABLES

## PHOTOGRAPHS

Chapter 1

# INTRODUCTION

## 1.1 OVERVIEW

Overseas literature reports that research in earth science education has received much less attention than the physical and life sciences (Gobert, 2000). This lack of research is most likely due to the fact that it has been under-represented in the National Science Curriculum like it was the case in New Zealand until recently (Ministry of Education, 1996). The introduction of earth sciences as a 'learning strand' (viz., 'Planet Earth and beyond') in the curriculum was seen as an opportunity for new teacher development and new teacher resources.

*Earthworks,* an interactive earth science exhibition was an initiative taken in response to a perceived demand for resources (Hodder, 1997). The design of the exhibition emphasised hands-on activities that represent simulations. Simulations are simplified versions of reality, showing sequences of earth science processes and allowing the participant to interact with them. Simulations have been traditionally described in connection with role play (Hensgens, Van Rosmalen and Van Der Baaren, 1995; Town, De Jong and Spada, 1993) and only in very recent studies brought into connection with scientific models (Harrison and Treagust, 2000). The discussion about models (Gobert and Buckley, 2000), the ongoing discussion about the value of representations at interactive science centres and museums (Geyer, 1995; Wizevich, 1993) and the discussion on geo-science education (Gobert, 2000; Nottis, 1999) provided both a challenge and the framework for this study to investigate the presentation and reception by school pupils and teachers of earth science simulations in New Zealand science centres.

This study is looking at simulations at the *Earthworks* exhibition and provides a broad analysis of how this exhibition communicated earth science concepts.

## 1.2 SCIENCE CENTRES

Science centres have evolved from a long history of the development of museums. Museums, as institutions, fundamental to the science centre 'movement', have undergone many changes (McManus, 1992) as have educational systems. Science centres can be considered as another expression of the changes that have occurred in science education. Perceptions of goals and practices of educators in science today is having an effect on schools and other educational institutions (e.g., Black and Atkin, 1996). The literature review in chapter 2 highlights the historical development of museums and the evolution of science centres because it seems that an understanding of the origins is indispensable to understand the philosophy of science centres.

Science centres brought with them a different approach of exhibit presentation and moved away from the traditional object focused approach of the 'classical' museums (McManus, 1992; Danilov, 1973). This change however has created a new educational environment that is confronted by internal and external criticism (Wizevich, 1993; Griggs, 1990). With the growing interest in research and the responsibility of science centres to be held accountable, reports about the failure of the communication process between the visitor and the exhibits have been mounting (Wizevich, 1993; Geyer, 1995).

Research on visitor studies aimsto address this failure of communication by describing the relationship between the visitor and the exhibit as a dialogue (Geyer, 1995). Section 2.4.3 in the literature review illustrates the development of visitor studies and different approaches are discussed.

## 1.3 GEO-SCIENCE EDUCATION

Research in geo-science education typically addresses one of the major difficulties within this field – the lack of observability (Gobert, 2000; Ault, 1987). Misconceptions that inhibit the novice in this field to integrate further concepts often result from this difficulty (Gobert, 2000).

The discussion often evaluates how to successfully teach earth science concepts (Hudak, 1998; Norris, 1993). Traditional strategies like field trips, it is argued, show concrete situations, which are easier to understand particularly for younger students (Manner, 1995). Other studies argue that the lack of visibility could result in causally and dynamically non-functional systems. Furthermore, misconceptions have been reported to persist into adolescence (Turner, Nigg and Daz, 1986). Section 2.5 illustrates the development of earth sciences in New Zealand over the past few years and highlights typical problems that arise in educational environments for teachers and their students.

## 1.4 MODELS AND SIMULATIONS

Science modelling has been traditionally researched within the context of teaching practices (Harrison and Treagust, 2000) and in respect to thinking processes (Newton and Newton, 1995). The description of exhibits in science centres and museums has been relatively vague and generally only concerned with whether an exhibit was static or interactive (Geyer, 1995). Only in recent times there has been more in depth study on the types of exhibits that are offered within science centres (Boisvert and Slez, 1995). These differentiate between different model characteristics but are still only looking at selected criteria leaving out issues that have been reported to be equally important in a model's possible source of communication success or breakdown.

This study aims to provide an analysis of a certain type of interactive exhibit - the simulation. It seeks to evaluate their impact by looking at the exhibit's ability to communicate, the students' behaviour with the simulations, teachers' attitudes and exhibit designers' intentions.

Despite many museum studies on exhibit communication, and educational studies on science modelling as well as geo-sciences assessing the effective teaching of earth sciences, no prior research has tied these three areas together and analysed the relationship of exhibit characteristics, visitor behaviour and exhibit designers. This research sets out to do this.

## 1.5 THE RESEARCH

This research examines the relationship between characteristics of exhibits identified as simulations and the visitors at the science centre. The exhibition *Earthworks*[*] was designed to cater specifically for the achievement objectives for level 4 – 6 students (year 8 – 10) (Hodder, 1997), outlined in the New Zealand Science Curriculum (Ministry of Education, 1993). The research will therefore focus on educational visitors to the science centres where *Earthworks* is exhibited.

This research aims to present a description of how earth science simulations operate and the means and factors by which students may be influenced. It will also be of interest for this study to find out what those who are directly concerned like students, teachers and designers regard as its advantages. This study does not endeavour to produce a prediction based on isolated factors, but aims to compare individual findings and cross-analyse.

---

[*] *Earthworks* was an earth science exhibition, designed to provide earth science experiences for students and teachers. It toured through major New Zealand science centres throughout 1996 –1998 ( Hodder, 1997).

The chief concern for this investigation is the suitability of the *Earthworks* simulations for communicating earth science concepts. The study investigates the proposition that learning earth science concepts can be better understood and facilitated by using simulations.

To investigate their impact this research will examine three groups:

- Students, who are going to visit the *Earthworks* exhibition.
- Teachers, who will bring their classes to the exhibition or come for teacher workshops.
- Designers, who created the exhibition.

An analysis of students' behaviour combined with interviews should supply information about the impact of the simulations. Behaviour study should allow a look at the prospects for learning as other studies (e.g., McManus, 1987) suggest.

Teachers are essential for this research in that it depends on their decision whether they chose to elect such an out-of-school experience and on what grounds. Their relationship with earth sciences needs to be investigated by using questionnaires and interviews. At least one other study suggests that many New Zealand teachers are unfamiliar with earth sciences and might therefore avoid teaching it at all (Hume, 1997).

Little research has been done on exhibition development; many studies focus on the final products - the exhibits. Only a few studies point out the importance of including this aspect in evaluation studies (Wizevich, 1993). Examining the designer's ideas by using document analysis, allows the basis and ideas by which the exhibition had been created to become apparent.

This thesis begins with a literature review in Chapter 2. It explains the background of the study and shows how this research relates to the ongoing discussion in the literature. Chapter 3 reflects on the literature and discusses the research questions and explains the methodology employed in this investigation. Chapter 4 presents and discusses the data. Finally Chapter 5 presents the conclusions by discussing the answers to the research questions of the thesis in relationship to the literature. Implications of this study for concerned groups as well as for future research are included in Chapter 5.

Science education has widely changed its approaches (Black and Atkin, 1996) in the past and is undergoing continuous and far reaching changes today. A key basis for the change includes the recognition of the learners' ideas and abilities as well as considering the teachers' abilities and facilities.

This research investigates whether earth science concepts can be better understood and facilitated when supported through an interactive simulation. This research acknowledges that it is not an assessment of the level that geo-science education is at but more a documentation of an open system that is constantly changing.

Chapter 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION TO THE LITERATURE REVIEW

This chapter discusses the literature that forms the framework of the investigation for this study. The chapter starts with a historical introduction to the development of museums (Section 2.2). It is appropriate to present the traditional development to understand how it has led to the evolution of the interactive science centre. Section 2.3 provides a focus on the different styles of exhibit presentation as well as a description of the science centres in New Zealand. Section 2.4 elaborates on the different learning environments that science centres represent and discusses the development and contribution of visitor studies to the understanding of this environment. Finally, as this thesis is looking at earth sciences in the context of a science centre, the current situation of earth sciences in New Zealand is discussed in section 2.5. This includes a literature review on student and teacher understanding in this field. A final summary looks at the overall outcomes of the review of related literature and points out the gaps that this study wishes to fill.

## 2.1.1 A BRIEF HISTORY OF HOW INTERACTIVE SCIENCE CENTRES DEVELOPED FROM THE TRADITIONAL MUSEUMS

## 2.1.2 INTRODUCTION

This section explores the historical development of museums. The early traditions are the focus of the first part and the section discusses the evolution of museums throughout the centuries with a special focus on the eighteenth, nineteenth and twentieth century. A summary is presented at the end of the section.

## 2.1.3 THE BEGINNING

There has been a long evolution in museums and science centres. Their history goes back to Greece in the third century BC when King Ptolemy the First, founded a place for the muses. The "Mouseion" housed collections from all areas of knowledge at the time, and included a library, botanical as well as zoological gardens and an observatory. It was to be a place devoted to research, a place for philosophers and their scholars who sought to reach a universal understanding (Ripley, 1970, p.24; Geyer, 1995). It was not only seen as a place that housed paintings and statues but also rare and curious collections of objects which would be "frequented by artists and scholars from the Greek lands and beyond" (Miller, 1973, p.19).

Museums continued to develop mainly because of people's urge to collect things, which was seen as a privilege. Private collections were a symbol of wealth and high status. It is therefore not surprising that in the Middle Ages especially, the Church accumulated a huge variety of collections of all kinds (Coe, 1986). The general trend of the following centuries of increasing stately wealth led these collections to later become the foundation for many museums. They were often collections of rarities, frequently called the Cabinets of Curiosities, and mirrored the fashions in collecting of their time. As the collections developed they were the "Theatrum Mundi" – the world theatre, meant to document the whole spectrum of human creation (Klein-Wisenberg, 1988).

One of the very exceptional collections of the seventeenth century was that of Duke Friedrich III von Holstein-Gotthorp zu Gotthorp, in Schleswig. It was one of the first "walk-in" exhibits of its time, housed in a globe three metres in diameter, constructed of copper. The outside showed the earth and the inside showed the sun, the moon and the stars. Through a door, up to 12 people could enter the globe and be seated on a bench. The globe was situated in a park, and by using waterpower could be turned around on its axis, to show the movement of the stars (Klemm, 1973). This could be considered as the precursor to the 'planetarium' – a popular modern-day addition to astronomical observatories.

In the seventeenth century collections started to become more systematically based. Objects were now organised, for example, into coin collections, or collections of art, as well as collections of the natural sciences. This organisation could now be described as the first distinction between the museum – as being a general documentation of human knowledge - and the pinacotheca – being a collection of paintings and sculptures (Weschenfelder and Zacharias, 1981).

Influenced by the ideas of Rene Descartes and Francis Bacon, museums evolved with a focus on technical artefacts (Klemm, 1973).

> We haue diuers curious Clocks; and other like motions of Return: and some perpetual Motions...We haue also Houses of deceits of the Senses; where we represent all manner of Feats of Juggling, False Apparitions, Impostures and Illusions; And their Fallaces...These are (my sonne) the Riches of Salomons House. (Bacon, 1627, p.41-42)

The museums of that time are described as having to serve a wider purpose (Geyer, 1995). Paintings for example, were not presented on their own but had to be integrated with the surrounding architecture. Even historical artefacts had to be brought into relationship with current beliefs. This early development of the Cabinets of Curiosities in becoming more organised collections saw a dramatic change in their accessibility to the general public in the eighteenth century.

### 2.1.4 THE EIGHTEENTH CENTURY

One of the hallmarks of the eighteenth century in the western world was social change. The power of the authorities was stated to be challenged, this being for example, the time of "liberté, egalité et fraternité" in France. The first monarch of his time to invite the general public to his private collections was King Louis XV of France, who announced in 1750 that parts of his collections in the Palais du Luxembourg could be viewed by the general public on two days during the week (Meyer, 1973). Josef II of Habsburg moved his collection of paintings to the Belvedere in Vienna and opened it on three days of the week to the public (Fliedl, 1988). His concept of presentation was also new as he did not just fill the walls with paintings but hung them up next to each other and labelled them as well (Hudson, 1975). This open invitation to the public did not always earn positive feedback, as some historians report the bad manners of the visitors, children, women and others, who did not behave in an orderly fashion. However, it appears that those museums attracted a wide range of audiences. Geyer, (1995) points out the significance of this observation by commenting that those museums seemed to attract people from every social status. In doing so, she says, those museums seemed to be more successful than many museums of today.

The British Museum has been portrayed as the first "real" museum, because it was founded by the state as a public institution. It opened in

1759. However, as Hudson (1975) describes, the complex regulations made it very difficult to visit:

> These laid down, among other things, that such studious and curious person as might wish to see the collections must first make a written application to the Porter, giving their occupation, name and address. They then had to call the following day for their tickets, which entitled them to visit the following day. This procedure was likely to last at least two weeks and the investigation into credentials could last as long as several months. (Hudson, 1975, p.9).

Reports from unhappy visitors in 1784, tell us that the guided tours, "which should not last longer than three hours", did not explain anything about the artefacts, but that guides moved their groups through the museum in silence. When asked to comment on the exhibits, guides would say that "they could not stop all the time" and that "exhibits were labelled anyway" (Hudson, 1975). In France, the Louvre opened in 1800 and was, in contrast to its British counterpart, very popular. Catalogues, which included descriptions of the paintings, were offered at a cheap price. This former collection of the King was now open to educate the general public (Geyer, 1995). It became increasingly popular, so much so that even the prostitutes moved their location owing to the increase in the number of people who visited (Klein and Bachmayer, 1981).

The museums of the eighteenth century had a more investigative character than ever before. Collections were being studied and researched. This new movement led to the opening of the first technical museum in Paris in 1794, the "Conservatoire des Arts et Metiers" (Klemm,1973). One of the reasons for this change of direction was the publication of Carl Linnaeus's "Systema Natura" which was a system designed to enable the classification of plants by the number of stamen and the number and organisation of the pistils in the flower. But Systema Naturae had the interesting side effect of allowing an order of species that was independent of human imaginative power and consequently eliminated the magic of fable and stories (Geyer, 1995). His system renewed interest in natural sciences, and public support grew for investigations into new areas of knowledge. James Cook's journeys into the Pacific and the travels and discoveries of Alexander von Humboldt occurred during this period and were also of great interest to the public. The "Musée d'Histoire Naturelle" in Paris is one example of the new urge to categorise natural sciences, with the division of science itself into Botany, Zoology, Agriculture, Chemistry, Mineralogy and Anatomy (Geyer,1995; Klemm, 1973).

The development of museums in the United States started much later but was from the beginning devoted to serve the public (Geyer, 1995). The pioneers of American museums were the Peale Museum in Philadelphia founded in 1782 and the Charleston Museum in South Carolina in 1793. Charles Wilson Peale, founder of the Peale Museum, started with the first experiments in taxidermy, life size representations of animals in their habitat, and was also reported as having recognised the importance of public relations work (Hudson, 1975). Hudson writes of the Charlston Museum:

> ..an extensive collection of beasts, reptiles, fishes, warlike arms, dresses and other curiosities. (Hudson, 1975, p.33).

Geyer (1995) describes the American development as being similar to the chaotic collections of the Old World. However, these museums did have a significant difference from their Old World counterparts, as they were entirely devoted to educating the general public:

> The American museum is an American phenomenon, developed by the people, for the people and of the people. (Geyer, 1995, p.10)

Geyer (1995, p.10) describes the American museum as a "democratic club", while the European counterpart was more of a "salon".

The development of the eighteenth century was dominated by the emancipation of the bourgeoisie and museums became places that educated the public. The nineteenth century saw a move toward the specialisation of museums and a strong emphasis on the latest progress in science.

### 2.1.5 THE NINETEENTH AND TWENTIETH CENTURY

The development of the European museums was strongly influenced by rapid developments in the sciences. This evolution led to a specialisation of museums (Ladendorf, 1973) which produced museums of Art and Culture – featuring objects that were produced by man and Natural Science Museums which concentrated on the representation of naturally occurring structures (Weschenfelder and Zacharias, 1981).

The architecture of museum buildings of the time was often temple-like with structures that were supposed to represent the important status of museums. The Prado in Madrid, the Hermitage in Leningrad, The National Gallery in London and the Vatican Museum in Rome are just a few surviving examples. Even in New Zealand this is the case, especially with the Auckland War Memorial Museum and the building, which formerly housed the National Museum in Wellington. Ripley (1970) suggests that this development has led people to associate museums with being dusty and old, a connection that, especially art museums, has been maintained in modern times.

The beginning of the nineteenth century was still characterised by the encyclopaedic character of museums featuring the natural sciences. Using systematic principles was a common way of displaying objects, for example featuring all species of one genus in an exhibit. Labels were typically written in Latin (Meyer, 1973), a feature which many visitors could have done without, illustrated by a comment of a visitor:

> A museum is a place where every separate object kills every other, and all of them together the visitor (Wittlin, 1970, in Geyer, 1995, p.13).

Museums, although open to the general public, really catered only for the specialist.

Change came in the second half of the nineteenth century with the division of objects into those for display and those for research. This revolutionary idea originated from a concept by Louis Agassiz, a Swiss scientist, who was Professor in Cambridge and founder of a museum for comparative zoology (Ripley, 1970). This "thinning" of displays opened new ways for didactic opportunities in the museum. Charles Darwin's theories published in "Origin of Species" contributed substantially to this change, just like Linne's system in the eighteenth century (Geyer, 1995).

Specialised museums started to appear in the Scandinavian societies, for example the open-air folk culture museums.

> Consisting of reassembled farm buildings, a manor house, craft industries a log church, stocks, whipping posts, and the like, the museum was staffed with guides dressed in folk costumes, with strolling musicians and folk dancers re-enacting traditional costumes (Bennet, 1995, p. 115).

This interest in the folk culture, which continued to develop in Europe was transplanted in the 1920s to American soil, but lost in popularity as interest in folk culture degenerated into a form of "backward looking romanticism" (Bennet, 1995, p.115).

One of the more important influences on the development of museums at the time was the concept of world exhibitions. The first world exhibition was in 1851 at the Crystal Palace in London, Great Britain. It has been said that such exhibitions opened the way for modern museums to become relevant to the social life of the community (Hudson, 1975). An immediate result of the World Exhibition was the foundation of the South Kensington Museum in 1852 (Geyer, 1995). This museum recorded and documented the scope and diversity of the industrial revolution. Science and technology material was originally housed next to art collections but later in 1909, the technical material became the beginnings of the Science Museum.

In the United States, colleges and universities were often the principal driving force to found new museums, which explains the stronger research commitment American museums had in comparison to their European counterparts. In the American Museum of Natural History in New York "displays and exhibits evoke the principle of public instruction" (Ripley, 1970, p.49). While the driving forces were often academic the basis and financial power came from private donations allowing rapid and strong development, (Geyer, 1995), as in the case of the Smithsonian Institute in 1846 founded by the Englishman James Smithson. The Smithsonian houses today 14 museums which together form the biggest museum complex in the world. Two million objects are on display out of a collection of 139 million. 6600 employees look after 50 million visitors each year. With a yearly budget of 300 million US Dollars it is a museum giant in its own right (Park, 1993).

The development of new museums in the early to mid twentieth century was halted by the two world wars. However, museums continued to change conceptually and moved towards displaying dioramas, featuring themed presentations of various exhibits rather than single objects:

> The "idea exhibit" was born, which emphasized concepts rather than objects. (Mensch, 1983, p. 49)

This new concept was much more quickly established in the United States than in Europe. America has led this audience-oriented development. The European museums stayed very specialised until the 1960s. These so called "Gelehrtenmuseum" [specialist museum] are characterised by huge collections on display, with no detailed explanations, only simple nametags (Geyer, 1995). One of the notable European exceptions was the foundation of the Deutsche Museum in Munich in 1903 by Oskar von Miller. This museum also embraced a range of new didactic ideas, like the use of dioramas and models as well as visitor participation. The Deutsche Museum was a symbol of the huge belief and trust society had in the development of new technology. Critics of the museum, however, claimed that visitors were trained to become uncritically respectful by the emphasis on the masterpieces of science and technology (Klemm, 1973).

Huge public interest in science and technology in the 1970s, led to the development of 40% of all Technical Museums in Germany in that decade (Klein and Bachmayer, 1981). In more recent times, the idea of using themes and concepts in Science Museums and Science Centres started in the United States. Their special character is to present contemporary science and Ripley (1970, p.68) calls them the "people's university". A very specialised form of the new hands-on philosophy is the recent development of Children's Museums pioneering the way in the development of participatory exhibits (Geyer, 1995). One of their main objectives is that exhibits can and should be touched so that the learning can be experience-driven. They also make use of learning activities like role-playing. The concept of the Children's Museum has had a long-standing tradition in the United States. The first opened in Brooklyn in 1899 and the second, in Boston, opened in 1913 and is considered today one of the most famous of its kind (Feber, 1987). Europe has not seen the same development in this special concept and only a few Children's Museums exist there today.

Since 1970 museums for natural sciences have become more focused on ecological issues. Environments featuring endangered species and the impact of mankind are new issues that serve to make museums more practical and relevant (Geyer, 1995; Duerr, 1992).

### 2.1.6 SUMMARY: A BRIEF HISTORY OF HOW INTERACTIVE SCIENCE CENTRES DEVELOPED FROM THE TRADITIONAL MUSEUMS

The Renaissance cabinets of curiosities, which were often based on private collections, formed the foundation for development of museums. Emancipation of the bourgeoisie at the time contributed to the opening of those early collections to the public.

The eighteenth century saw the opening of the first real museum in London but was renowned for its lengthy guided tours without explanations and overall, and being a rather strenuous experience for visitors.

Giant temples of knowledge symbolised the museums of the nineteenth century. These museums were highly specialised and difficult to understand by the general public. However, it was during this time that collections were being subdivided into exhibits for display and collections for study and this led to a general reduction of the number of exhibits actually on display.

The twentieth century saw a move towards both research on collections and public education. Art and culture were separated from science and technology. This created an environment that allowed Science Museums and Science Centres to evolve. Science Centres were characterised by their strong commitment to public education about ideas with less emphasis on 'objects'. As a special form of participatory museums the children's museums develop using play and active participation to educate.

Science museums have experienced a change in direction. From the original focus on natural history (Linné and Darwin) they have shifted towards the presentation of nature and ecology and have become in Duerr 's (1992) terms more "socially responsible".

## 2.2 INTERACTIVE SCIENCE CENTRES

### 2.2.1 INTRODUCTION

The intellectual development of Science Centres is the focus of this section, which begins with a discussion on the origins of science centres and particularly highlights the development of science centres in New Zealand. Participatory exhibits are also discussed and the different ways of describing them are presented. A summary concludes this section.

### 2.2.2 THE ORIGINS OF SCIENCE CENTRES

Science centres are amongst the most popular kinds of science museums today. The modern science and technology museum movement has experienced a huge boom in the last decades, most notably in the United States (Shortland, 1987). Their origin is to be found in the late eighteenth century with the "Conservatoire des Arts Metiers" in Paris and the "Science Museum" in London. The most influential development however was the foundation, in 1903, of the "Deutsche Museum" in Munich by a leading electrical engineer Oskar von Miller. This museum is still one of the world's most important institutions of its kind. Miller's philosophy was that working section models and visitor participation were vital to illustrate scientific ideas and principles (Danilov, 1973). In 1911, the businessman Julius Rosenwald and his family visited the Deutsche Museum and were fascinated by what they saw. Viktor Danilov describes the experiences Rosenwald had:

> By pushing a button, working a lever, or depositing a coin, it was possible to generate static electricity, move the pistons in a cutaway engine or examine the effect of an x-ray machine. The approach was a dramatic departure from the traditional museum

> collecting and preserving of original objects from the past. (Danilov, 1973, p.183)

Impressed by what he had seen, Rosenwald went back to Chicago and initiated the foundation of the Chicago museum, which was opened in 1933. Similarly, the Palais de la Decouverte in Paris which opened four years later, was also based on the principles of the Deutsche Museum.

The development of museums in the United States of America which were "dedicated to explaining scientific and technological principles and their applications in society and industry" (Danilov, 1973, p.185) was rapid and extensive. It was during this development that the distinction between traditional science technology museums and modern science centres began to develop. The distinguishing factor was that the former were frequently becoming outdated whereas the philosophy of the later was to make use of the latest level of presentation of science and technology.

> Unlike many traditional museums, the principal thrust of most science and technology centres is education. Virtually all of a science centre's undertakings, whether they are collections, exhibits, educational programs, membership activities or community services, are aimed at furthering public education in science and technology. (Danilov, 1982, p.245)

McManus (1992, p.163) describes this development as the "Third Generation Museum" and said they differ from their predecessors because "they have moved away from the object based approach". They do this by the use of interactive exhibits, which "require visitors thoughts and manipulation as vehicles for communication".

The very first of its kind was the "Exploratorium" in San Francisco, which opened in 1969. The name is made up of the word *exploration* and *auditorium* and was founded by Frank Oppenheimer. The revolutionary nature of this museum is first apparent in the building's architecture, which had little in common with that of a traditional museum. It was a dark industrial hall type of structure, housing up to 600 exhibits. Oppenheimer himself, was a professor at the University of Colorado, started of with a collection of 'requisites', which he used as teaching tools. His concept was that students would learn and understand more by handling objects (Ward Moser, 1987) and implemented this in his teaching. The Exploratorium was to him an institution of learning, where natural phenomena should be studied and analysed (Hein, 1987). The exhibits had labels saying "To Do", "Notice" and asked, "What's going on" (Geyer, 1995). More notable among the exhibits at the Exploratorium are a Mini Tornado in a glass house, a Smelling Test where 18 different smells confronted the senses of the visitor. One very special attraction is the "Tactile Dome" which is explored in complete darkness. This attraction is so popular that it has to be pre-booked by visitors (Geyer, 1995).

> Science centres provide a whole new field of self motivating experiences in learning, through environmental exhibits that appeal to the senses, emotions and intellect (Kimche, 1978, p.270).

Victor Danilov (1975, p.87) compiled four criteria for science and technology centres to describe their special status:

1. *The emphasis is on contemporary science and its technological applications.* The presentation of historical objects has declined in importance and the typical areas that are represented are Physics, Biology, Medicine and Chemistry (Geyer, 1995).
2. They encourage visitors to touch exhibits and interact by pushing buttons and turning cranks. Rennie and McClafferty (1996, p.56) characterises the exhibits to be both "interactive and participatory"

where "visitors are meant to handle, explore and enjoy the experience."

3. *Exhibits are educationally orientated, and aim to explain scientific principles and processes.* One of the most important differences between conventional museum exhibits and those in the science centre is that the former are displayed for their intrinsic interest whereas the latter are just the tools to explain difficult concepts. Museum collections are no longer confusingly large and the emphasis is on producing robust and wear-resistant exhibits which can be either "cloned" for other science centres or may even become a travelling exhibition (McManus, 1992).
4. *Special educational programmes offer a supplement to the formal school programmes.* Educational activities describes a wide range of activities. Danilov (1975, p.248) distinguishes three categories of activities;

- basic educational activities which would include exhibit interpretation, science demonstrations, lessons and workshops,
- school and outreach services including educational publications, audio-visual material and in-service teacher programs, and
- other educational programs for example pre-school programs, independent study and science fairs.

The depth to which a science centre is involved in these activities depends largely on its institutional objectives, resources and community needs (Danilov, 1975).

Science centres are also described as belonging to the multifunctional type of museums which present different types of exhibits as well as additional attractions like playgrounds, restaurants and shops in contrast with the classical type, such as art museums for example (Geyer, 1995; Eisenbeis, 1972). This could be interpreted as the response to a wide and much more incoherent audience than art museums would expect to cater for.

As a further development McManus (1992) distinguishes between two kinds of science centres. First, those, which are concerned with larger concepts "that arouse personal response" with ideas, like evolution heredity or ecology. The second kind of science centre is characterised by "exploring stations of ideas" typically representing physical sciences.

The philosophy behind science museums like the Deutsche Museum has evolved into science centres like the Exploratorium, which offer special educational programmes and focus on learning by discovery and exploration. Exhibits are not dominated by the objects themselves but have become vehicles that communicate ideas and phenomena. This development, which started in Europe, became much more established In the United States of America. The following section takes a look at the development of science centres in New Zealand.

### 2.2.3 SCIENCE CENTRES IN NEW ZEALAND

In New Zealand, the first permanent science and technology centre was established in 1988 as a part of the Museum of Transport and Technology (MOTAT) in Auckland. This was a relatively late development when compared to American counterparts and was initiated by the central government. Hodder, (1997) describes the science centre movement in New Zealand as initiated by the idea of improving the public attitude towards science. The declining numbers of young people moving into science careers sparked discussion in New Zealand which resulted in the initiative. Funded by the New Zealand Lottery Grants Board, a network of science and technology centres was established in the main centres throughout New Zealand. After MOTAT in Auckland, the following few science and technology centres were not associated with another museum, but stand-alone entities. However at a later stage the principal fund providers felt concerned about the financial viability of the centres, so that those that were opened later were associated with regional museums (Hodder, 1997). The early science centres - MOTAT in Auckland and Capital Discovery Place in Wellington - have not survived in their original form owing to financial difficulties and have reopened with a changed emphasis (Wright and Hodder, 1998). Since New Zealand science centres target the educational market in particular, exhibitions are often based around criteria in the National School Curriculum (Schwartz, 1996), as is the case overseas (Moffat, 1991). This decision to do this however is more often based on financial grounds. Making valuable learning experiences by going to a science centre was one of the key issues in exhibition design; as Kimche (1978) points out "The possibilities of learning through participatory exhibits seems to be endless" (Kimche, 1978, p.273).

This possibility was certainly recognised by the Ministry of Education in New Zealand and so from 1994 it made available funds to support Learning Experiences Outside The Classroom (LEOTC). LEOTC encompasses programs and services by recognised non-school educational providers. The programs have to be linked to the New Zealand curricula as Hodder (1997) explains:

> A science or technology exhibition funded under such an arrangement would need to meet the educational objectives of the Ministry of Education by being targeted both in terms of age or 'level' or content. (Hodder, 1997, p.148)

Black and Atkin (1996) argue that new realities facing science and technology centres - like LEOTC - are part of a change in direction of science education. They describe four reasons that form the basis for this change, which can be applied to New Zealand's development of science centres:

I. *The national economy*: Many innovations in science education are driven by a country's concern about being economically competitive. It is clear that the economy's future is increasingly dependent on up-skilled workers and innovation in industry. The withdrawal of government funding for scientific research in the late 1980s and the declining numbers of young people going into science careers drew the attention of scientists and managers towards this problem (Hodder, 1997). Black and Atkin (1996) also point out that sometimes, general economic concerns become highly specific after a curriculum is modified (e.g. the introduction of earth sciences in to the New Zealand science curriculum in 1993) and concerns arise about the employability of new graduates.

II. *Preparing future citizens*: This aim is wider than only improving future prospects of the economy, and arguably, may well include it. This is also described in the New Zealand science curriculum under the section of general aims of science education where it says:

> Science education contributes to the growth and development of all students, as individuals, as responsible and informed members of society and as productive contributors to New Zealand's economy and future. (Ministry of Education, 1996, p. 9)

III. *Inclusiveness and equity*: Students' education has to serve their diversity. The New Zealand science curriculum states under the section 'Science for all':

> Science education of the highest standard must be available to all New Zealand students – for those whose formal learning in science will cease when they leave school, for those who develop an interest in a particular aspect of science and may choose a science related career, and for those who excel at science and may become our future scientists, technologists, technicians, and science educators. (Ministry of Education, 1996, p. 11)

This should include issues such as girls in science, Maori and science as well as students with special abilities or special needs.

IV. *Better student learning – and empowering teachers:* Black and Atkin (1996) say that, typically, new educational projects are formed by new conceptions about learning, which should involve teachers. Exhibitions may hold resources and information that are inclusive of new ideas and are accessible to teachers. Hodder (1997) observes that science centres are typically more than exhibition halls offering a range of activities, but they include resources for teachers and students or science clubs and the like for children.

Travelling exhibitions that are typical for science centres everywhere (McManus, 1992) also form an important component of New Zealand's science centres both as outreach from "fixed" science centres and as a separate travelling science-technology "roadshow". Hodder (1997) points out that offering a programme of changing exhibitions should encourage return visitors, important because of the small population catchment of the science centres. The type of exhibits should be so inviting that students typically return to the science centre with their parents after they had visited a science centre with their school. Wright and Hodder (1997) report that for financial reasons New Zealand science centres have had to produce exhibits which appeal to the general public, the students and their teachers. This is quite different from many overseas centres. An annual visitor level of 100,000 in the United States or Europe represents 1% or less of the population living within an hour's travel of the majority of international science centres, whereas in New Zealand this would require 10% of Auckland's population to visit annually and a far higher percentage for other centres. (Wright and Hodder, 1997).

The New Zealand development of science centres has been quite different when compared to its American or European counterparts. The motivation behind the creation of science centres was to raise the profile of science to the general public and improve the attitude towards science, particularly of the students. The chief philosophy for creating an inspiring environment and subsequently visitor enthusiasm at a science centre is experience by participation. The following section presents what the literature tells us about participatory exhibits.

### 2.2.4 PARTICIPATORY EXHIBITS

Participatory exhibits are probably the hallmarks of science centres. Science and technology are not easy to portray because they are concept based knowledge systems of the natural world and " objects from science museums collections are often understandable only in terms of the ideas they helped form or served to uphold" (Butler, 1992, p.108). Participatory exhibits have been described as being able "to induce discovery of information through participation in the demonstration process" (Eason and Linn, 1976). Orchiston and Bhathal (1984, p.36) comment that they "are able to bring an experience of the science kind to the average person, in an 'un-museum like' setting."

Perry (1990) identifies six steps to create intrinsically motivating exhibits. She proposes that exhibits should pique the visitor's *curiosity*, and make them feel *confident*. Further, exhibits should be a *challenge*, but the visitor should have a sense of *control*, and the experience should be playful, *enjoyable* and intrinsically motivating. Exhibits should further stimulate participants towards meaningful social interaction.

Perry (1990) also points out that not every exhibit needs to include all of those steps and exhibit evaluation would have to be done as a part of the development stage. Rennie and McClafferty (1996, p.58) extend the argument by saying, that "a good interactive exhibit can personalise the experience for a visitor." They report that exhibits can be classified to distinguished between "hands-on" and "interactive".

Hands-on exhibits are characterised by physically engaging visitors in an activity. They acknowledge that other authors (e.g., Lucas, 1983) show that the physical engagement in an activity does not necessarily mean that anything has been learned from that experience. In contrast, an interactive exhibit is one "that allows the visitor to make some response using the information in the exhibit" (Moscardo, 1988, p.31). Geyer (1995) creates, as a further distinction, the "push-button exhibit", which, she explains, shows processes, but the amount of participation is rather simple and limited. However, she also points out that these are still very popular exhibits in science centres although they have been described as "first generation exhibits" within the group of participatory exhibits (e.g., Shettel, 1973; Screven, 1969).

The following is a brief description, together with examples, of the types of participatory exhibits.

Participatory exhibits; are those which show changing processes. They require that the visitors manipulate the exhibit. The three kinds of participatory exhibits differ in their levels of interactions and thought processes involved.

> Push-button exhibit: Simple display of changing processes by the push of a button. The visitor has no influence on the outcomes of the changes. This type of exhibit was one of the earliest types of participatory exhibits of the 'Deutsche Museum', but is still common today.
>
> Hands-on: These exhibits offer a multi sensual experience. Visitors can smell, taste, touch or feel their experiences. A famous exhibit of this kind is the Tactile Dome of the 'Exploratorium' in San Francisco.

Interactive exhibits: This type of exhibit requires the visitor to make a decision. Computers that are widely used in modern science centres are a good example, as they can offer quite complex information, which the visitor can use to solve problems.

### 2.2.5 A NEW WAY OF DESCRIBING PARTICIPATORY EXHIBITS

The discussions about participatory exhibits have typically concentrated on the type of participation in which a visitor could become engaged. Published studies are mostly concerned with learning by visitors, whether they are child, adult, in school groups, or casual visitor (e.g., Beiers and McRobbie, 1992; Miles and Tout, 1990; Flagg, 1990; Falk, 1983). Therefore, science impact studies report the characteristics of ideal museum exhibits and often classify them in terms of visitor perception (e.g., Alt and Shaw, 1984; Borun, 1977). Studies often examine the behaviour of visitors while they are at an exhibition (Philips, 1994; Borun, Massey and Lutter, 1993; Diamond, 1986; Borun and Miller, 1980), but fewer studies investigate the learning philosophy behind the concept of the exhibit. Boisvert and Slez (1995) go one step further in their investigation into the relationship of specific characteristics of an exhibit and the behaviour associated with learning. They distinguish three different categories by which they assess an exhibit's impact. Those categories are:

I. the level of interaction (high or low),
II. the presentation (concrete or abstract),
III. the level of information (simple or complex).

Boisvert's and Slez's (1995) description take a different approach from their predecessors. They look more closely at the different categories of the exhibits and conclude that there is a significant difference in the combinations of categories an exhibit had.

By taking a closer look at the kind of participatory exhibits, it is possible to further describe them and distinguish them by the kind of learning experiences they offer.

I. *Models* are typically simplified versions of reality. They might be reductions (e.g., a model of an open pit mine in the Deutsche Museum) or enlargements (e.g., a magnified walk through salt crystal; in Kroen, Geyer and Wagner, 1994). Models show scenes and processes that are often not possible to observe in reality because they are on too large a scale or too inaccessible. Models may also provide same size views of things that are not observable under normal conditions (e.g., *Visabill* and *Visabelle*, life-sized models of transparent man and woman; in Danilov, 1973). Participation may be offered by pushing buttons or handling the model in such a way that it shows a different aspect of the presentation. The visitor has, however, no influence on the presentation and even if there is a possibility to participate, the final result is often pre-determined. Gobert and Buckley (2000, p.891) use a definition by Ingham and Gilbert (1991) that highlights the point that a model concentrates on specific aspects of a system. They state that models can actually add complexity, structure and a certain level of explanation that is often not inherent in the phenomena itself.

II. *Experiments* offer the visitor a set of tools and instructions. This is a way of presenting abstract concepts, which is commonly used in areas like physics or chemistry (e.g., lifting weights of different densities). Presentations of concepts in these areas have typically been reported to use an analogue (Harrison and Treagust, 1993) but require that the person is familiar with the analogy (Newton and Newton, 1995; Treagust, Lindauer and Joslin, 1989). Experiments invite the visitors to make a discovery, by using a set of instructions. They often require the visitor to use their senses (hearing, sight, and touch). The set of instructions for an experiment in a science centre is written in an inviting way so as to spark the visitors' curiosity (Perry, 1990) and usually does not provide answers. The result can be different for each visitor and is not necessarily pre-determined. The presentation can be abstract, and sometimes an analogue situation of the discussed concept is presented. Quasi-scientific explanations may be used e.g.: "Radar works like an echo" (Rowan, 1990), to help visitors to form a mental model of the concept. The interaction in the experiment may allow the visitor to form a mental construction of novelty information. The successful mental construct helps by visualisation, even if it is in an analogue structure (Schwartz, 1993).

*Simulations* invite exploratory learning, by providing a model that can be used to solve individual problems. Hensgens, Van Rosmalen and Van Der Baaren (1995, p.269) state that simulations "are used to support decisions by experimenting with different scenarios". They present a combination of a simplified version of reality (model) and an open-end discovery (experiment) as a way to support exploratory learning (Towne De Jong and Spada, 1993). However, the concept of simulations has been traditionally investigated either with role-play as a teaching tool (Hensgens et al., 1995) or in relation to computer modeling (e.g., Hudak, 1998; Njoo and De Jong, 1993). Simulations make use of a set of tools and provide a realistic picture of the situation. Newton (1995) argues that by using pictures complex information can be made accessible and can help to verify or shape models. Simulations seek to provide an instructional environment either without interfering with the simulation, or else by interweaving their instructions with the simulation (Hensgens et al., 1995). However, the degree of realism portrayed varies: modern flight simulators are probably the closest approach to reality presently achievable. This is particularly useful when the discussed idea is either abstract or new. Newton (1996, p.208), argues that " providing a picture of the initial state of the situation seems to help children as young as five years of age to construct an appropriate mental model for articulation as events proceed." Learning to read is greatly supported by using the visual aid of pictures (Newton, 1995), the recognition and understanding of geological concepts might also follow this sequence. Exploration and generation of hypothesis and the testing of those are the on-going activities in simulations. These types of exhibits, which explore different aspects of a phenomenon, have been described as providing a richer learning environment (Feher and Rice, 1985).

One of the few studies that included simulations as a type of school science model is that of Harrison and Treagust (2000). They say that students often view a science model as reality and want to find the "best model' in order to learn about it. From their classification of analogical models they assert that simulations fall within the group of "Models depicting multiple concepts and/or processes":

> Simulation is a unique category of multiple dynamic models. Simulations model complex and sophisticated processes...and enable novices and researchers to develop and hon [sic] skills without risking life and property and also may include 'virtual reality' experiences. (Harrison and Treagust, 2000, p.1016)

The authors argue that a simulation belongs to the group of analogical models because it "is a simplified or exaggerated representation of an object or process." They further argue that simulations are analogical in character because "mappings between the analogue model and the science phenomena describe and explain structures and functions" (Harrison and Treagust , 2000, p.1017).

This study, however, argues that simulations are *not* analogue in character, as an analogue will try to explain something unfamiliar by using a familiar but dissimilar item and build understanding by highlighting the key features, but ignoring the differences. For example, an apple cut through in half could be used to explain the internal structure of the earth. The apple would be the dissimilar analogical object, which might help the learners bridge their understanding. Simulations, as defined from the classification herein are a type of model that shows a simplification of reality and, thereby, is showing a similar picture of a real life situation. This does not mean that a simulation *is* the real thing *but*, it does not require the learner to be familiar with its object, as would be the case for an effective analogical model.

### 2.2.6 SUMMARY: INTERACTIVE SCIENCE CENTRES

Interactive science centres evolved from the classical science museums at the beginning of the twentieth century and were inspired by the concept of moving away from objects towards the ideas they were representing. Visitor participation was a new way for museums to communicate scientific concepts. The Exploratorium in San Francisco was one of the first of its kind. Henceforth interactive science centres have been characterised by their emphasis on presentation of contemporary science, the encouragement of interaction with exhibits, the educational emphasis of the exhibits and the special programmes they offer.

In New Zealand the first science centre was established in 1988. The development of other centres was driven by an expressed wish of educationalists and policymakers to stimulate more interest in science and technology. In 1994, the New Zealand Ministry of Education made funds available to science centres and similar providers to develop learning experiences outside the classroom (LEOTC). This provided an impetus to develop curriculum targeted programmes. This development has been described as a change in the direction of science learning and with that there has been the inclusion of "new" learning experiences (Black and Atkin, 1996).

Participatory exhibits are the hallmark of science centres and have been previously classified into three categories: push-button exhibits, hands-on exhibits and interactive exhibits. This order represents an increase in complexity of the type of engagement and perhaps also the quality of that engagement.

This simple classification, however, does not include the concept of how the information is communicated. This justifies a different classification of participatory exhibits, based on the learning experience the exhibit offers. This division organises participatory exhibits into models, experiments and simulations.

## 2.3 SCIENCE CENTRES: A NEW LEARNING ENVIRONMENT

### 2.3.1 INTRODUCTION

This section discusses the difficult situation science centres, particularly in New Zealand, have found themselves in because of the expectation that they will provide a formal learning environment. The development of visitor studies is described, as is how visitor behaviour is being predicted. The section continues with a discussion on the learning potential of exhibits and how the social structure of visitors affects behaviour and learning outcomes. Evaluation studies appear to offer opportunities to identify those aspects.

### 2.3.2 THE DILEMMA OF A NEW LEARNING ENVIRONMENT

Traditional museums around the world have continued to develop but the continuing focus was on their collections, while the new places for learning and discovery – the science centres – moved towards being concerned about their audiences. Hooper-Greenhill (1994, p.2) says of this change in philosophy:

> The museum is becoming once more the university of the people, and their schoolroom, but in relation to a new interpretation of education, which is understood today as structured discovery within a life-long framework.

The philosophy of science centres empowering the discovery of scientific ideas by participation has received overwhelming support by educators (Griffin, 1994; Sakofs, 1984; Wright, 1980). Kimche (1978, p. 270) says that:

> Science centres provide a whole new field of self motivating experiences in learning, through environmental exhibits that appeal to the senses, emotions and intellect.

However, there seemed to be a difference in the learning experience whether visitors 'found a button to push' or whether they participated in experimental procedures (Oppenheimer, 1968). The huge popularity that science centres enjoyed by offering a mixture of education and entertainment overpowered for quite some time the inconvenient question of whether or not visitors really learned something from 'turning a crank'. Some science centres concentrate on offering such a multitude of various activities that they become activity centres with the focus on being entertaining (e.g., Friedman, 1996; Geyer, 1995; Cameron, 1971).

The focus of research about the learning potential of science centres has concentrated on describing their learning environment. Rennie and McClafferty (1996, p.60) discuss the "learning potential of interactive exhibits". They state that in order to have a *"rewarding experience"* the experience had to be " *intrinsically motivating"*. This could be achieved if the visitor would become *"deeply absorbed"* in the exhibit, which would then lead to learning. Descriptions of how to produce successful exhibits concentrate on step-by-step experiences that ought to be made by a participant (e.g., Perry, 1990).

There has not been much reported on the specific differences in the kinds of participatory exhibits, apart from the general description presented in section 2.2.4. This is not surprising, given the difficulties of assessing the different kinds of exhibits in an environment like a science centre. While the intention is to test the extent of communication the exhibits achieve, this is often done by timing the visitors. These studies, of course, give no insight as to whether or not the visitors learned anything from their experience or whether they enjoyed it. Also, it seems common that some science centres opt out of this issue by declaring:

"There is no 'required' reading, listening or viewing'" (Kimche, 1978, p.271).

Many museum experts are critical about the learning outcomes of visits on the basis that many visitors, particularly children, rush around without waiting for explanations (Shaw-Miller and Mason, 1995; Ault, 1987; Shortland, 1987). This new style of scientific presentation is being described as a 'push-button wonderland' where children run around without fear and without respect for the natural laws they are presented with (Imbeck, 1990; Rost, 1984).

The philosophy of science centres of having visitors participate and interact with the displays did sound very promising (Geyer, 1995); however it seems obvious that the scientific principles are not likely to be understood by simply pushing a button. Friedman (1996) reports serious concerns about this philosophy of science centres and asks how much they focus on being entertaining rather than educational. The concept of the Ontario Science Circus illustrates this concern:

> In the Science Circus, however fun comes first and education is a spin-off. (Gillies and Wilson, 1982, p. 131).

With this problematic aspect of science centres, the quality of education being offered was worth of further study. In this confusion visitor studies seemed to be a promising possibility to identify the strengths and weaknesses of the new informal learning environment.

### 2.3.3 THE DEVELOPMENT OF VISITOR STUDIES

In 1924 Charles R. Richards, who was then the director of the American Association of Museums, commissioned Edward S. Robinson, a psychologist at Yale University, to conduct studies about the behaviour of visitors at museums. The co-operation with a university sought to ensure a professional analysis (Geyer, 1995). Robinson developed a programme for a behavioural study that was primarily based on methods employed in the field of psychology. The methods he employed were later described as the attracting power and holding power of exhibits. His study focused on what the average visitor in a museum was doing (Robinson, 1928). In his research he was particularly concerned with how visitor behaviour was influenced by the exhibits. He investigated how extrinsic factors like the number of displays and their presentation affected visitor behaviour. For his study he selected four different art museums, for he considered pictures as objects to be the simplest kind to evaluate. He considered other types of museum exhibits to be too varied and complex in their effects on the visitors and, therefore, too hard to compare (Geyer, 1995). He concentrated on factors that could be measured and developed a tracking system that concentrated on time (total time for the visit, time spent with each picture) and counting the number of rooms that were viewed. In his conclusions Robinson identified the number of pictures as the main factor that determines the behaviour, however he had eliminated a lot of other factors before deciding on this interpretation.

In a second part of his investigation he looked into museum-fatigue, the phenomenon of getting tired during a visit at the museum. Robinson and his associates compared the times that visitors stopped for individual pictures and found comparatively short durations at the beginning (warming-up) and at the end (actual fatigue) of the visit. He tested a control group of subjects who had to view double the number of pictures than the subjects that were observed at the museum. The test group, however, were sitting comfortably in order to eliminate the physical fatigue effect. The results showed that the test group had a much higher fatigue effect than the museum visitors. Robinson explained this by asserting that although museum visitors got physically tired faster they seemed to have a recovery effect through the walking between viewing different pictures (Geyer, 1995). In a further part of his studies Robinson also investigated whether guiding material would have any influence on the time that visitors would spend with exhibits. People who used the guide (64%) increased the average time they spent with the exhibits from 15 seconds to 17 seconds and they also viewed more pictures (46 pictures) than those people who did not get a guide (30 pictures) (Robinson, 1928, p.62). Arthur Melton, one of Robinson's students developed Robinson's concepts further by stressing the importance of time as a measure of how visitors react to museum exhibits. Melton (1936) concentrated on the difference between static and interactive exhibits and found an increase of time as soon as physical manipulation was offered to the visitors.

This approach has made Robinson's study the most influential in the area of museum studies. Unobtrusive observation was one of his innovations. His study also showed a measurable difference the presentation of objects in a museum had on the visitors' behaviour. It was in this that Robinson initiated the concepts of 'attracting-power' and 'holding power' of exhibits.

### 2.3.4 PREDICTING BEHAVIOUR

Robinson's study was mostly concerned about how the exhibits affected the behaviour of the visitors, which he measured by observing the time visitors spent in a museum. This is still an essential part of exhibit evaluation and the basis of many studies. Geyer (1995, p. 28) defined behavioural measures as follows:

> **Attracting Power** is defined as the percentage of people who stop at an exhibit.
> **Holding Power** of an exhibit is the average time that visitors spent with the exhibit.

Many museum researchers have since adopted these measures of exhibit assessment and they are well documented in the literature (e.g., Miles and Tout, 1990; Haesler, 1989; Miles, 1988; Falk, Koran, Dierking and Dreblow, 1985; Peart, 1984). However, there are some problems related to this evaluation method. The time visitors spend with exhibits can be affected by the group situation the visitor is in, it may be affected by the type of exhibit being viewed and also by the relationship the visitor has with the exhibit. These key concerns are listed below:

➢ Time affected by the social group

Robinson's observations were done with single subjects to avoid any influence of social interaction on the behaviour of those observed. This however, might be a distortion of reality. McManus (1992) presents an audience profile of the Natural History Museum in which only 12.9% are single subjects. In her description of visitor profiles, she points out that "singletons" were "characterised by brief visits to exhibits and comprehensive reading of text material", whereas visitors in groups show interaction between themselves and the exhibits which is quite different (McManus, 1992, p.170). In Geyer's study (1995) single visitors and small groups had the shortest time for the overall visit. Visits of large groups (characterised by containing at least 10 subjects, with the majority being the same age – typically school groups) and family groups (a group of at least 2 subjects of different generations) doubled the total time for the visit. Adult pairs or small groups (characterised by containing less than 10, typically both children and adults) achieved visits that were 1.5 times the duration of the short visits. Geyer's observations demonstrate how much difference the impact of the social structure has on the time spent.

➢ Time affected by the type of exhibit

An exhibit with a high holding power value may indicate that the exhibit is either rich in information or hard to understand (Miles and Tout, 1990). Boisvert and Slez (1995) present findings in their study of how characteristics of an exhibit affect the time visitors spend with it. These findings are also supported by comparing studies of static displays (e.g., Geyer, 1995; Screven, 1975) with studies about interactive exhibits (e.g., Boisvert and Slez, 1995; Graf and Treinen, 1983). Geyer's study (1995, p.363) shows that the largest number of exhibit stops made by subjects had average viewing times of 20 seconds, whereas in the study of interactive exhibits (Boisvert and Slez, 1995, p. 515) the exhibit with the largest number of stops made by visitors had average viewing times of 47 seconds.

➢ Time affected by the relationship of the visitor and the exhibition

The personal agenda of the visitor (e.g. school trip, family visit) will influence the time the visitor spends at each exhibit (Rennie and McClafferty, 1996). Melton (1936) pointed out that visitors set their own limits of tolerance and would not spend too much time with exhibits that are too difficult to understand. Beer (1987) indicated that most visitors will stay at an exhibit for a brief interval, with a decreasing tendency the more time has passed. The average visit to a museum or science centre lasts less than two hours, of which each exhibit receives between 30 seconds to three and five minutes attention (Falk, 1982; McManus, 1992). However, Miles and Tout (1990) reported that visitors spend most of their time moving in order to get a sense of the whole exhibition rather than individual exhibits.

Falk et al. (1985) state that generalisations about museum visitors' behaviour are difficult to make unless psychological and museological perspectives are considered. He describes three main areas: the "exhibit perspective", the "setting perspective" and the "visitor perspective" (Falk et al. 1985, p.250-251). In his study he evaluates those criteria by looking at how much time visitors pay attention to each of those aspects (e.g., the exhibit, the setting, themselves). He concludes that visitor behaviour, although very variable, is predictable and, hence, can be influenced. Most of these studies have been set in medium-sized or large museums and, as Robinson's (1928) research indicates, might not necessarily suit the interpretation of a small museum or science centre. Although analysis of visitor behaviour by considering only the time factor is debatable, it is important to note how influential Robinson's and Melton's work are even today.

### 2.3.5 LEARNING POTENTIAL OF EXHIBITS AT SCIENCE CENTRES

Interactive science centres have received increasing recognition as providing the opportunity for science learning (Beiers and Robbie, 1992; Lucas, 1991; Wellington, 1991). It has been argued that learning from sources other than the traditional ones like classrooms, occurs all the time, including from newspapers, television and other sources (Lucas, 1991). Lucas notes that science centres, by comparison with other informal sources, are increasingly expected to make major contributions to teaching science concepts. He notes that they certainly provide a more accessible environment for the assessment of outcomes than many other informal sources and they may very well have created their own niche market.

The usual evaluation of exhibits describes the attracting power and the holding power of an exhibit and compares them with goals that museum staff asserted they had tried to achieve (e.g., Wizevich, 1993). If the researcher's intention is to find out more detailed information, for example upon the exhibits' effectiveness in teaching concepts, different approaches have to be taken, which are sometimes intrusive (Miles and Tout, 1990; Shettel, 1968).

Minda Borun (1977) argues that museums have to carefully evaluate and understand the experiences of their visitors in order to succeed as a place of education. In her study she made use of questionnaires and conducts pre- and post-visit tests. She found that visitors preferred more complex exhibits with a greater number of participatory devices. The museum where Minda Borun conducted her research was found to be quite effective in achieving its educational goals, but was somewhat less effective in stimulating curiosity, interest as well as a positive attitude towards the presented themes. In another approach museum staff interested in evaluating audience needs have implemented strategies like marketing or public relations methodologies, as described by Hooper-Greenhill (1994).

> Market research focuses on what people think and feel about a particular product or experience and this kind of work in relation to museums has produced startling results. (Hooper-Greenhill, 1994, p.19)

Alt and Shaw's (1984) study tried to determine how visitors perceive exhibits and how to identify the most effective characteristics of exhibits. One of the differences in their approach was to concentrate in their study on visitor perceptions rather than testing the views of museum professionals. They used interviews, where visitors were asked about anything that had 'struck' them about an exhibit. From this information they compiled descriptive categories, which they again used for a second study where visitors were asked to use these categories.

Stevenson (1991, p.522) presents, from the viewpoint of a museum professional, the experiences of visitors to Launch Pad, the Discovery Room at the Science Museum in London. These are:

- *A set of experiences or memories*
- *A set of effects*
- *A set of explanations*
- *A set of applications*
- *More understanding*
- *A change in attitude*

Those expectations however, often prove to be unmatched by the participants' perception of the exhibits' effect. Other studies show similar discrepancies. For example, Beer (1987), who compared the discrepancy between the actual behaviour of museum visitors and the beliefs of museum staff members, found that staff members often over-estimated the time spent with the displays. She also pointed out that staff members should account for the fact that not all visitors have educational-related goals for their visit. Interestingly, most of those studies evaluated the exhibits as given entities rather than testing the educational philosophy behind them. Rowan (1990, p.35) says that museum staff have to explain complex ideas. This might be confusing because they use either a "difficult language" or they are explaining "difficult-to-picture structures or processes" or the "notions are difficult to believe". He notes that in order to explain complex ideas museum staff make use of new language like:

- Elucidating – to clarify the meaning of the term.
- Quasi scientific – to mentally model complex phenomena.
- Transformative – to understand implausible ideas.

In spite of many of the explanations being analogies and needing to be handled with great care, this is not well documented in the literature about exhibits in science centres.

In their study Boisvert and Slez (1995, p.503) recognise the differences of exhibit characteristics and organise them into:

- Exhibits with high or low **interaction**
- Exhibits with concrete or abstract **presentation**
- Exhibits presenting simple or complex **information**

Their observations of science museum visitors evaluated attracting power and holding power for the differently categorised exhibits and they found that attraction level and holding power were highest for exhibits with high interaction and concrete presentation.

These findings may well be interpreted to say that simulations, with their high levels of interaction and concreteness, will fit the characteristics of an exhibit that offers high attraction and holding power. This description also marks a turning point for the interpretation of exhibits at science centres by focusing on the exhibit characteristics. In addition, the impact of a visit to a science centre is influenced by the visitor's social group. This is discussed in the following section.

### 2.3.6 SOCIAL STRUCTURE OF VISITORS

The basic museum philosophy is to preserve, to study and to communicate (Hooper-Greenhill, 1994, p.140). The aim to preserve and to study relates particularly to the museums whereas the science centres have a strong emphasis on communication. Hooper-Greenhill (1994) includes education as a part of communication. She says communication includes publicity and marketing, research and evaluation as well as education and entertainment. Educational and entertaining needs are provided for through the exhibits. However, how the visitors perceive this environment may depend on intrinsic factors like the exhibits and their educational task as well as on extrinsic factors like the social influence. Hooper-Greenhill (1995) says that for museums and science centres to become effective communicative mediums it is important to know the audience and their specific interests attitudes and opinions.

In Boisvert and Slez' (1995) study on exhibit characteristics, visitors were observed at the exhibition and their individual times were taken. Although the researchers noted in which group arrangement the visitors came, it was not part of their analysis and was not discussed.

One of the earliest studies about the impact of the social group on the exhibition experience was from Paulette McManus in 1987:

> It has become commonplace to say that a visit to a science museum is a social event for the museum-goer. (McManus, 1987, p. 263).

She observed 641 groups with five different exhibits at the British Museum of Natural History. She noted various issues affecting the behaviour (reading, talking, time spent in front of the exhibit, interactive behaviour with the exhibit). Her observations made clear that the social arrangement of museum visitors has distinctive effects on their behaviour.

Rennie and McClafferty (1996), Hooper Greenhill (1994) and McManus (1992) all report that the social group affects the agenda of the visitors and their behaviour and, with that, any possible learning outcomes e.g.,

> People will behave differently depending on the nature of the social group in which they find themselves. (McManus, 1992, p.169)

Nearly half of all visitors in McManus's (1992) study were groups with children. She characterises this group by:

> ...the extreme likelihood of play at interactive exhibits and of long conversational periods within the group. (McManus, 1992, p.170)

By comparison, single visitors were characterised by stops of 'short duration' and 'intense reading'.

The learning experience can also be expected to markedly differ between groups and single visitors, considering that the group is more likely to have plenty of hands-on interaction and the single visitor receives information in a much more passive way. Her interpretation of the different social groups was initially derived from looking at eleven groups which she then reduced to only four types: groups containing children, single visitors, couples and adult groups (McManus, 1992; McManus, 1987).

- <u>Groups containing children</u>

Social groups of this type typically "played" with interactive exhibits, showed long conversational periods, but did not read. Within this group she included families, groups of children without accompanying adults and groups of children who were accompanied by teachers. Of these groups, families spent the longest periods with the exhibits and had the longest conversations. Groups of children had less conversation and spent less time at the exhibits. Teacher – student groups spent the shortest time at the exhibit.

From earlier studies it was known that groups with children showed particular characteristics (e.g., Hilke, 1989; Diamond, 1986). Much less was known about the other three groups and McManus (1987) comments:

> In contrast to the first constituency [groups containing children], the behaviour of visitors in the following three constituencies [singleton, couples and adult social group] has not been described in comprehensive detail in the literature on museum visitor research. (McManus, 1987, p.267)

She continues and describes the characteristics of the other three groups.

- <u>Singletons</u>

Singletons were characterised by only brief visits to exhibits and "comprehensive reading of texts". They were also less likely to "play" with interactive exhibits.

- <u>Couples</u>

These groups were less likely to "play" with exhibits, but are very comprehensive readers. They also stayed for longer periods with the exhibits. Interestingly they showed a lack of conversation (48.8% did not speak with each other).

- <u>Adult groups</u>

Adult groups spent only short periods of time with exhibits, did not read much and not often observed to play with interactive exhibits. However, when women were part of the group the likelihood of interaction with exhibits increased.

Many studies have not widened their picture of interpretation of museum visitors and have continued to look at isolated criteria, such as time. One of the reasons why those criteria are often not included in studies of attracting power and holding power is because it makes it more difficult to interpret, but our need to really understand the core issues means that we can no longer isolate them.

### 2.3.7 EVALUATION STUDIES

Considering the ever-growing interest in science centres there is evidence that some exhibitions still do not address certain intellectual or physical needs. Hein (1995) says that when an exhibit is designed with a particular didactic function in mind it is only reasonable to query whether that function has been achieved. Wizevich (1993) postulates that there is a particular gap between the communication envisaged by exhibition designers and what visitors perceive. Many museums recognise this by employing evaluation techniques that help them to identify discrepancies. Evaluation studies typically employ qualitative methods of investigation, which are then coupled with quantitative measurements (Hein, 1995; Wizevich, 1993; Miles, 1988). According to Hein (1995) the typical questions asked are based on the didactic functions of the exhibit, formulated by the designer, or 'teacher' (Hein, 1995, p.190) and represent what the teacher decided what was to be learned. He also reports that museums are usually less interested in discovering the experience visitors have had. Although evaluation may achieve changes of the design of the exhibition, one criticism is that the methods employed often only report on whether ideas that have been formulated by the exhibition designers have been achieved (Wizevich, 1993).

> I argue that most evaluation work in museums has been based on the premise that we need to modify our exhibits so as to maximise what visitors learn of the content we want to teach. (Hein, 1995, p.201)

Another criticism concerns the issue that many museums employ evaluation studies once the exhibition has been designed and put in place. As a result of this there are limited opportunities for improvement of any deficiencies that are discovered. This 'post-design evaluation' is also referred to as summative evaluation and typically assesses whether the objectives of the museum have been reached. Formative evaluation, investigating the work in progress, is less frequently employed because of the time and money that are involved (Kelman, 1995). Borun et al. (1993) provided a front-end evaluation to gain a sense of how visitors understand phenomena, by this they gained more than merely whether exhibits or programmes have reached the developers' intentions. Research, by comparison, examines the nature of the experience and the impact on the visitor. Hein (1995) comments on the need for more than only evaluation studies:

> In order to understand the museum visitors and find out what they have learned, we need a broad approach to museum evaluation which includes a rich infusion of qualitative, naturalistic research into the museum field (Hein, 1995, p.201).

He gives examples of activities that can be employed to achieve this goal, like ethnographic studies, analysis of conversations, retrospective interviews, in-depth interviews and focus group interviews. The decision of which method is the most appropriate to use is then dependent on the context of the programme and the kind of learning outcomes to be evaluated. Kelman (1995) describes this process as a "responsive evaluation", which employs a naturalistic process of evaluation. This, in turn, produces subjectivity and bias but is considered by him as more likely to produce information about how learning takes place.

### 2.3.8 SUMMARY: SCIENCE CENTRES – THE NEW LEARNING ENVIRONMENTS

This section discussed science centres as places that communicate information and how this environment can be understood.

It is clear that there is a special character to science centres that sets them apart from the normal settings of learning and teaching. The expectations of producing entertaining as well as educational places are higher than those of other informal learning sources. Participatory exhibits are described as the key ingredient in science centres and focus has been on the identification and modification of any weaknesses in their presentation. By studying the potential of those exhibits, there seems a general consensus that while participatory exhibits engage visitors much more than static displays, there is not a necessary implication that a visitor has learned anything from simple interaction.

As a consequence, visitor studies were developed and those studies have concentrated on the times that visitors spend during their visits and at individual exhibits. Attracting and holding power were attributes that were developed to describe the engagement of visitors by exhibits. Problematic aspects of this method of investigation arise due to the observations that the time a visitor spends with an exhibit may be affected by factors like the social group, the type of exhibit and the relationship of the visitor with the exhibition. More recent methods of evaluation have expanded the range of factors that affect visitor behaviour. Questionnaires and interviews have been used in addition to the more established unobtrusive observation and timing of visitors to obtain a fuller picture of the environment. Further research suggested that there were significant differences in viewing times and behaviour between types of social groups of visitors. Science centres and museums have attempted to improve their understanding of visitor behaviour, however, only a few museums are committed to this field of study. Museums employed market research to develop and understanding of the visitor, but not for providing 'better' exhibits. Evaluation studies are a tool to discover the potential of exhibits. As discussed, there are two kinds: first, the formative evaluation, which concentrates on discovering strengths and weaknesses of exhibits while they are in development. Summative evaluation evaluates the finished exhibition. The second type – summative evaluation – evaluates the finished exhibition. Although this is currently considered of less value, it is, nevertheless, for cost reasons more often employed.

The 'new' methodologies employ more naturalistic approaches to the field of investigation allowing what is currently considered a more realistic view. The following section portrays how earth science fits into the role of being presented in science centres in a New Zealand perspective.

## 2.4 EARTH SCIENCE IN NEW ZEALAND

### 2.4.1 INTRODUCTION

This section describes the introduction of earth sciences as a result of the changes in the New Zealand science curriculum. The next two sections discuss what the research tells about students' and teachers' difficulties in earth sciences, which is then followed by a section presenting teaching strategies for this subject.

### 2.4.2 THE SCIENCE CURRICULUM IN NEW ZEALAND

Since 1993, New Zealand has had a science curriculum that includes earth sciences as one of its "learning strands" (Ministry of Education, 1993). This last iteration in the development of the curriculum was the outcome of a long process of reviews. Bell, Jones and Carr, (1995, p.74) write: "There had been a growing dissatisfaction among many New Zealanders with the curriculum, assessment and qualifications during the 1970s and 1980s." Since the late 1980s, the curriculum went through several stages of reviews and new drafts (e.g., Department of Education, 1987, 1988, 1989).

In the 1990s, concurrently with the main curriculum review, the science syllabus for students from year 7 to 11 was revised. The decision to redesign and restructure the former document was "a departure from the notion of a syllabus or examination prescription which prescribes the content to be learnt and examined" (Bell et al., 1995, p.78). The underlying philosophy for this review was to include the theoretical perspective of "a personal constructivist view of learning" (Bell et al., 1995, p.78). One of the notable aspects of the new syllabus was " earth sciences as an area of science along with biology, chemistry, astronomy and physics" (Bell et al., 1995, p.79).

However, this original syllabus was never ratified and was overtaken by two events. First, by the establishment of a task force to Review Education Administration, secondly by a change in government to the New Right National Party. The curriculum development was contracted out and the process monitored by the Minister of Education Policy Advisory Group (Science) and by the Ministry of Education's science curriculum contract review group. After months of workshops and drafts the final version was produced at the beginning of 1993 (Ministry of Education, 1993), the final document was available to schools towards the end of 1993 and became the official curriculum document for science in January 1995 (Bell et al., 1995).

The advantages and disadvantages of the new curriculum were debated (e.g., Bell and Gilbert, 1996; Bell et al., 1995; Matthews, 1995). Whatever the merits or drawbacks of the new curriculum were, the fact that earth sciences was officially implemented as a science strand, was an opportunity that had long been campaigned for (e.g., Lee, 1993). This was derived from the wish of the "geology fraternity" to secure space in the science curriculum for earth sciences. In Britain prior to 1986, earth sciences were more likely to be included in integrated science courses than in separate sciences courses as it was for biology, chemistry and physics (Trend, 1996).

Summers and Mant (1995) note that without formal recognition of a subject area in a curriculum, neither the teachers nor the science programmes of the individual schools could be expected to incorporate any facets of such subjects.

The New Zealand Science Curriculum is organised into six learning strands, which span eight levels using two "integrating" strands interwoven across four" contextual" strands.

The two integrating learning strands are:

I. Making sense of the nature of science and its relationship to technology,

II. Developing scientific skills and attitudes.

The four contextual learning strands are:

I. Making sense of the Living World (biology),

II. Making sense of the Physical World (physics),

III. Making sense of the Material World (chemistry), and

IV. Making sense of Planet Earth and beyond (geology and astronomy).

At the lower levels the 'Planet Earth and beyond' strand emphasises the composition of rock materials, at intermediate levels the understanding of geological processes and the focus for the higher levels is in environmental and social impacts of geological processes (Hodder, 1997). In its curriculum, the Ministry of Education (1993) states for the 'Planet Earth and beyond' strand:

> The learning emphasis is on the development of an awareness of the unique nature of planet Earth within the solar system. Also important is the need to value Earth's resources in ways which recognise that the special environment it provides for living things is constantly changing and vulnerable. (Ministry of Education, 1993, p. 107)

The document lists in particular four areas as the 'achievement aims' for 'Making sense of Planet Earth and beyond'.

- The composition of planet Earth and the processes which have formed it and continue to form it.
- The geological history of planet Earth.

- The relationship between Earth and other planets within our solar system, galaxy and the universe.
- People's influence on the environment and resources of planet Earth.

In each of these areas students were expected to apply scientific knowledge, skills and attitudes. Emphasis was also to be placed on local and national earth science features. Examples for 'possible learning outcomes' are given in the document for each school level and also 'assessment examples'.

Despite the debate, the resultant Science Curriculum does not incorporate a great deal of constructivist ideas. Even though it was initially designed to include constructivist views in the Draft for the science syllabus for students from year 7 to 11 (Bell et al., 1995), it is prescriptive, particularly in the kind of achievements and outcomes it expects and does not incorporate students alternative notions in science.

Constructivism in science has identified the notion that pupils are already scientists (Solomon, 1994; Gilbert, Osborne and Fensham, 1982). While many scientists nowadays accept the constructivist approach as an important teaching tool in earth sciences (Philips, 1991), it has been described as being difficult to incorporate particularly in the field of earth sciences (Shea, 1996). Many fields of study in this subject deal with products of processes that can not be observed in a lifetime. Many earth science features will not be recognised if not portrayed in a stereotypical way (e.g., a 'typical' cone volcano and a caldera volcano). Incorporation of people's different ideas in earth sciences has been described as being "antiscientific" and constructivism a way of abandoning "the idea of science as a method of understanding the real world" (Shea, 1996, p.242).

The earth science community has nevertheless acknowledged that science is also a process of hypothesis formation, experimental design, collection of data, analysis, interpretation and re-questioning (Kastens, van Esselstyn and McClintock, 1996).

The future for earth science education in New Zealand schools has been described as being uncertain (Munro, 1999) as new achievement standards are sought to be implemented. The proposed new framework will reduce the importance of the Planet Earth and beyond strand and from year 11 onwards none of the science units will be compulsory. Munro (1999) highlights the potential loss of importance for earth sciences because the School Certificate requirements often govern what is being taught at school.

### 2.4.3 STUDENTS AND EARTH SCIENCES

The process of learning of earth sciences has not been well studied. This lack of research has partially been blamed on the minimal amount of earth sciences in schools, particularly when compared to other physical sciences (Gobert, 2000). However, with a growing recognition of earth sciences in schools and school curricula, the importance and depth of research in this area is likely to increase. Happs (1982) presented aspects of student understanding of specific geological landforms in one of the earliest examples of earth science education in New Zealand. Problems commonly identified in students' understanding were associated with geological time and the processes involved that form earth's features. Idiosyncratic views like "a mountain with snow on top cannot be a volcano" (Happs, 1982, p.9) were common and represent the associations children often make. Similar findings about the difficulties in understanding science phenomena for subjects other than earth science have been reported elsewhere (e.g., Buckley, 2000).

Work on conceptions in science in general and earth science in particular has attracted a lot of interest about children's ideas in those areas. Those ideas have been labelled 'naive intuitive' (Arnold, Sarge and Worral, 1995), 'misconceptions' (Philips, 1991), 'alternative conceptions' (Marin and Benarroch, 1994), student's views of the world' (Osborne and Gilbert, 1980) 'children's notions' (Solomon, 1992), 'children's scientific knowledge' (Solomon, 1993) and 'children's science' (Gilbert, Osborne and Fensham, 1982) just to name a few. They all have in common the recognition that children's conceptions of scientific ideas are often different from the mainstream science theories. Research into teaching practice has revealed that teachers sometimes hope that the answers given by students are so 'off-track' that learning will be possible simply by the difference in perspective of science theories for students' ideas (Gilbert et al., 1982).

Other studies have looked into applying theoretical understanding of scientific processes by students and teachers. Snyder (2000) provides some interesting information about the differences between expert and novice problem solving processes in physics. She refers to studies by Larkin (1983, in Snyder 2000) where experts would try to apply theoretical understanding to the interpretation of a problem, whereas novices would represent problems in terms of physical objects and produce descriptions of the problem situation themselves. The main difference was reported to be the application of a theory. Snyder also points out however, that knowledge (in physics) was neither entirely theory nor model-based, but a combination of both and, that the ratio of theory to model used, depended on whether the subject was relatively an expert or a novice.

The difficulties that students experience in earth sciences have often been described in terms of various misconceptions, (Philips, 1991) or more commonly, by looking at one particular misconception (Arnold, Sarge and Worral, 1995). For example, Trend (1998) presents findings from a study about students' understanding of geological deep time, being a core concept within geology and associated with many of the earth science processes. He identifies this area as one of the major 'stumbling blocks' for understanding geological concepts. He comments that although children have an awareness of major geological events, an understanding of the events' chronology is almost entirely lacking. Comparisons with studies that look at children's ability to interpret historical times (e.g., Barton and Levstik, 1996) show that even young children have a good understanding of historical chronology. Visual images help to distinguish between historical times (Barton and Levstik, 1996). Such a visual aid for deep time is more complex to provide. In a study by Philips (1991) young children had ideas that dinosaurs and caveman lived at the same time. A common misconception in the group of ten-year-olds was that humans not only lived at the same time as the dinosaurs but that they were also responsible for their extinction. These findings seem to imply that the subjects in those studies tried to relate geological time with historical time and the existence of humans.

In a study by Gobert (2000) students were given textual information and then asked to produce a picture of the information. Part of the investigation was a case study of a student who produced spatial and causal incorrect drawings. The drawing of the internal layering of the earth for example depicted the core at the bottom of a circle followed by the mantle (in the centre of the circle) and the crust on top (see Figure 1). The same picture was produced even after the student read through the text once more. The student revised the spatial problems when the interviewer gave her an analogue description and compared the layering of the earth with an onion cut in half. The revised drawings now provided a model for the student that she could reason and make inferences. It appears that without the mental picture of the onion the student would not have been able to get to a similar result.

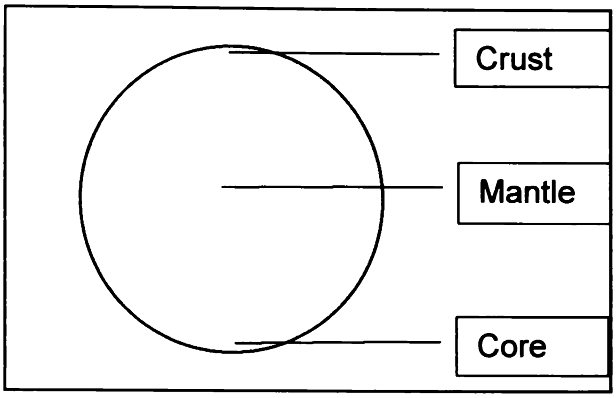



**Figure 1** Spatially incorrect drawing of the Earth's interior after Gobert (2000)

The attempt to explain scientific concepts by using everyday experiences has been blamed for misconceptions, for example, in relation to the Earth's shape and its gravitational field (Arnold, Sarge and Worral, 1995). These authors state that gravity models for Earth develop with a child's exposure to culturally accepted information, which often relates to the child's age. Philips (1991, p.22) reports a similar age-related hierarchy, which includes misconceptions like 'gravity increases with height' or 'gravity cannot exist without air'. Gilbert, Osborne and Fensham (1982, p.625) identify five patterns in the development of children's alternative ideas:

I. *Everyday Language*: Gilbert et al. (1982) points out that words with a specific meaning in science, which are also used in common everyday language may be used by students in an interpretation which might not be appropriate to a scientific point of view. (Example of the authors: particle, scientific meaning for a non-visible part like an atom or molecule, in everyday language meaning a small but visible solid substance. Gilbert et al. 1982, p.625)

II. *Self-Centred and Human-Centred Viewpoint:* Interpretations are typically based on human experiences or commonly held values.

Children will often attempt to interpret phenomena from their own experiences. The self-centred interpretation is reported to be less typical for children older than nine or ten, but is then based on common beliefs, i.e. so human centred evolves into the self centred viewpoint.

III. *Non-observables do not exist:* This applies particularly to physical phenomena, which cannot be watched. The authors refer this observation also to comments like "if you can't feel an electric current it is not present" (Gilbert at al., 1982, p. 626). Visibility is, of course, not the only 'valid' observation that children can make, other sensual impressions are also important.

IV. *Endowing objects with the characteristics of humans and animals:* The authors refer to an observation, that children attribute human quantities like "will" to physical properties.

V. *Endowing objects with a certain amount of physical quantity:* The authors refer to an observation they made that students gave heat a physical entity, which allows it to apply force to other elements.

Gilbert's et al. (1982) observations were based on interviewing children about physical concepts. Most of this can be appropriately applicable to the field of earth sciences, which comprises many aspects from physics, chemistry, biology and mathematics.

By looking at misconceptions in earth science, similarities can be found between Philips (1991) and Gilbert's et al. (1982) observations. One of the most common interpretations of younger children (Year 1 – 6) reflect the notion that "non-observables do not exist" as well as the self-centred viewpoint. Children relate to what they can see based on their own experiences. Philips (1991, p. 22) gives examples like "The earth is larger than the sun or sun disappears at night." Many phenomena in earth sciences cannot be observed, which leads to many quasi-scientific explanations, often observations that are made with something that is associated or has similar qualities. For example: "Rain occurs when clouds get scrambled and melt" or "All rivers flow down from north to south" (Philips, 1991, p.23). In the process of getting older most students adapt to more accepted scientific ideas and Arnold, Sarge and Worral (1995) report that this is done by going through a series of "intermediate models" (p.635). However, Phillips's study also shows that some misconceptions are held by adults as well as students, which implies that they are concepts that have been rejected even after comparing them with alternative ideas e.g.: "The sun goes around the Earth (Adult)" (Philips, 1991, p.22). Gobert (2000) refers to other studies (Turner, Nigg and Daz, 1986 and Bezzi, 1989) that report that misconceptions in earth sciences are not necessarily likely to become more scientifically correct as children become adults.

### 2.4.4 TEACHERS AND EARTH SCIENCE

Before the implementation of earth sciences into the New Zealand science curriculum there was concern about how this area was taught by teachers. Hume (1990) presented a small-scale study of some New Zealand teachers in which she highlighted the extent to which earth sciences was being taught in five New Zealand schools. Her findings were that earth sciences were often not taught at schools (year 7 – 12) at all, and if taught, then only by enthusiastic teachers who had studied earth sciences in their degree. Traditionally, Geography covered more aspects of earth sciences and therefore teachers with geography training were more capable of applying their understanding to teach this area. Hodder and Hodder (1997) asked whether there have been any changes for the tertiary teaching sector since earth sciences had been introduced. In particular, they looked at performance measures for first year courses for the years 1994 up to 1996 in environmental sciences. Those findings are contradictory to the changes in the curriculum, as they do not indicate any improvement of earth science performance, but indeed only declining trends. They concluded that there had been no significant changes in the academic abilities of students on entry. This might suggest that although earth sciences had been introduced, not all teachers did teach it at schools.

International studies on teacher understanding in earth science present interesting findings. Fang (1996) states that there is still a big gap between teachers' beliefs and their practice and that there should be more focus on how teachers can apply theoretical knowledge rather then arguing whether they should posses it, because he argues they should possess it anyway. The author also points out that that attention should be paid on particular components of a subject area, which has been often neglected. Summers and Mant (1995, p.3) report in their study on British primary school teachers' understanding of the 'Earth's place in the universe', namely the earth science strand in the national curriculum for England and Wales. They show a significant mismatch between the teacher's existing knowledge and the requirements of the curriculum in this area. They report similar findings about teachers' concepts in earth science as earlier reported misconceptions within children's knowledge of science (e.g., Philips, 1991; Gilbert, Osborne and Fensham, 1982). The areas they identified where teachers were showing unsatisfactory results were:

- observational experience and knowledge;
- knowledge of accurate scientific, structural models of the earth in relationship to the rest of the solar system and the stars;
- 'real' understanding, in the sense of being able to use these models to explain and predict simple phenomena of the kind targeted by this research, leading to confidence in, and ownership of, newly acquired knowledge;
- knowledge of the type and range of ideas that children are likely to have about these conceptual areas; (Summers and Mant, 1995, p.14)

The previous section discussed the research about children's difficulties with geological time in comparison with historical time (Trend, 1998; Barton and Levstik, 1996). Trend (2000) presents findings about the conceptions of geological time of primary school teacher trainees and relates it with teaching history and science. His findings are that teacher trainees vary in their interest and classroom experience with geological time but are generally more comfortable and imaginative teaching historical time. Trend argues that understanding of geological time is fundamental within geoscience: " It is suggested that, if we have an insecure deep time framework, we will be less able to accommodate new learning of geoscience concepts with a strong (deep) temporal component." (Trend, 2000, p.539)

The quality of teacher training has been also blamed in playing a distinctive role, as there has not been a lot of attention towards the learning environments of trainee teachers. Hardy (1994) pays tribute to the science tutors who have to create environments that improve and develop teacher attitudes and competencies. He argues that it is more important to help teachers become reflective practitioners than to focus on isolated areas like content knowledge or pedagogical skills. This change also involves changing the tertiary setting but the question is raised as to how to encourage and support science educators. However, later studies suggest that the level of knowledge that teachers obtain is highly crucial to maximising the potential learning opportunity of students, by the teachers' ability of "responding with powerful learning pointers" (Trend, 1998, p.986).

### 2.4.5 TEACHING EARTH SCIENCES

Many of the recent studies published about teaching strategies for earth sciences report on the tertiary sector (e.g., Hudak, 1998; Dove, 1996; Kastens, van Esselstyn and McClintock, 1996). The majority of those studies acknowledge the problem in teaching aspects in this area. One of the key threads that links those reports is the difficulty in visualising the processes that are involved in forming geological features. Understanding the process is necessary to get a basic understanding of the subject. The focus of many studies lies, therefore, on finding ways to translate the processes that occur in reality into an understandable format for students or novices.

One of the traditional teaching practices in earth sciences is field-studies. Norris (1993, p.324) writes that: "Most geologists would agree, I think, that there is no better way to learn about rock structures and geological processes then seeing them and their effects in a natural setting." Norris's point of view comes from that of a geologist rather than that of a teacher. He also points out the meaningfulness of the social experience that fieldtrips have, and how it can enhance the attitude towards studies in this field.

Manner (1995) describes in more detail the advances and limitations of fieldtrips for secondary school students and their teachers. She points out that according to Piaget the cognitive ability of students to deal with abstract images is not fully developed until the age of 14 or 15 years. Therefore she concludes, concrete objects as they are presented in a field excursion are a more appropriate teaching tool.

The social impact of an excursion she states is an important aspect. It spans from a positive effect on the attitude of the students to a building of enhanced human relationships and an improvement of self-esteem. Thus, appreciation for nature, opportunities to increase science skills and learning skills like co-operative learning is also listed as a benefit for students.

She also applies the same attributes to the teaching of primary school children. Teachers are said to benefit as well as students because 'certain situations are only encountered on field trips' (Manner, 1995, p.129). Manner also points out that a limitation of fieldtrips is that unless teachers are properly trained they are not effective in conducting a field study. The teachers are often reported to feel uncomfortable and inadequate in conducting successful excursions. Other limitations are the time restrictions that schools have for their trips, transport, resources, preparations and follow-ups of field trips and also that the community is often said to perceive field trips as not "useful". Further, she reported that while school grounds would have the advantage of offering field trips without extra costs, they are often not the ideal places where geology can be seen. Nevertheless, Kowal (1995) points out that there are many sites within a short distance of schools that can be potentially interesting to view, but it involves careful planning and a competent, knowledgeable teacher.

Other authors have acknowledged the difficulties in comprehending natural systems. Gobert (2000, p. 939) refers to four reasons why it is difficult to learn about plate tectonics for example. First, she states, is the problem of the un-observability of the earth's internal layers. Secondly she points out the difficulty to comprehend the size scale. Thirdly the problematic conceptualisation of geological time and fourthly she points out that in order to fully understand the system it requires comprehension and integration of spatial, causal and dynamic information. De Wet (1994, p.264) describes four reasons why modelling is useful to supplement or even replace field observations.

I. *Complexity-* Natural systems are very complex. They can be difficult to comprehend, whereas a model can supply a much simpler version that supports understanding.

II. *Temporal scale-* Most of the processes that form geological features are either too short (e.g., an earthquake) or span too long periods of time for us to observe.

III. *Spatial scale*- Many geological features occur on an either too small scale (e.g., minerals) or too large scale (e.g., transform faults) to be adequately observed in the field.

IV. *Prediction*- The use of models enables one to make predictions about changes in the system. Processes can be re-played and hypotheses can be tested.

Several types of models can be envisaged, as de Wet (1994) describes:

I. *Conceptual models*- Being descriptive rather then quantitative conceptual, models represent a stylised version of the reality in order to illustrate the situation. A diagram is such a model.

II. *Physical model*- A physical replica of the natural system offers a reduction of the complexity and the scale.

III. *Numerical/computer model*- These are particularly useful for making quantitative measurements. They offer the possibility to test and predict a natural system.

The use of computer animated programs within the field of earth sciences is claimed to enhance understanding of physical processes (Hodge, Bursik and Barclay, 1995) particularly for novices. Even at a more advanced level, computer programs are reported as being able to help translate abstract images like maps to the natural setting (Kastens, van Esselstyn and McClintock, 1996). Computer models have been also developed that allow visualisation of aspects that can not be observed at all like groundwater hydrology (Hudak, 1998).

In spite of this, many geoscientists make a plea for a more deliberate linkage of field observations and laboratory practice to allow successful co-operation between understanding and improvement in the attitude toward earth science (e.g., Mayer, 1997).

### 2.4.6 SUMMARY: EARTH SCIENCE IN NEW ZEALAND

The previous section discussed the current state of geoscience education with a particular focus on the New Zealand situation.

Earth sciences within the New Zealand school system has seen a change from its being incorporated within the geography syllabus, to its being a science strand within the science curriculum. The section also alludes the development of the new science curriculum. The implementation of constructivist ideas within earth sciences was somewhat controversial. The future prospects for earth science education in New Zealand are unsure due to a proposed framework that reduces the importance of Earth Sciences from year 11.

Research about earth science students has focused on the misconceptions younger students had, and indicated that these misconceptions are based on commonly held views, society views and views that exist in our educators. Some of the problems that have been identified lie within the understanding of fundamental geological principles like geological time. Problematic aspects of science teaching have been described from the perspective of teaching physical principles. This description can be adapted for earth sciences. Comparison of the kind of misconceptions that have been identified points to one major problem in earth sciences - visualisation.

The next section deals with teachers and earth science teaching. Studies that have been published in New Zealand and overseas show that unless earth sciences are formally implemented in a science curriculum, they are only taught by teachers who have a personal interest in this area. New Zealand studies from the tertiary sector have not seen an impact of the introduction of earth sciences into the school curriculum and a corresponding change in achievement levels for first year students. Overseas studies show that many teachers face quite similar gaps in earth science understanding to those reported in studies about children's understanding. Research says that apart from the need to train teachers formally in earth science, a focus should also lie on teaching didactical applications for this science strand. Other studies suggest putting much more attention on providing sufficiently trained educators in the tertiary sector to create an effective learning environment.

The final part of this section reflects on teaching practices in earth sciences. Most of the studies are reflecting experiences from the tertiary sector. The difficulty of visualisation is again a key issue. A traditional teaching technique in earth sciences is to go on fieldtrips. More recent studies focus on the problematic areas and the use of physical models or computer programs to overcome limiting factors like the process duration or spatial limitations. The general consensus is to link those applications in order to provide sufficient information to earth science learners.

## 2.5 SUMMARY

It was envisaged that this chapter would accomplish several purposes, namely that it would provide a framework for establishing the importance of the study, share results and outcomes of other studies relevant to the study being reported and aim to relate the study to the ongoing dialogue in the literature. The theory that is being addressed in this thesis is whether earth science processes can be successfully demonstrated by using simulations in a science centre. The literature review, therefore, started by introducing the origins of science centres and the underlying philosophies. This introduction showed that the early museums were exhibitions of weird and often strange curiosities initially only accessible to the rich and famous but eventually being opened to the wider public. This development illustrates how, from the early beginnings of civilised mankind, there has been much interest in establishing places where one could go and see new and often different things. Today's visitors to museums, galleries, science centres or zoos will often have similar intentions, which is certainly acknowledged by those institutions. Typically the weird curiosities of today are the things that are hard to observe. So, by exhibiting gigantic models of insects for example, visitors are allowed views of the world around them that they usually do not experience.

The literature review illustrated further that the new development of museums led to a concentration on the educational aspects of those establishments. Initially it was an obedient attitude of visitors that was encouraged, to come and see and not to ask any questions. Architecture, the design of exhibition halls and exhibit labelling was intended to give the visitors the feeling that they were in the temples of wisdom, which must not be questioned. This type of presentation changed over time and nowadays museums have become places where questions can and should be asked. The focus on science centres in this study documents the change in the philosophy of exhibit presentation which is not so much focused on the object that is exhibited and rather more on the phenomenon it is representing. Not surprisingly this development has specifically targeted the natural sciences.

With this new focal point research has devoted its attention to the 'new places of learning'. Research in museums and science centres has been largely devoted to describing how much time a visitor would spend at an exhibition and has taken this as a measurement of how successful the presentation was. Other studies looked at factors that will influence a visitor's behaviour. Only a few studies reported on the type of exhibits that were produced and most of those simplified this description even further as to whether it was a static or dynamic presentation. This is one of the very important aspects for this study, as it aims to take the earlier findings of the museum research into account and combine them with a new description of participatory exhibits – simulations. This new interpretation of a learning device has its origins in the research of science education rather than in museum studies. The ability of simulations to demonstrate a complex system through participation breaks through the problem of visualisation in relation to earth sciences.

The recent implementation of earth sciences into the New Zealand curriculum has led to a heightened interest in the difficulties of learning and teaching earth sciences. The bulk of research on geo-science education remains led by overseas studies. This study aims to address the lack of New Zealand specific research. It is argued that simulations are an appropriate tool to overcome typical spatial, causal and dynamic difficulties, particularly when 'new' information is taught to 'novices' in earth science. This literature review sought to tie the different areas of research together as this research is also aiming to provide a description that is of interest for earth sciences, science education and museum studies groups alike.

The next chapter will continue with a reflection on the research questions and will discuss the methodology and methods that were selected to help answer those questions.

Chapter 3

# METHODOLOGY AND METHOD

## 3.1 INTRODUCTION TO THE ASSUMPTIONS AND RATIONALE FOR THE RESEARCH DESIGN

The literature chapter showed that although New Zealand is a country with active volcanoes and frequent earthquakes many science teachers do experience difficulties in the understanding and teaching of geological sciences. Studies on student understanding in earth science also show that many of the misconceptions are based on a visualisation problem of earth science processes. The implementation of earth sciences into the school curriculum as the 'Planet Earth and Beyond' strand of the science curriculum is potentially a big step forward towards a wider understanding of earth science but there has been little change thus far.

The development of science and technology centres in New Zealand which coincided with the implementation of the new science curriculum, inspired the development of a geoscience exhibition 'Earthworks' that aimed to focus on visitor participation. The exhibits in this exhibition were aimed at portraying earth science processes, while concurrently reflecting the achievement aims in the science curriculum. For this, the exhibition providers chose to feature participatory exhibits, many of which were simulations as characterised in section 2.3.4. Interactive exhibits are part of every science centre and many museums also now feature them within their range of exhibits. Most of the research in this area has focused on evaluating the overall appearance of exhibitions and learning outcomes (e.g., Geyer, 1995; McManus, 1994; Wizevich, 1993; Rowan, 1990). Although much of the literature documents visitor behaviour studies (e.g., Brooke, 1994; McManus, 1992; Javlekar, 1989; Koran, Foster and Koran, 1989; Nuissl, 1988) which are then used to assess how successful an exhibition has been, less is reported about the kind of interactive exhibits that are being used, despite its equal importance.

Simulations, even if they are part of many science centre exhibitions, have not been further discussed other than as educational tools in classroom situations or in the context of computer animated simulators. Simulations in science centres that concentrate on portraying earth science concepts are the focus of this research. The literature review also showed that there had been little research done on geo-science education with a New Zealand perspective, particularly with the focus on out of classroom activities. Hence, this study will include this as an additional research question and follow up the New Zealand situation on earth science education in a science centre.

This chapter presents the research methodology used in this thesis. After discussing and justifying the research questions, the discussion begins with a description and comparison of traditional educational research. This is followed by discussion on the limitations of the study and the ethical considerations of this investigation. The section ends with a description of the data collecting techniques used and the analysis technique employed.

## 3.2 RESEARCH QUESTIONS

This research considers the hypothesis that learning in the earth sciences can be better understood and facilitated when supported through an interactive simulation. Even if it is generally held that a positive learning environment should give good learning outcomes, there is no necessary guarantee of this. Previous studies had reported students and teachers being less enthusiastic about earth sciences compared with other subjects (e.g., Tulip, O'Connell and English, 1994; Robinson, 1991; Hume, 1990). Therefore this research sought to find out:

I. How does an exhibition that portrays earth sciences influence the audience's perception about the subject?

It has been discussed that children as well as adults find it difficult to comprehend and hard to visualize earth science processes. Simulations may offer the visual bridge to understand those processes as well as offering a pedagogical teaching tool. This research consequently sought to find out if:

II. Can simulation based models teach a non-specialist in earth science the functionality of the real system?

There are literature reports about follow-up interviews that were conducted after visitors viewed exhibitions (e.g., Stevenson, 1991). Results indicate that visitors are generally positive about their visit, but recall was often episodic and often directed towards recalling effects rather than explanations. Hence, this study sought to investigate whether:

III. Do students and teachers perceive their visit to a science centre featuring earth science simulations as enjoyable and what do they remember, after a reasonable amount of time?

There have been few New Zealand studies on earth science education (Hodder and Hodder, 1997; Hume, 1997), and even less is reported on out of school activities for New Zealand educators or students` (Hodder, 1997). Only a little has been reported on the special characteristics of science exhibitions in a New Zealand context (Hodder and Otrel-Cass, 2000; Schwartz, 1996). It is clear from the literature review that it is worthwhile to investigate:

IV. What is the New Zealand perspective on earth sciences in science centres.

These four research questions define the aims of this study. The aim of this study is to produce a description of earth science teaching and learning in an environment such as a science centre. The research design, therefore, as a vital part of the study, had to embrace a selection of qualitative and quantitative methods to achieve the desired outcomes. The following section will discuss the traditional views and elaborate the methods chosen for this study.

## 3.3 EDUCATIONAL METHODOLOGY TRADITIONS

This section addresses the research questions of this study by looking at the methodology that has been used. Anderson (1990), in comparing the methodology to fine cooking, notes:

> What you achieve as your product depends both on the quality of the data and on the way in which it is processed. (Anderson, 1990, p.107)

Research in an educational environment seeks to promote the values of systematic inquiry while respecting the evidence. While social scientists recognise that the single most important notion is the pursuit of truth, they also recognise that absolute truth in this field cannot be achieved:

> We seek to describe, illuminate, portray and hopefully sometimes, even explain that small section of reality that serves as the focus for our particular enquiry. (Broadfoot, 1988, p.26)

From an empirical point of view there were two basic principles that produce two ways of representing reality, which Hughes (1990) describes to be the *nomothetic* and the *ideographic* way. The nomothetic way is characteristic for the natural scientists, who are:

> ... interested in forming general concepts by abstracting from the concrete case those features which are in common with other phenomena. (Hughes, 1990, p. 91)

The ideographic way is more characteristic for historic research which is:

> ... concerned to understand the concrete and unique case. (Hughes, 1990, p. 91)

Both use their own unique selection of elements to present general or individual concepts. However, realistically both methods are needed to obtain an objective result and avoid presenting a one-sided view.

Today there are two general positions that dominate the debate over social science methods: the positivist and the interpretative approaches. The relative popularity of the two has shown a shift over time towards the latter. Each method uses different ways of obtaining their information, but both have their roots in twentieth-century philosophical thinking.

Hughes (1990) argues that with respect to the social and natural worlds, positivism could not gain adequate knowledge, as it is concerned with the rational, and is technically orientated based on instrumental activity. The perception of research neutrality is fostered by the apparent anonymity of participants in a large sample size. However, the real difference within the scientific inquiry lies within the object that is being researched:

> All irrational and emotive aspects of human behaviour are to be seen as deviations from a conceptually pure type of rational action. (Hughes, 1990, p.93)

'Understanding' is the key word also described as the method of *verstehen*. The interpretation gives the researcher a method that aims to not distort the social world of those being studied.

So instead of searching for *causal relationships* involving large samples, so that data can be generalised and be of statistical significance, the researcher should remain distant and independent of that being researched (Cohen and Manion, 1994; Creswell, 1994). The focus of the interpretation lies in constructing a meaning and bringing order into the data (Carr, 1997). These methods have become acceptable ways of investigating students' understanding and learning of science (Smith, 1987).

In the interpretative tradition the researcher may interact with those being studied to understand the meaning of the subject's action. By admitting the individuality and uniqueness of the event: the investigator admits the value-laden nature of the study (Rodrigues, 1993; Creswell, 1994). Often a study is continuously evaluated to modify any changes with the goal of improving a later practical implementation of the research outcomes (Cohen and Manion, 1994). This approach makes it particularly 'value laden'. Interpretative traditions allow using both quantitative as well as qualitative measurements.

## 3.4 RESEARCH METHOD

### 3.4.1 INTRODUCTION

The method that was used to collect data for this study is called the *Illuminative Evaluation* methodology (Parlett and Hamilton, 1972). This method, which is derived from the more traditional focus of Programme Evaluation, is designed to take account of the wider contexts in which educational programs function (Parlett and Hamilton, 1972), embracing the interpretive tradition and using quantitative and qualitative measurements.

### 3.4.2 CHOICE OF METHOD

The typical type of evaluation, is "an assessment of the effectiveness of an innovation by examining whether it has reached the required standards on the pre-specified criteria " (Parlett and Hamilton, 1972, p.7). Anderson, (1990, p.111) refers to the traditional Evaluation "as a mode with a focus on a more practical type of research". This classical type of evaluation study measures performance as a function of intentions, specified by program creators. This approach can be criticised because the study variables (program, users) are isolated, which may distort reality (Parlett and Hamilton, 1972).

The primary concern of the Illuminative Evaluation Technique is with description and interpretation rather than with measurement and prediction. This research has much in common with qualitative research in education, even though it may make use of some quantitative material. Through the selection of this type of evaluation method the relationship between variables can be described. The way of conducting research in this study using the Illuminative Evaluation technique was described by Parlett and Hamilton (1972).

## 3.5 ILLUMINATIVE EVALUATION

The main features of Illuminative Evaluation in its description of an educational programme are:

- How it (the educational programme) operates.
- How it is influenced by the various situations, with which it or its participants interact.
- What those directly concerned regard as its advantages.

➢ How students' intellectual tasks and academic experiences are most affected.

Illuminative Evaluation attempts to discover and document what it is like to be a participant in a scheme, whether as a pupil or as a teacher, and to discern and discuss the programme's most significant features (Parlett and Hamilton, 1972). Two central concepts in Illuminative Evaluation are (shown in Figure 2):

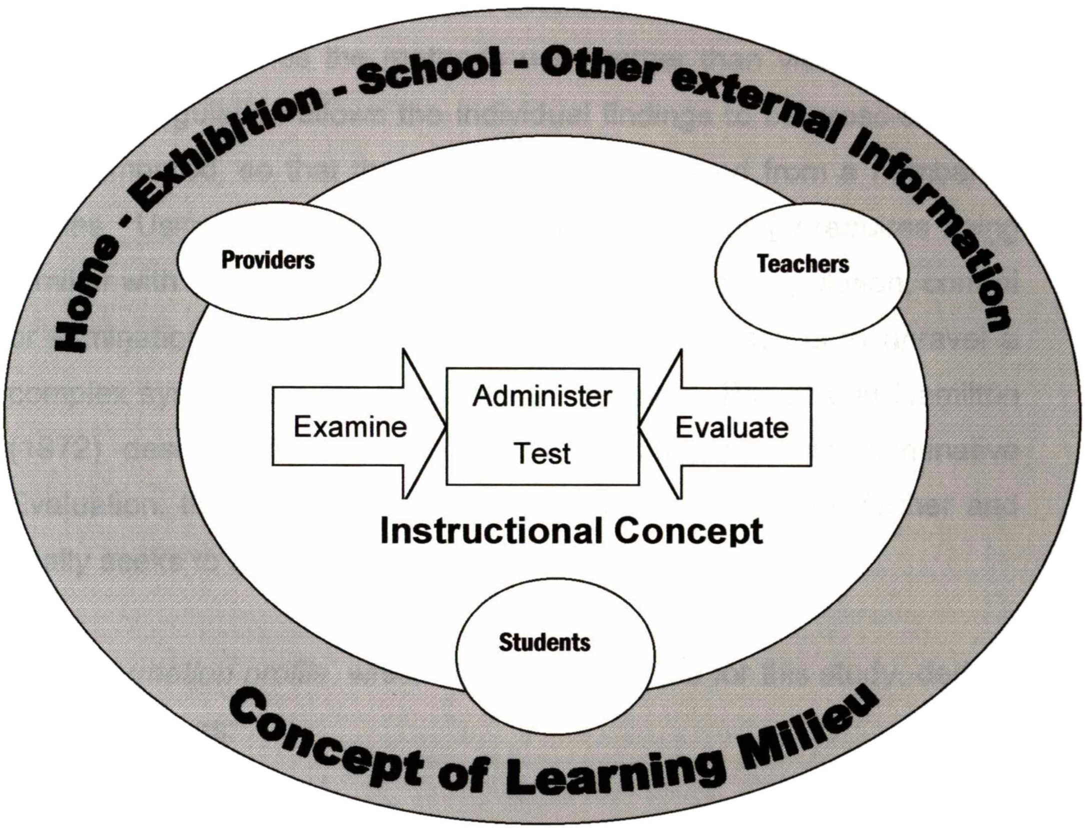



**Figure 2:** Two concepts in Illuminative Evaluation: the Instructional Concept and the concept of the Learning Milieu

The *Instructional Concept or Catalogue Description*, where the researcher examines the plan, or programme goals, objectives and its the desired outcomes. From these are derived the tests and attitude inventories to be administered.

This concept of the *Learning Milieu* is required when switching from discussing the instructional system in abstract form to describing the details of its implementation. The Learning Milieu is the environment in which students and teachers work together. Acknowledging the diversity and complexity of the learning milieu is an essential part of the study.

Illuminative Evaluation is a general research strategy, not a standard methodological package. It aims to be adaptable and eclectic. The choice of the research tactics follows not from the research doctrine, but from decisions as to the best available techniques for each case. The problem defines the methods used rather than vice versa. The use of triangulation allows the individual findings to be cross-checked and compared, so that the problem can be viewed from a number of angles. Using the Illuminative Evaluation methodology requires being familiar with the reality of the setting. There is no manipulation, control or elimination of situational variables. The chief task is to unravel a complex system and isolate significant features. Parlett and Hamilton (1972) describe the three characteristic stages within Illuminative Evaluation: the investigator firstly observes, then inquires further and finally seeks to explain.

The *information profile*, which has been selected for this study, derives from four areas:

1. Observation,
2. Interviews,
3. Questionnaires and
4. Documentary and background sources.

Figure 3 shows how Illuminative Evaluation can be applied to this research to achieve an understanding from the diverse pool of data.

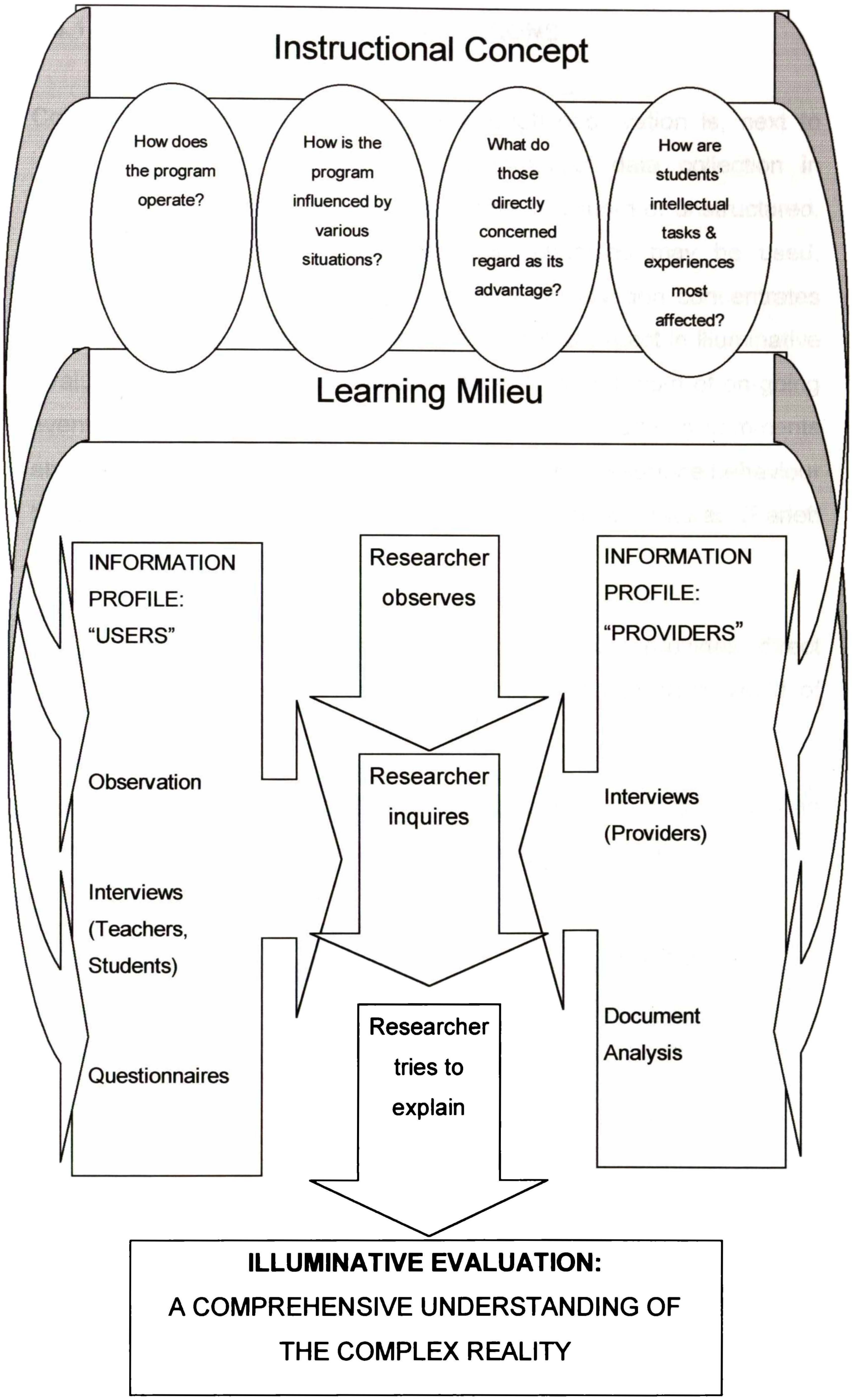



**Figure 3:** Illuminative Evaluation applied to this study

### 3.5.1 OBSERVATION AND ITS LIMITATIONS

Collecting descriptions of behaviour through observation is, next to interviews, one of the most popular forms of data collection in educational research. Observations can be structured or unstructured. In structured observations checklists or schedules may be used, whereas the unstructured or more 'natural' observation concentrates on collecting field notes. Observation is a central aspect in Illuminative Evaluation. The researcher builds up a continuous record of on-going events and seeks to organise this data source by adding comments about the situation. The researcher records only the surface behaviour but does not facilitate the uncovering of underlying features (Parlett and Hamilton, 1972).

> The methodology of participant observation provides direct experiential and observational access to the insiders' world of meaning. (Jorgensen, 1989, p.15)

The researcher, being an outsider, has the possibility of becoming an insider from looking at the recorded information (Figure 4).

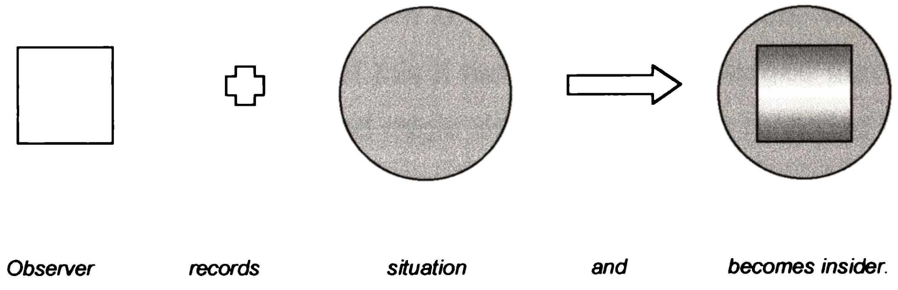



**Figure 4:** Observation as a central concept in Illuminative Evaluation

However this humanistic approach of observations reveals two major difficulties, the first being the subjective nature of the approach. The research study requires skilled human judgement and is, therefore, vulnerable.

Parlett and Hamilton (1972), argue that even in studies that handle numerical data, judgement is necessary at every stage. The second difficulty with the study is the position of the investigator and that the presence of the researcher creates disturbance. This affects mostly the investigations during the phase of observation and interviews. Yet, in a setting like a science centre being observed is believed to have minimal effect on the individuals, as it is a public place where people quite regularly observe each other.

Estimating people's age and assessing whether they read or talk about the exhibits are difficult to achieve by observation alone and this limits the reliability of the data. Such data can be used to provide some additional information to receive a better understanding of the scene, but must be developed carefully to retain integrity. Observation, however, is useful as a research tool when data are being collected from non-verbal behaviour (Cohen and Manion, 1994). In this study part of the observation is to make a judgement whether students are reading labels of exhibits. McManus (1989) highlights that reading is difficult to observe and, not surprisingly, many visitors are described in museum studies as being non-readers. However, she asserts that although exhibits are a form of visual communication *"words come first"* (p.186). Because of this it has to be acknowledged that the true number of those who read might differ from what is recorded because it is hard to observe:

> A visitor can read twenty words or more in five seconds while walking towards an exhibit. (McManus, 1989, p.186)

As students are part of the study yet another parameter appears, namely the readability of the text. Assessing the readability is yet another problematic matter. It has been recognised that the comprehension of a text does not merely depend on the text but also on the knowledge and understanding of the person who reads it (Elley, 1975). Some of the problems that arise when testing the readability include the reliance of the researcher's use of readability formulas. An example is the noun frequency formula, which concentrates on a collection of statistics about a text but does not assess how comprehensible the text is to the reader (Kintsch and Miller, 1984). Readability tests, then, provide only a guide to how difficult a text is rather than supplying a prediction. It does not tell about the conceptual understanding, which would require conceptual tools and measures. Another problem is that few testing systems have studied texts complex enough to require significant conceptual processing (Kintsch and Miller, 1984).

Differing considerably from typical positivistic approaches like experiments or surveys, observations concentrate on in-depth description and analysis of some phenomenon or set of phenomena. The methodology of participant observation is an appropriate way to address the research problems of this study, as it focuses on human interaction and aims to generate a practical and theoretical truth (Jorgensen, 1989).

Typically, participant observation is often described as being subjective, biased impressionistic, idiosyncratic and lacking in precise quantifiable measures (Cohen and Manion, 1994; Delamont, 1992):

> Whilst it is probably true that nothing can give better insight into the life of a gang of juvenile delinquents than going to live with them for an extended period of time..critics point to the danger of 'going native' as a result of playing a role within such a group. (Cohen and Manion, 1994, p.110-111)

### 3.5.2 INTERVIEWS AND THEIR LIMITATIONS

In educational research, interviews are one of the most widely used methods of data collection. This research method may serve three particular purposes, namely measuring a person's knowledge or information, providing access to a person's values and preferences and, finally, finding out about a person's attitudes and beliefs (after Tuckman, 1972 in Cohen and Manion, 1994). Discovering the views of participants is crucial to judging the impact of any innovation. Interviews can assess different educational settings and work with different educational groups.

> An interview is defined as a specialised form of communication between people for a specific purpose associated with some agreed matter. (Anderson, 1990, p.222)

Interviews vary in the type of information or common comment sought. Four kinds of interviews may be used as research tools, each having a different structure and with that a different research purpose: the structured interview, the unstructured interview, the non-directive interview and the focused interview (Cohen and Manion, 1994). In this study two of those kinds of interviews were used.

Firstly, the unstructured interview, which is used in open situations allowing flexibility and freedom. This technique was used when teachers were interviewed. While the interview purpose is governed by the questions asked, it is imperative for this technique to be carefully planned. Participants may be asked about a new innovation, what they think of it, how it compares with their previous experience and then they may comment on the use and value of the experience. Content, sequence and wording of the questions are entirely in the hands of the interviewer and by that enabled flexibility and adjustment of them to the development of the interview. This technique evolved from the psychiatric and therapeutic fields where a respondent is responsible for initiating and directing the course of the encounter and for the attitude she expresses in it. (Cohen and Manion, 1994)

The other interviewing technique used in this study is focused interviews, also called focus group interviews. One of the first times that this research tool has been used was for evaluations of an audience response to radio programmes in 1941 (Stewart and Shamdsani, 1991). Since then the focus group interview technique has become an important research tool, its particular strength being the flexibility to adapt to the desired level of focus and structure. The main context of this technique can be described as a number of interacting individuals, small enough in number to permit a genuine discussion, who are having a community of interest and are concentrating on a small number of issues to elicit information at a level of inter-personal relationships (Stewart and Shamdsani, 1991).

For this research this technique was used to interview small groups of students. Stewart and Shamdsani (1991) observes that the interviewer provides the structure, but that if the process is less structured participants will tend to pursue issues and topics, which are perceived of great importance to the group (p.11). This is, in fact, a desired outcome when the research is seeking to learn about things that are important to the group.

Interviewees may be selected randomly or by a sampling, which actively seeks out informants or groups, who have special insights or whose position makes their viewpoints noteworthy.

> The situation of interest is one where individuals interact, take action or engage in a process in response to a phenomenon (Parlett and Hamilton, 1976, p.201).

The principal limitation of interviewing in a group setting is that the interaction of respondents with one another restricts the results that can be generalised because responses are not independent from one another. Results may also be biased because the more dominant members of the group will promote their opinion, compared with more reserved participants who may be hesitant to talk. The immediate nature of the interaction may lead to placing greater faith than statistically justifiable into the findings. Also, subjects, who are willing to participate might not necessarily represent the average group of population. But this Group interviewing can provide a feeling of security for some individuals because responses might not be identified with the individual and since not each subject is required to reply to each question, responses tend to be more spontaneous. Furthermore Stewart and Shamdsani, (1991) states that:

> Children can make outstanding participants in focus groups...but it is important to assure that children are comfortable and relaxed. Younger children have less verbal facility than older students and adults so the use of more stimulus materials may be warranted. (Stewart and Shamdsani, 1991, p.98-99)

In addition the interviewer might influence the type of responses by knowingly or unknowingly providing clues about the type of desirable responses (Stewart and Shamdsani, 1991). The extent, to which information from interviewing becomes more 'reliable' - if by that it is meant that the interviewer becomes more rational, calculating and detached - often occurs at the cost of the validity of the study.

> The distinctively human element in the interview is necessary to its validity. (Kitwood, 1977 in Cohen and Manion, 1994, p.282)

One way of achieving more validity is by comparing other measures of proven validity with the interview data. Known as 'convergent validity' (Cohen and Manion, 1994) it reassures measures that have been taken (see also section 3.7.5, Triangulation of data). The interaction with the participants in the interviewing situation is both an advantage and disadvantage. The relative freedom in the unstructured format of the interviewing techniques allows greater depth of information. Neither the unstructured interviews nor focus group interviews are random discussions among groups of individuals who are brought together by chance, but they are carefully prepared group discussions with cautiously selected individuals guided by a thoughtfully prepared interview guide.

### 3.5.3 QUESTIONNAIRES AND THEIR LIMITATIONS

Questionnaires are the most widely used survey data collection technique because they are quite reliable and very economical. If a questionnaire is well constructed it permits collection of reasonable valid data relatively cheaply in a short time (Anderson, 1990). Typically questionnaires are highly structured whereby each respondent is asked the same set of questions. When using questionnaires, it is difficult to go back to people to collect additional information that might be later needed, so it is crucial to anticipate the information needed to ensure that the relevant questions are asked (De Vaus, 1991). Dillman (1978 in De Vaus, 1991) makes a distinction between four types of questions that address different problems and identify four key areas: behaviour, beliefs, attitudes and attributes.

Questions that are interested in *behaviour* have to ask participants what they *do.* If interested in someone's *beliefs*, the focus has to lie on establishing what people think is *true* and what is *false.* When asking for people's attitudes, questions have to ask what people think is 'desirable'. A*ttribute* questions ask for information on the person's *characteristics*, such as age, gender, and education.

The free and fixed response formats of the questionnaire used in this study include all of those types of questions. However, questionnaires can present a problem to people of limited literacy, which was the reason for using this particular research tool with adults only and not with children. Some respondents might be reluctant to answer open-ended questions. Yet, the interest of this study lies not so much in relating different test scores, but in accounting for them using the research's findings as a whole. Anonymity, one of the questionnaires' greatest advantages, allows the respondent to be honest and, therefore, produces reliable data.

Good questionnaires are difficult to construct and demand a lot of preparation including pilot testing, revision and formatting. While the preparation for questionnaires has to be done thoughtfully, the information gathered is in an organised format, which ultimately helps in analysing the data.

### 3.5.4 DOCUMENTARY AND BACKGROUND INFORMATION AND ITS LIMITATIONS

Educational innovations do not arise unheralded. They are preceded by a committee's minutes, funding proposals, architectural plans or contracting reports. This information gives a historical perspective to the development of an educational programme (Parlett and Hamilton, 1972). Document analysis does have the advantage of being very economical for obtaining data. Documentation of ideas and background philosophies can be studied without involving costly techniques. Furthermore, processes can be studied that occur over a long period of time. The progression of the design of *Earthworks* took over several months and the documentation is a reflection of that. However, one of the disadvantages is that document analysis is limited to examining only written communication (Babbie, 1992). Changes that were made during the work in progress are often not well documented or omitted because a different design might have proven to be more successful. Document analysis might also prove to be problematic in terms of validity, as there might still be the question whether *these* documents *were* a valid measurement of the ideas of the exhibit designers. Every document was written to suit a specific purpose and might not incorporate measurements that are of importance for a subsequent study. However, this technique is, for the just stated reason, the most unobtrusive way of data collection, with the researcher having no effect on the subjects being studied. The concreteness of the material studied gives it a high level of reliability.

### 3.5.5 ETHICAL ISSUES

The previous discussion about the techniques employed to gather data for this investigation highlighted some of the problems concerning the subjective nature of the study. Ethical issues had to be addressed, particularly because of the complex nature of the different methods used. Ethical concerns have to balance between the pursuit of truth while protecting the rights of the informants. One of the difficulties of this research was the various methods of data gathering. Also the researcher had to be very careful to remain objective yet still get a full insight into the situation, while not violating people's privacy. However, the role of the investigator as the primary data collection instrument has been described by Creswell (1994) to contribute in a useful and positive way to a study rather than in a detrimental way. The ethical issues in this study varied for each investigation technique.

For example the position of the interviewer in the interviews was of considerable importance. While it is important for the interviewer to keep the interviews running smoothly, the amount of direction must not violate people's feelings or ideas. Although the direct personal influence of the researcher is removed when questionnaires are conducted, other issues arise like ensuring anonymity that will encourage participants to respond more honestly.

Cohen and Manion (1994) write:

> Whatever the specific nature of their work, social researchers must take into account the effects of the research on participants, and act in such a way as to preserve their dignity as human beings. Such is ethical behaviour. (Cohen and Manion, 1994, p.359)

Ethical issues have been taken seriously in this study and care was taken to ensure informed consent, privacy, anonymity, and confidentiality to the parties involved. The research plan was submitted and approved by the University of Waikato Ethics Committee.

While it was important to receive as much information about the natural setting through *Observation* it was equally important to ensure people's privacy. Participant observation invades the life of the informants, particularly when they reveal sensitive information (Creswell, 1994). The only time people were observed in this study, was when they came to visit the science centre. In public places, however, the presumption can be taken that people are prepared to be observed and that they do not generally see it as an invasion of their privacy (Snook, 1981).

*Interviews* are considerably more invasive, as they demand for a person's opinion on some matter. Justification is only valid if any harm is avoided to the interviewee, which includes minimising deceit and the assurance of confidentiality (Snook, 1981). In this study children and adults were interviewed. For the interviews with children, parents, the schools and the interviewed children had to give written permission for the interviews. They were informed that identities of the children would be confidential as well as that of the schools involved. Students knew that they were tape-recorded and the procedure for the interview was once more explained to them before each interview. They were also informed that they were allowed to leave the interview at any time. Adult interviews complied with the same set of rules.

Participants for the *questionnaires* were selected by matters of convenience. They represent a group of teachers who chose to participate. All the appropriate ethical considerations were taken to respect the rights, needs, values and desires of the informants. Those measures included the participants' right to privacy, confidentiality and minimising the use of deception (Cohen and Manion, 1994; Creswell, 1994).

Document analysis was the most unobtrusive way of data collection in the study. The investigation had to take into account for what purpose the documents were written which limited their level of completeness but no further ethical issues derived from this. Even here ethical considerations had to be taken into account. Documents may include protected information that was not intended to be used for research purposes (Creswell, 1994). This was not the case in this study. The authors of the documents had produced them for wider audiences.

## 3.6 RESEARCH DESIGN

### 3.6.1 INFORMATION PROFILE

Based on the descriptions of Parlett and Hamilton, (1972) the research instruments are developed and adjusted to the particular circumstances. Information was obtained through the suggested use of observation, interviews, questionnaires and document analysis.

Data were sought which reflected students' and teachers' experiences with earth science simulations in a science centre and also data that revealed the intentions of the providers of this earth science resource. The research design traversed three different groups, who were either providing or using the earth science resource.

The teachers:
The feelings, experiences and knowledge of teachers who are learning and/or teaching earth science since the introduction of the new learning strand into the science curriculum was investigated.

The students:
The experiences of students at the earth science exhibition and whether students made subsequent connections between what had they experienced and their existing understanding were investigated.

The resource providers:
This involved an investigation of the intentions and ideas of resource providers and their reactions to earth science simulations.

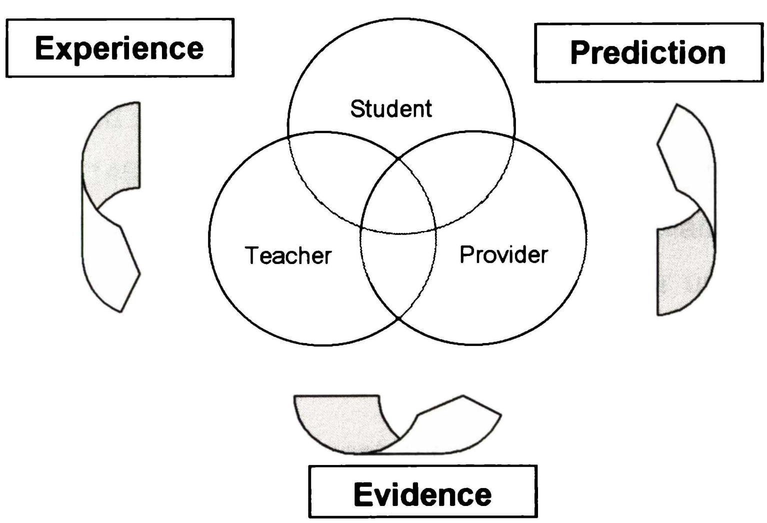



**Figure 5:** Interaction between teacher-, student- and provider group.

The experiences of the individuals of each group influenced not only themselves or their group members but interacted between other groups as well (e.g., teacher – student) and therefore influenced each other's interpretation of the practical experience. Figure 5 shows the ideal interactions between the groups. The extent to which these groups actually interacted with each other depended on the relative influence of prediction, evidence and experience. For this research it is important not to look at isolated groups but to look at the interactions between them in order to represent reality.

## 3.7 THE EARTHWORKS PROGRAMME

### 3.7.1 INTRODUCTION

*Earthworks* – the exhibition, corresponded to selected topics in the 'Planet Earth and beyond' strand of the New Zealand Science Curriculum. Possible interactive exhibits were developed to fit with topics at levels 4 – 6 of the "*possible learning experiences*" and the "*assessment examples*" mentioned for various levels of the Planet Earth and Beyond strand of the curriculum. These earth science topics seemed to have inspired exhibition providers so much that they were also described as "to have lent themselves to interactive exhibits" (Hodder, 1997, p.149). Apart from being interactive exhibits, they were sought to be models and simulations as "models and simulations have long been important means for earth scientists to better understand geological processes" (Hodder, 1997, p.149).

*Earthworks* was the first LEOTC[1] contract to provide an earth science experience for schools. Its principal feature was an exhibition that

---

[1] LEOTC = Learning Experience Outside The Classroom

travelled through four New Zealand's science centres to a visitor audience of some 20,000 school children. *Earthworks* was arranged in themes of clusters of exhibits, targeted at Form 1-4 (level 4-6) students. These corresponded to topics in the earth science curriculum. In addition the exhibition was supported by workshops offered to teachers and a teachers' guide (Hodder, Hume, Jenks and Peters, 1996), in which themes were explained and suggestions made for follow-up activities.

### 3.7.2 THE EARTHWORKS EXHIBITS

The *Earthworks* exhibition consisted of fifteen interactive simulations and six static displays. The exhibits were designed to link to the curriculum aims of the science curriculum.

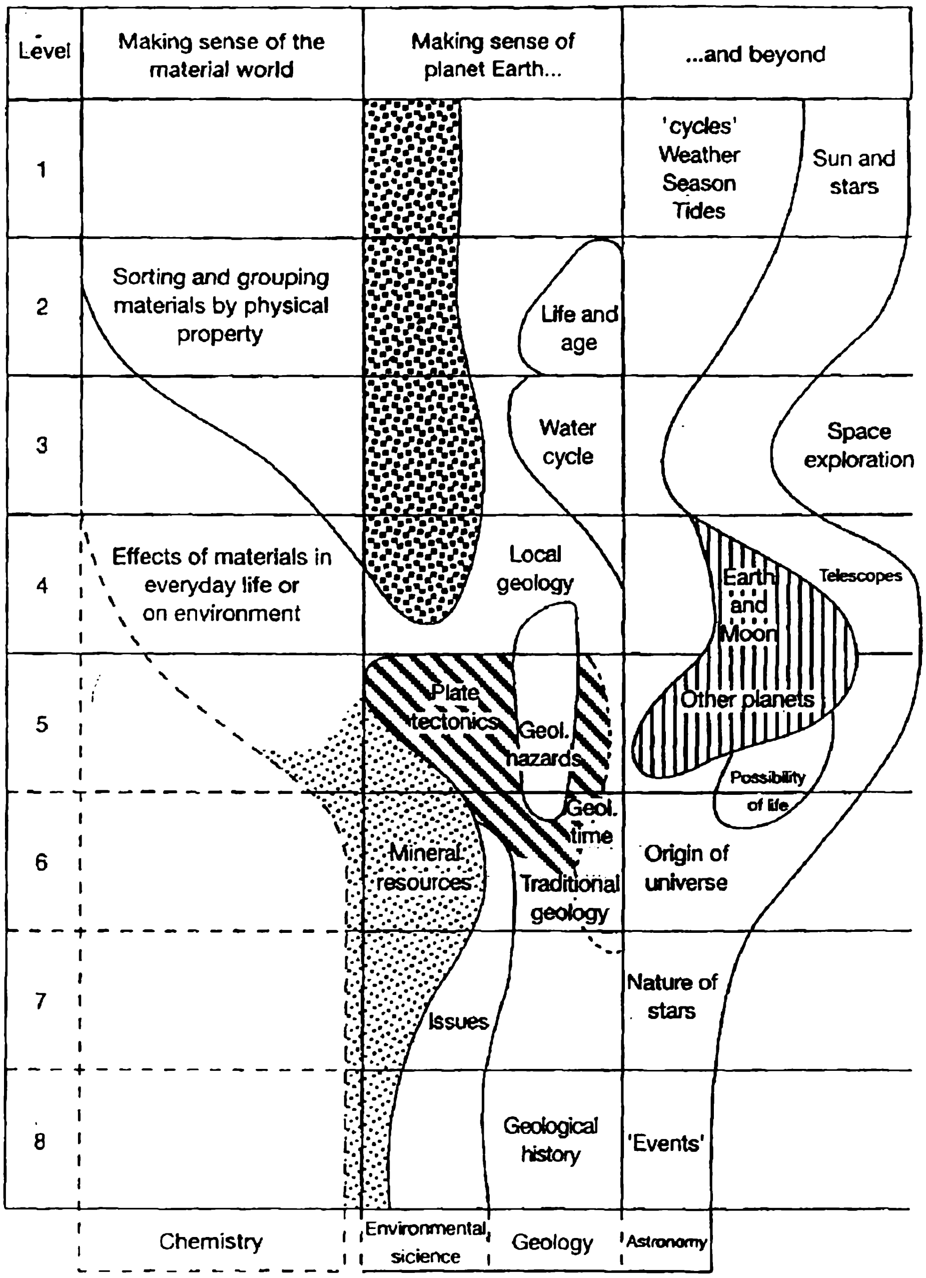



**Figure 6:** Earth science topics in the New Zealand science curriculum corresponding to topics at the Earthworks exhibition (Source: Hodder, 1997)

This presentation of topics (Figure 6) presented at *Earthworks* includes also aspects from the 'Making sense of the material world' strand. At lower school levels the strands emphasise the properties of materials, levels 4-6 are dominated by the presentation of geological processes and higher levels are involved with environmental and social effects of geological processes. The exhibition emphasising geological processes targeted year 4 to 6 students for the development of the exhibition activities (Hodder, 1997).

This study was particularly concerned with simulations; thus, from all the exhibits at *Earthworks* this study focused on the simulations only, defined below.

Simulations invite the learner to participate and they offer visualisation of formal and abstract concepts. Simulations invite exploratory learning, allowing the learner to ask questions and construct answers. Hensgens, Van Rosmalen and Van Der Baaren (1995, p.269) state that simulations "are used to support decisions by experimenting with different scenarios". Simulations offer open inquiry learning environments, which are at times considered by teachers to be too time consuming for teaching prescribed curricula (Roth, 1998). Both Hensgens et al. (1995) and Roth's (1998) definitions came from the perspective that simulation was role playing; however in this study their description is superimposed in the exhibits as simulations because they have the potential to get the 'player' (visitor) involved as if it was in a role play. They offer new learning practices and provide different perspectives on a phenomenon. The activity increases familiarity with both the phenomenon and the practice. Tansey (1971, p.4) writes "simulation takes those who take part out of the role of a spectator and moves them into the role of a player".

Choosing Illuminative Evaluation as a method to examine *Earthworks* simulations should provide research data about:

The processes by which earth science resource providers (exhibit designers) decide which ways were appropriate to teach the subject to non-specialists. *(ACTION)*

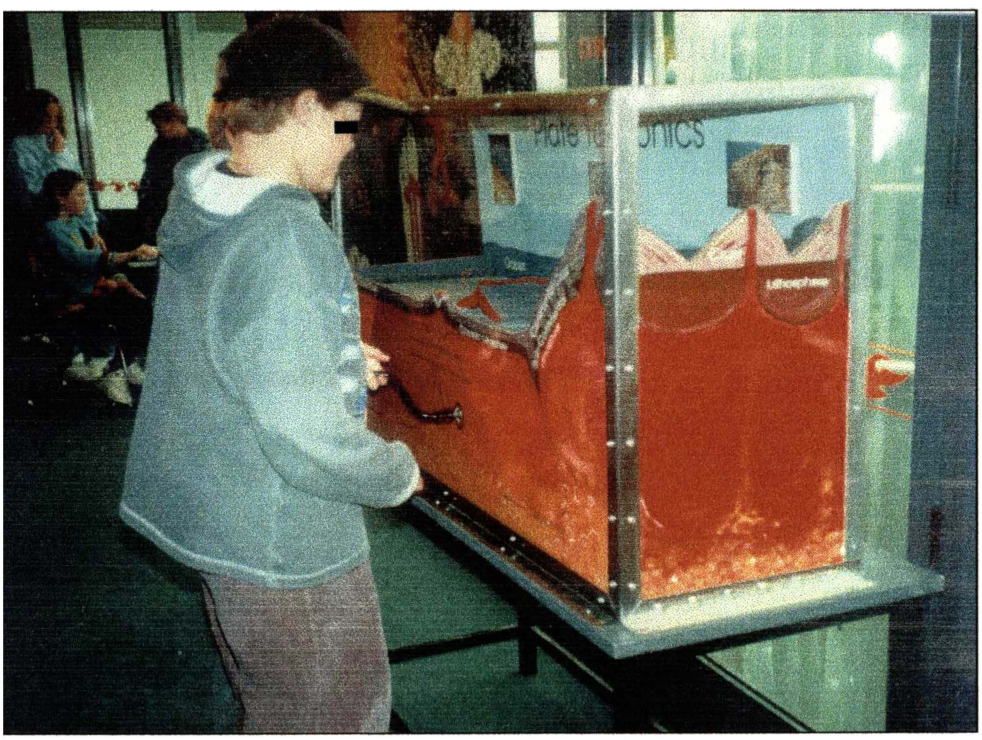
The processes by which educational users (teachers, students) of a purpose-built exhibition perceive earth science simulations. *(REACTION)*

The *Earthworks* exhibits are presented below. The identity of visitors has been concealed.

The *Earthworks* exhibits

I. Mechanical Model of Plate Tectonics

The exhibit shows a three dimensional model of the ocean floor. The ocean floor features painted stripes to suggest magnetic stripes. The 'floor' can be moved with a mechanical crank. The 'sea floor' can 'spread' away from the middle and towards the coast, where it collides with the continent. Through mechanical manipulation a 'subduction zone' and an 'orogenic zone' can be simulated.



**Photograph 1:** Mechanical Model of Plate Tectonics

II. Continental jigsaw

Three big hemispheric globes are covered with rubber foam jigsaws. The three globes represent three periods during the last 570 million years, consistent with the concept of the 'super-continent' Pangea, followed by the 'super fragments', Laurasia and Gondwana. Each jigsaw is painted underneath in a different colour and on top it shows representations of geologic data (fossils, coal, etc.). The jigsaw pieces can be matched up and its size allows several students to work simultaneously at each globe.

**Photograph 2:** Continental Jigsaw

## III. Flume

A 2 m long flume is filled with water that is being drawn off at one end and added at the other to simulate a flowing river. A vertical damming construction at the end can be altered in its angle, enabling different flow rates. The flow of the water is constrained by materials like sand and stones, the positions of which can be manually altered. Through manipulations of obstacles in the river, effects like meandering or erosion can be observed.

**Photograph 3:** Flume

IV. Model Geyser

A large exhibit, featuring three glass containers each fitted with water heating elements. From there, three 1.5-m high glass columns lead up high to a shower tray. The tray is screened in perspex to a further 1m in height, which allows recycling of most of the erupted water. To further simulate the commercial exploitation of geothermal resources, water can be diverted into a little geothermal bath. This action affects the style of eruption, particularly its intensity and the length of time between eruptions.


**Photograph 4:** Geyser

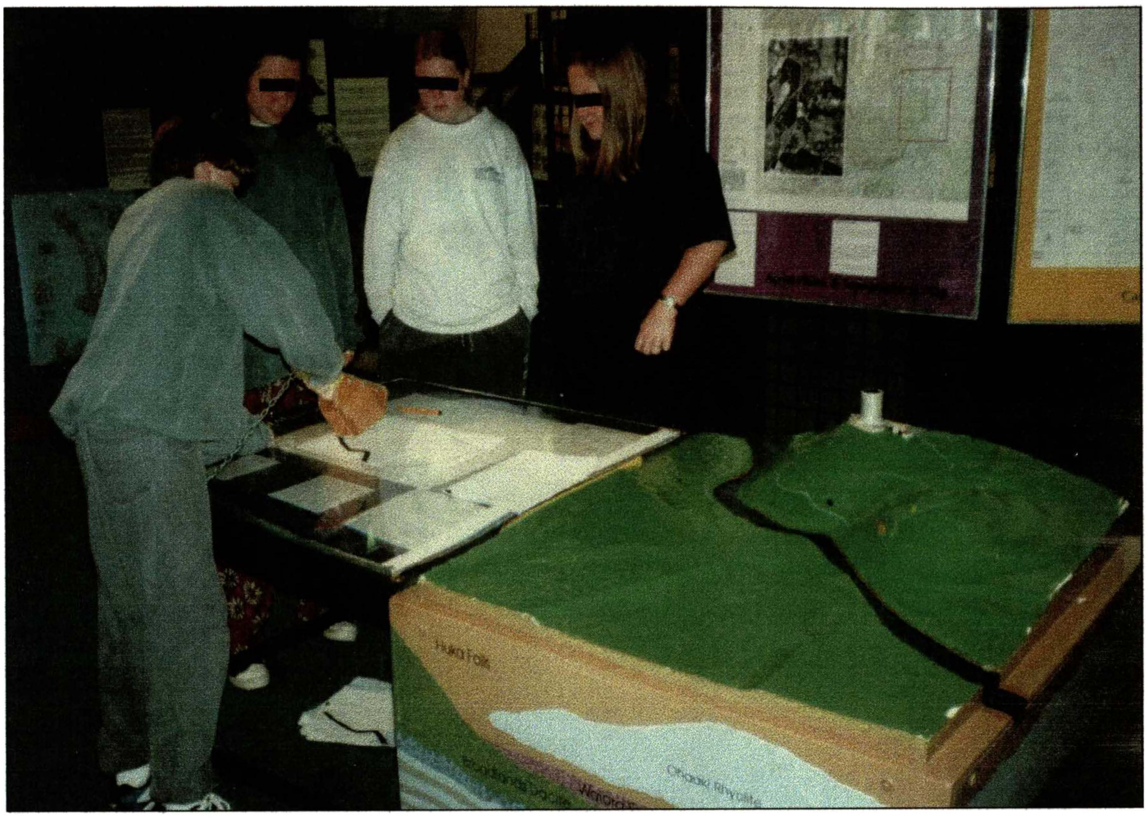
V. "Blow-up" a volcanic eruption simulation

A model of a volcano shows on one side a cross-section, i.e., magma chamber, vent, layering and side vents). Partly compressible foam balls sit in a tube. The top is closed with a stopper. An air pump is used to increase the pressure in the magma chamber up to the point where the foam balls are pushed up through the vent and "blow-up" the stopper. The expelled balls simulate the type of lava flow occurring, depending on the amount of gas pressure that was used.

**Photograph 5:** Volcano

VI. GIS-Ohaaki

This is a three-dimensional model of an actual geothermal field with its geothermal power station. The model is associated with maps of the area. Using a modified 'studfinder', that responded to a conducting foil 'hidden' beneath the map, the geothermal field could be contoured.



**Photograph 6:** GIS-Ohaaki

VII. Buck'n'Ham Palace – an earthquake simulator

A small house with seats facing opposite directions gets 'rocked', in a similar way to vibrations of earthquakes with set magnitudes 6 and 7.7 on the Richter scale. The users can choose the magnitude of the shaking and read about information on earthquakes of that magnitude both in New Zealand and elsewhere in the world (local and international references).


**Photograph 7:** Buck'n'Ham Palace

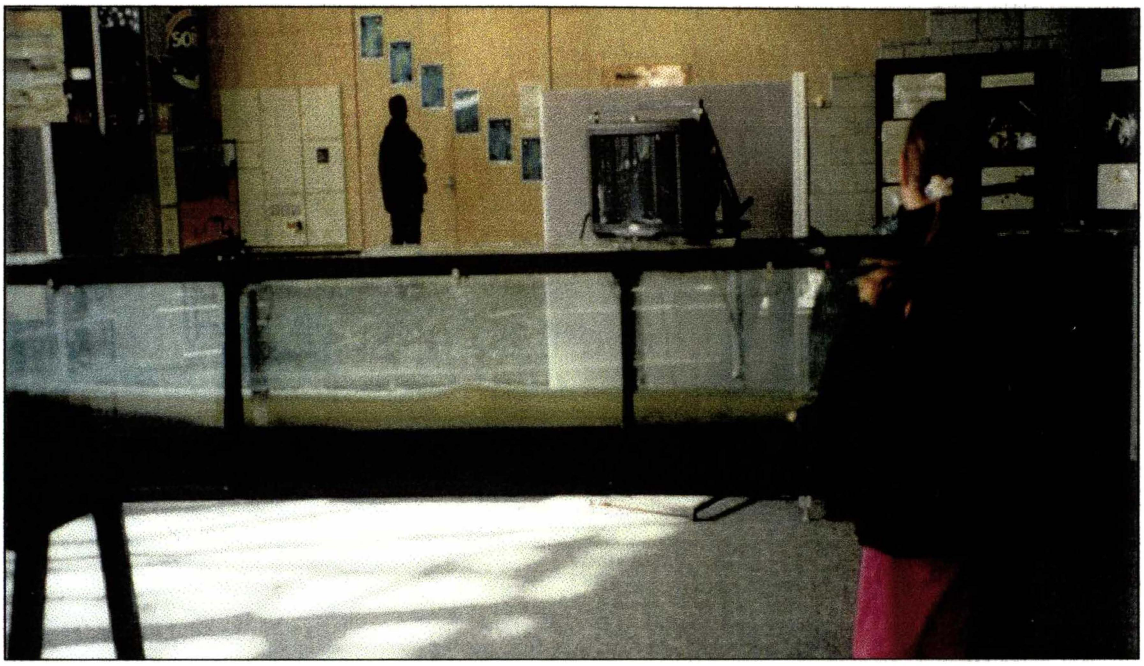
VIII. Shaking table

A shaking table contains trays with different foundation materials (e.g. dry sand, wet sand). The frequency of the vibrations can be altered. Blocks, both discrete and interlocking are provided for students to experiment how structures withstand vibrating forces under different soil-circumstances.

**Photograph 8:** Shaking Table

IX. Wave maker

A water-filled glass tank has a paddle at one end, which is connected to a lever outside to put the water in motion. On the other side a 'continental shelf' is simulated with sand. The slope of the beach can be altered by hand, as well as by the travelling waves that move the sediment.



**Photograph 9:** Wave maker

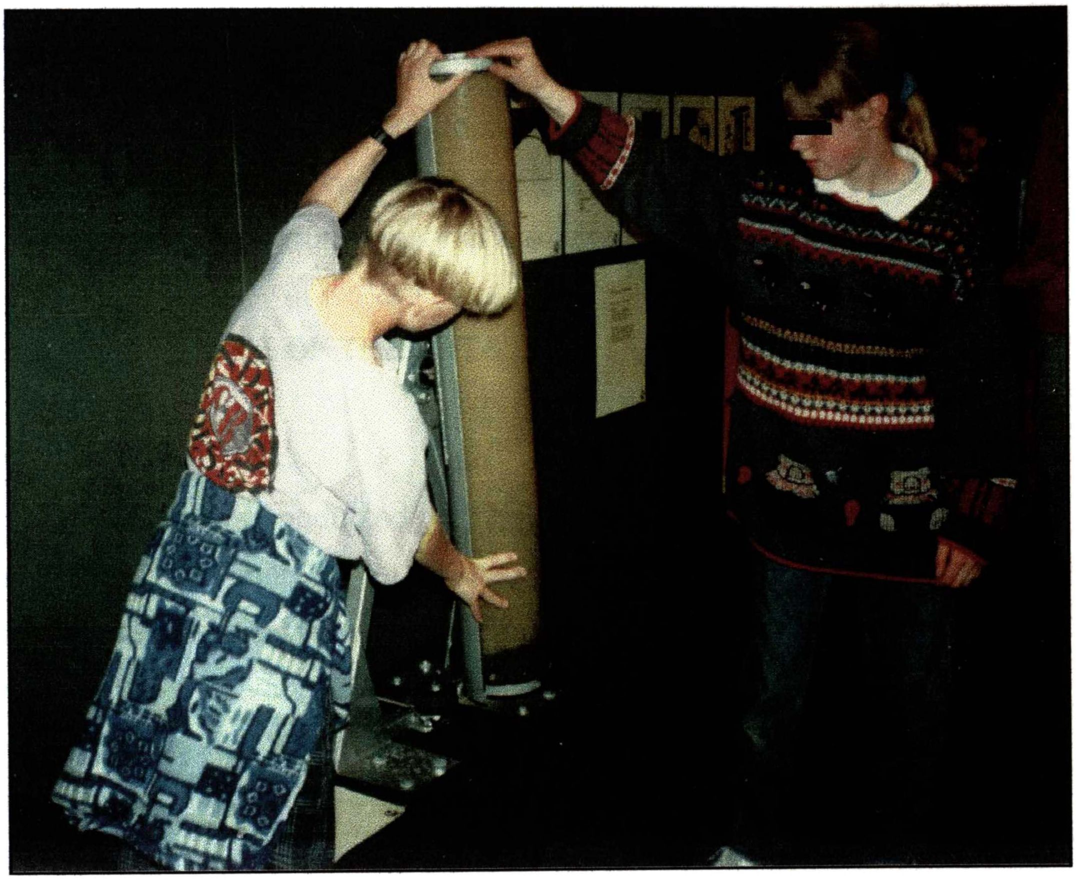
X. Rock Fall

A three-dimensional jigsaw model can be built up of a cliff face. The jigsaw pieces show drawings of fossils or materials. The students can use clues on the 3-D pieces themselves as well as clues given by vertical dioramas featuring the life forms, which were present during the past geological times represented in the cliff.


**Photograph 10:** Rock Fall

XI. Settling down

A water-filled tube sits on a pivot that allows the tube to be turned upside down. This tank also contains granular materials of different sized sand and silt. By turning the tube it can be observed which materials settle first. Disturbances that occur while the grains are settling simulate the effect of currents.



**Photograph 11:** Settling down

### 3.7.3 SUMMARY: THE EARTHWORKS EXHIBITS

This study concentrated on the portrayal of 11 simulations at the *Earthworks* exhibition. Simulations have been defined as offering participation to the learner, concentrating on visualisation of formal and abstract concepts. Exploratory learning is the main concept of this activity. The Earthworks exhibits offer participation to various degrees. All exhibits show geological landforms and /or the processes involved that form them that would not be possible to observe under realistic circumstances. Furthermore the exhibits Flume, Shaking table and Wave maker provide outcomes that are not predictable.

### 3.7.4 SAMPLE SIZE OF THE DATA

<u>*Observation*</u>

Observations were conducted on three days in August, 1996, each day between 10 a.m. and 3 p.m. During this time 118 students and 11 adults were observed at the EXSCITE science centre in Hamilton, New Zealand.

<u>*Interviews with students*</u>

Forty seven students, who had visited the exhibition *Earthworks*, were interviewed between November and December, 1996. The students had visited the exhibition either at the EXSCITE science centre in Hamilton or at the SCMM science centre in Palmerston North prior to the interviews. 28 of the interviewees were female and 19 were male. The students were between eight and thirteen years old.

<u>Age – Gender Distribution:</u>

8 years: 4 female /4 male

9 years: 5 female / 4 male

10 years: Nil.

11 years: 7 female / 2 male

12 years: 7 female / 8 male

13 years: 5 female / 1male

*Interviews with teachers*

Thirty seven teachers were interviewed at the EXSCITE science centre in July 1996. The teachers had not seen the exhibition prior to the interviews. Of the interviewees, 19 were female, 15 were male and three interviewees chose not to declare their gender.

*Questionnaires*

One hundred and fifty six teachers took part in pre-visit questionnaires in July, 1996. Participants came from four New Zealand cities, two in each of the North and South Islands. Of the participants 99 were female, 52 were male and 5 participants chose not to state their gender. Only 26 of those teachers replied in a post-visit questionnaire, 13 of those were female and 13 were male.

*Document Analysis*

Three documents were examined:

*Earthworks* – a guide to the exhibition,

*Earthworks* Maintenance Manual, and

*Earthworks* – the teachers guide

### 3.7.5 TRIANGULATION OF DATA

To enhance validity of the information obtained the research design utilised triangulation, defined by Cohen and Manion (1994) as the use of two or more methods of data collection in educational research. Related information that can be used to support findings, can give a much fuller picture of the situation.

Denzin (1970) identified a typology for triangulation, which is used for this research. Triangulation is characterised by using either (a) the same method on different occasions (triangulation within), or (b) different methods on the same object of study (triangulation between methods). To illustrate their way in which the research methodology proposed to use information in a triangulating way the following table was designed (developed after Cohen and Manion, 1994).

| | | ***Methods*** [*] | | | |
|---|---|---|---|---|---|
| | | Observation | Interviews | Questionnaires | Document Analysis |
| ***Information*** [+] | Academic Achievement | | X | XX | |
| | Individual Viewpoint | X | XX | X | X |
| | On-Site Experiences | XX | X | X | |
| | Historical Perspective | | X | | XX |

**Table 1:** Triangulation of data in this study. X = supportive means, XX = Most effective means (after Cohen and Manion, 1994)

In this study the triangulation approach is used to enhance validity through the use of independent measures with the same objective.

## 3.8 SUMMARY

This chapter on procedure showed the relationship of the researcher with the subject being researched and, based on methodological assumptions, how the entire research process is being conceptualised. The issues of this study are situated within the philosophical and theoretical framework of the investigation by the research design.

One of the key issues of this study was to find appropriate ways to address issues that other studies had failed to show. The aim was to

---

[*] i.e., the research instruments that were used to obtain information
[+] i.e., the different 'levels' of information that was collected

find methods that had been proven successful in other investigations and add to them additional techniques to broaden the spectrum of information.

As the overall framework, Illuminative Evaluation was chosen because it embraces several methods of investigation and allows qualitative as well as quantitative measurements. The four methods that were used to implement Illuminative Evaluation were Observation, Interviews, Questionnaires and Document Analysis.

In this study, Observation focused on the time that subjects spent with an exhibit and concentrated on recording behaviour rather than just tracking the visitors through the exhibition and timing their stops. By comparison with other studies (e.g., Boisvert and Slez, 1995; McManus, 1987), it became clear that time alone is not a valid measurement and had to be compared, at least, with the effect of the social group and associated behavioural characteristics. This method of observing the visitor also gave information about the exhibits and how well they communicated their message.

Additional methods like Interviews sought to gather information about the visitors' experience, but this time from a different point of view. Questionnaires were designed to find out what impressions the teachers had which, again, gave a different view of the same situation. In addition, the Questionnaires also provided information about the background and teaching practices of New Zealand teachers.

The Document analysis provided yet another viewpoint, that of the exhibition providers' position. This gave this study an interesting insight into how earth sciences were presented in a New Zealand science centre.

The combination of the four methods provided complementary information and gave an insight from different perspectives, giving the study validity and reliability.

Chapter 4

# RESEARCH DATA

## 4.1 INTRODUCTION

This chapter, which presents and discusses the data that were collected, is divided into four parts *Observations at Earthworks*, *Interviews with students and teachers*, *Questionnaires* and *Document analysis*. Each of the four parts is further divided into sections that deal with issues such as the setting of the specific study, data analysis and a summary of the findings. The several methods of data collection have been used in this research should lend internal validity to the study. In the following paragraphs I outline each of the four parts.

*Section 4.1, Observation at Earthworks* was one of the key techniques to gain insight into what was happening at the exhibition *Earthworks*. A defined tracking system (or observational protocol) allowed a relatively unbiased impression of the setting. Not interfering with the visitors enhanced that effect. Outcomes from this technique were compared with information that was collected by other means (interviews, questionnaires and document analysis). This section is organised into three key categories; *the visitors*, *the time* they spent at an exhibit and their recorded *behaviour* with the exhibits. Observations of those three categories are presented and discussed.

*Section 4.2, Interviews with students and teachers* provides information about perceptions, experiences and understanding those groups had with the *Earthworks* simulations. All participants were interviewed in group settings and innovative interviewing techniques were employed for interviewing students.

*Section 4.3, Questionnaires* were utilised to gain insight into teacher experiences teaching the subject Earth Sciences and the experience they had at *Earthworks*. This tool was particularly effective for conducting fast and inexpensive research over a large number of participants. Teachers were forthcoming in opinion based questions perhaps due to the confidentiality built into the questionnaires.

*Section 4.4, Document analysis* produced information about the developers of *Earthworks*. This method allowed an insight into the background of *Earthworks* without causing any interference by the investigation. Information was sought about each of the simulations, how the developers related them to geological concepts and their justification for the design. Interference by interpretation is consistent over the exercise and has a limited impact.

Finally *Section 4.5* will summarise the discussion of the data.

## 4.2 OBSERVATION AT EARTHWORKS

### 4.2.1 INTRODUCTION

To focus on observations means that the research is primarily concerned about reporting the process, rather than outcomes or products. So, for example, it was less important for this study to count the number of people who went through the exhibition, than to look at what people did while they were there. The "fieldwork" for this particular study required an observation of behaviour at the exhibition. The primary instrument for data collection and analysis was myself – the mediation of data through a human instrument. This explicit way of reporting of such interpretative research has been previously considered to be "useful and positive" by other researchers (e.g., Creswell, 1994). Even though the settings and protocols were not exactly the same, Creswell concentrated on describing situations that investigate human behaviour. In addition, Jorgensen (1989, p. 15) describes it as a methodology that provides "direct experiential and observational access to the insiders' world of meaning."

### 4.2.2 DATA ANALYSIS

The behaviour of visitors with the exhibits was the main focus of the observation. This was intended to gain a better understanding of the processes of the interaction with the exhibits. The data were organised into three different categories:

- The **type of visitor**,
- the **time spent** with an exhibit, and
- the **5 different behavioural categories**: Looking, Reading, Talking, Hands-on and Reading and Hands-on

To store and organise the information after it was collected, the hand-written notes from the observational protocols were transformed to the computer program Microsoft Access for storage and sorting.

### 4.2.3 TYPE OF VISITOR

Three days in August 1996, were chosen for the observation, on the basis that on those days the exhibition was fully booked by schools. The observations were scheduled between 10 a.m. and 3 p.m. During the three-day observation period, records were taken from 118 individuals, of whom 108 were in group-settings and 10 were individuals. Accompanying parents or teachers (11 subjects) were not included in the number of individuals.

Of the 118 individuals, 16 instances were recorded where subjects did not stop for any exhibit (see Table 2). Subjects, who stopped for exhibits (86%) were mostly from student groups (comprising 76 individuals in 27 groups), followed by students who were accompanied by parents or teachers (20 individuals or 10 groups) and five students who were on their own.

'Not stopping' for an exhibit was characterised as those subjects who were noted as making eye contact with the exhibit but did not choose to come closer to have a look and went on to do something else. Interestingly, all the students who did not stop were in student groups, none of the single students or students who were accompanied by parents or teachers were observed to show that kind of behaviour.

| *Stopped for exhibit: 86%* | *Not stopped for exhibit: 14%* |
|---|---|
| ***Student groups**: 75%*<br>***Student + parent or teacher: 20%***<br>***Single students: 5%*** | ***Student groups**: 100%* |

**Table 2** Distribution of visitors who stopped for exhibits and type of group settings

This observation showed that the majority of visitors who viewed the exhibits were in a group setting. These findings are not surprising considering that students feel comfortable in group settings and many of the exhibits invited multiple interactions. Groups with parents or teachers were generally less often observed. Typically, adults accompanied the student groups but because the adults played a supervisory role, rather than a participatory role, the groups observed with adults were smaller in number.

### 4.2.4 TIME SPENT WITH AN EXHIBIT

The time that a visitor spent with an exhibit was an important measurement as it could indicate how intensively a subject interacts with an exhibit (Geyer, 1995; Falk, 1983). The time that people spent with an exhibit, whether they stopped for it (86%) or not (14%) was measured in seconds. The five percent of single students (Table 2) were not recorded to stop for an exhibit for more than 1 minute. If an individual of a group decided to leave the group earlier, the time was recorded as an individual time, so that the overall time of the group was not affected.

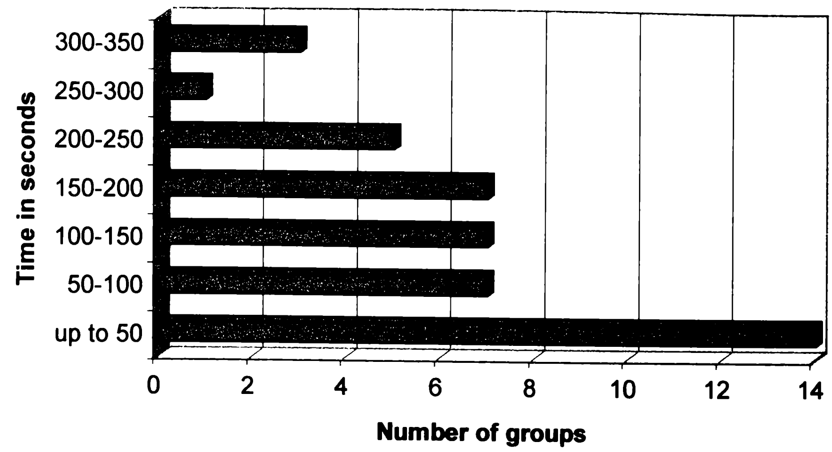



**Figure 7:** Time groups spent with an exhibit

Figure 7 shows the length of time groups of visitors (each single student visitor was counted as a group for this purpose) spent with an exhibit. A decision was made to show the viewing time in relationship to the groups and not the individual subjects. This derived from the observation that subjects of a group would stay within that group for the whole viewing time and individuals on their own were hardly ever observed. Students who were on their own were only observed five times. Within the discussion, the number of individuals is shown to complement the group data. Figure 7 shows a high frequency of groups (accounts for 14 groups or 37 individuals) that spent up to 50 seconds with an exhibit. Nearly half of the observed people viewed exhibits for between 100 and 200 seconds (14 groups or 41 individuals). The number of groups decreases very rapidly when it comes to viewing times between 250 and 300 seconds (1 group or 5 individuals). Viewing times of up to 350 seconds show a slight final increase in the number of groups for (3 groups or 12 individuals). These findings seem to correlate well with another study that looked at viewing times of visitors (Geyer, 1995). Geyer's study showed a very similar tendency in viewing time with the difference that visitors in her study had viewing times of only up to 200 seconds. The percentage of those who were observed with viewing times of more than 120 seconds was very small. Her study observed visitors that were looking at static displays.

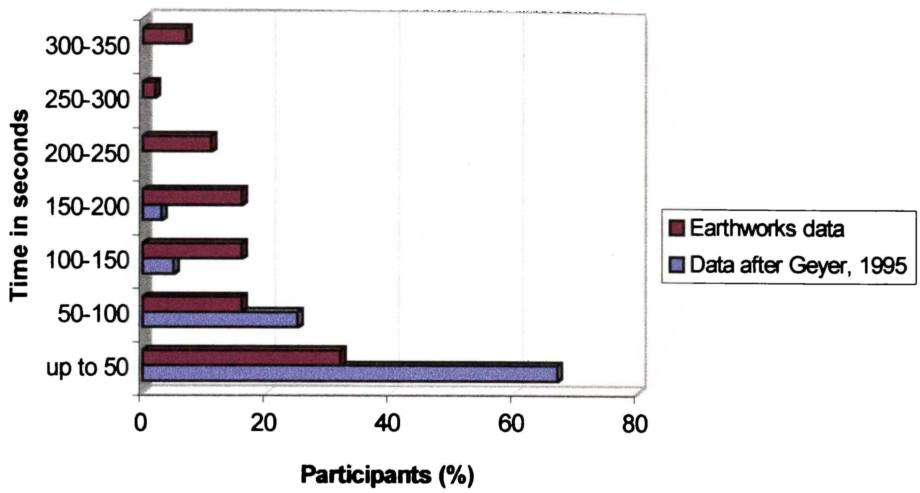



**Figure 8:** Viewing time of Earthworks data compared with study by Geyer (1995)

Figure 8 illustrates how the data from Geyer's study of static displays compares with this study of simulations. More than half of the observed subjects in her study spent less than fifty seconds with an exhibit whereas in this study it was just over 30 percent. The declining trend in viewing time is similar for both observations; however, viewing times in this study were much longer. Observations in the Geyer study show only 8% of visitors viewed for a period of more than 100 seconds and the maximum viewing time was 200 seconds. This study showed over 50 % of visitors were observed with viewing times of between 100 seconds and 350 seconds. Geyer states that she observed another 1.6% of visitors with viewing times of up to 547 seconds, which she neglected in her study. Even if that last group of long viewing times had been included, it still shows the vast majority of visitors within the group observed for less than two minutes. This suggests that interactive exhibits might nearly double the viewing time.

### 4.2.5 VIEWING TIME FOR PARTICULAR EXHIBITS

In the previous section, the time that students spent in the exhibition were shown by comparing viewing times. It seemed appropriate to investigate if some exhibits invited and, in fact, held visitor attention longer than others. The viewing times for each exhibit showed that some exhibits would generally induce people to stay longer (e.g., Continental Jigsaw, Wave maker) than others (e.g., GIS – Ohaaki). The following graph (Figure 9) shows the distribution of viewing times for the exhibits.

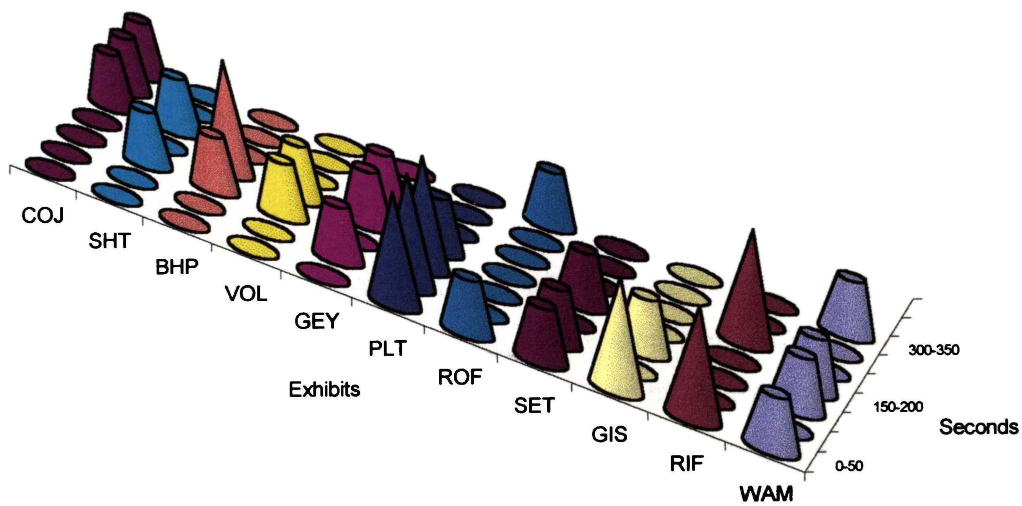



**Figure 9:** Viewing times for each simulation (WAM –Wave maker, RIF –River flume, GIS –GIS-Ohaaki, SET –Settling tube, ROF –Rock Fall, PLT –Plate tectonics, GEY –Geyser, VOL –Volcano, BHP –Buck'n'Ham Palace, SHT - Shaking Table, COJ –Continental Jigsaw). The cones in the diagram equal the number of groups that viewed exhibits (e.g.: half cone = one group, peaked cone = two groups).

Wave Maker (WAM)

Viewing times at the Wave Maker varied considerably, with viewers spending either a very short or very long time with the exhibit and few viewers spending intermediate times. Students who spent only a short period of time with the Wave Maker typically had a quick try and left again. They would move the lever once or twice back and forth look at the wave that is being produced and leave (viewing times up to 50 seconds). Longer viewing times (100-200 seconds) were typically achieved when students engaged in other related activities. For example they would put their arm in the water at the left end of the Wave Maker to alter the slope of the beach or they would read some information on tsunamis located on the right end of the exhibit. Longer engagements that were measured (up to 350 seconds), were typically a combination of the above. Students would move around the exhibit and view changes along the tank floor (transportation of sediments).

River Flume (RIF)

The exhibit River Flume showed a similar distribution of viewing times to those for the Wave Maker. Students either came and had only a short look at the exhibit (viewing times up to 50 second) or they would engage in a more detailed investigation of what could be done with this exhibit, which subsequently resulted in longer viewing times (up to 250 seconds). Typically they would then start to alter the riverbed by moving some of the rocks provided or they would change the flow rate of the water. Observations with this exhibit, in particular, clearly showed that time reflected the level of discovery and engagement.

GIS – Ohaaki (GIS)

Observations of this exhibit showed that students were not engaged with it for longer than 150 seconds. Often it appeared that students were unsure about the purpose of the exhibit and even when they became actively involved it seemed that they did not exactly know what to do. For example students were not observed tracing the outline of the geothermal area on a piece of paper (maybe due to not having read the instructions). However, some tracings from previous days, (on which observations had not been made) were with the exhibit, which indicates that some visitors had obviously understood instructions and perhaps the purpose of the exhibit. It is only speculation on the type of groups or visitors from which these came.

Settling Tube (SET)

Viewing times between 50 and 200 seconds were observed. This exhibit was one of those that was well recalled in later interviews (see section 4.3.2). However, it did not show evidence that students were engaged with it for very long. This is most likely because of the limitations of what could be done with the exhibit. The glass tube could be tipped and then they would have to wait only for a short while for most of the sediments to settle. Longer engagements were only observed when students also read about information on the label, which therefore increased their total engagement time.

Rock Fall (ROF)

The exhibit Rock Fall showed two extremes in viewing times. In the first extreme a group with a teacher approached the exhibit. One boy stepped out of the group and started to play with the jigsaw, but was quickly told by the teacher not to touch anything. The group left shortly after that without any further interaction (total time: 35 seconds). In the other extreme, a group of students approached the exhibit and had obviously a lot of fun rebuilding the rock face. They put on hard hats that were supplied (for a more quarry-like ambience) and showed a lot of interaction during the whole time of engagement (total time:

420seconds). The reason why the teacher asked the student in the first case not to touch the exhibit is unknown.

Plate Tectonics (PLT)

This exhibit engaged students for up to 200 seconds and the likely maximum time somebody could be involved with it was certainly determined by what could be done with this exhibit. Students could move the conveyer belt in one or other direction, which did not take very long. Some subjects were observed to watch carefully all the changes in the exhibit while they were turning the crank. In other cases students were observed to turn the conveyor belts only into the "subduction and mountain building " positions and then leave the exhibit.

Geyser (GEY)

This exhibit was one of those that were commonly viewed for more than 50 seconds. Viewing times spanned from 50 seconds to 250 seconds. The long viewing time was initially unexpected considering the low level of interaction the visitor could have with the exhibit. However this long observation time was a result of the duration of a full heating cycle, which took a minute or more. Visitors were also invited to look at this exhibit from two levels which had an effect on how long they would spent with it. This time could be further expanded if subjects chose to "exploit" the source by filling up the stylised hot pool, which would increase the time until the next Geyser eruption.

Volcano (VOL)

The volcano exhibit was observed to have viewing times between 100 and 200 seconds. The duration can be mostly attributed to the fact that this exhibit invited a lot of activity: stuffing the magma chamber, putting the cork in and pumping the exhibit up until it "exploded". The viewing was further increased if several students in a group wanted to have a turn.

Buck'n'Ham Palace (BHP)

Students were observed to spend 100 to 200 seconds with the earthquake machine. This exhibit was noticed to be one of the most popular exhibits, the time one person spent in the Buck'n'Ham Palace was often limited by other students who also wanted to have a turn, thereby skewing the viewing time downwards.

Shaking Table (SHT)

Students were observed to spend between 100 and 250 seconds with this exhibit. It involved various activities like placing model houses in sand trays, turning on the shaking device, which included an option to alter the frequency. Students could build different terrains (hills, flat land) and had also the option of trying out different building materials (wet and dry sand). The variety of options increased the number of different experiences they could have and obviously influenced the time spent with the exhibit.

Continental Jigsaw (COJ)

It was interesting to observe that this exhibit would engage subjects for at least 250 seconds up to 350 seconds. When students started with the three dimensional puzzle they would always aim to finish it. Observations showed that students were very enthusiastic about the activity.

### 4.2.6 SUMMARY: TIME AND EXHIBITS

Students that were observed at *Earthworks* spent up to 350 seconds with the exhibits (see Figure 7). Compared with studies that measured viewing times of static exhibits (Geyer, 1995), these findings suggest that interactive exhibits could double the viewing time.

Exhibits which engaged students for long periods of time (more then 300 seconds), were those that offered active interaction to quite a high degree (e.g., Continental Jigsaw, Rock Fall, Wave Maker). The nature of those interactions were recorded as being meaningful, as the students were interacting with the exhibits, often pausing for a result and then modifying their actions or repeating them depending on the students response. However, even exhibits that offered fewer interactions had high viewing times (e.g., Geyser up to 250 seconds). The reason for the long viewing time might be because of the long heating cycle of the hot water and that the exhibit itself offered a spectacular display when it erupted, so it was therefore perceived to be worthwhile waiting. Each simulation had viewing times of up to 150 seconds, which is quite a high result compared to Geyer's (1995) findings. The exhibit that showed the shortest viewing time (between 50 and 150 seconds) was surprisingly one that was offering a high degree of activity based experience. The low outcome in viewing time for the exhibit GIS-Ohaaki, might not be directly related to the degree of interaction but have some other reasons, perhaps because the exhibit did not communicate its purpose well enough. The viewing time for some exhibits ranged from up to 50 seconds to 300, while other exhibits showed viewing times of at least 150 seconds (Continental Jigsaw, Shaking Table, Buck'n'Ham palace and Volcano). All of those exhibits with viewing times of at least 150 seconds offered more activity, so once students made contact the exhibits seemed to have enough "holding power".

### 4.2.7 BEHAVIOURAL CATEGORIES

As an important part of the observation, behaviour of students was recorded. The observational protocol identified five behavioural categories either singly or in combination on which visitors' interaction with the exhibits at Earthworks was judged.

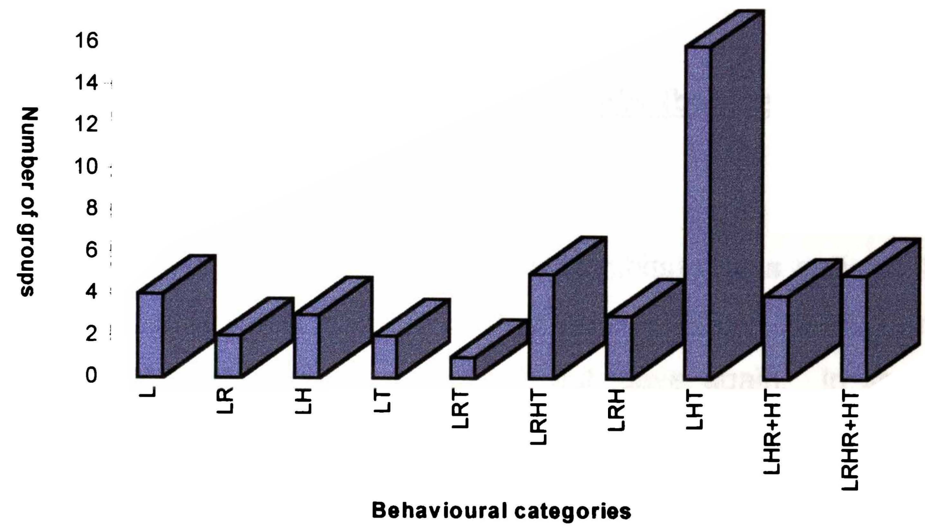



**Figure 10:** Behavioural categories by the number of groups (L = Looking, R = Reading, T = Talking, H = Hands on, R + H = Reading and Hands on)

Figure 10 illustrates the relationship between the behavioural categories and the number of visitors. The graph uses the same abbreviations for the behavioural categories as were used in section 4.2.5. The combination of Looking, Hands-on and Talk certainly far exceeded the other combinations. This observation is supported by findings stating that "groups containing children constituency are characterised by ... long conversational periods within the group with a tendency towards longer visits" (McManus, 1992, p.170). Each category that was observed on its own or in combination (as listed in Figure 10) is discussed below.

Looking (L) – only 9% (up to 40 seconds)

In 9 % of all observed subjects, only "looking at exhibits" could be noted. In particular, three exhibits (out of four with category L only) were not further approached, but several visitors (17 out of 124) had a look at the exhibit and then decided to go somewhere else. One exhibit was looked at and the student came closer. An explainer came and told her what to do, but she decided to go somewhere else, without either responding to the explainer or initiating any kind of noticeable physical involvement.

Combination: Looking and Reading (L, R) – 4% (between 35 and 43 seconds)

In 4 % of the observations (at two different exhibits) it was noticed that students would make their first eye contact with the object, get closer to the exhibit's label and appeared to read, but leave again. In several cases, single students viewed the exhibits with the purpose of filling in a worksheet.

Combination: Looking and Talking (L, T) – 4% (between 72 and 197 seconds)

This behavioural combination was noticed only with one of the exhibits: the geyser. In several cases groups of students would spend quite a considerable amount of time with the exhibit, but they were not observed to read information or to try out the exploitation button.

Combination: Looking and Hands-on (L, H) – 7% (between 20 and 35 seconds)

This combination was observed with single students and student groups, at three different exhibits. Combinations of those behavioural categories resulted in short viewing times. A single student spent up to 35 seconds with the Settling tube, groups of students were observed with the GIS-Ohaaki exhibit (27 seconds) and the River flume (20seconds).

Combination: Looking, Reading and Talking (L, R, T) – 2% (200 seconds)

There was only one example of this combination. It was observed with a student group viewing the Geyser. They did spend a considerable amount of time at the exhibit (200 seconds) but were not observed to become more active. The students were watching a full heating cycle, which explains the long time (200 seconds). The reason why they did not choose to push the exploitation button is unknown but it may be simply that they did not see it. The observation that this exhibit did not include active involvement is also because the exhibit could not invite much hands-on activity.

Combination: Looking, Hands-on and Reading (L, H, R) – 7% (between 20 and 60 seconds)

Looking, Hands-on and reading was noticed usually with single students. In just one instance was a student group actively engaged with an exhibit while not talking with each other. In all cases viewing times were not observed to exceed 47seconds and typically students had worksheets. In the case of the group situation only one student was observed to put hands on the exhibit while the others watched (Wavemaker – 20seconds).

Combination: Looking, Hands-on and Talking (L, H, T) – 36% (between 30 and 350 seconds)

This activity was the most observed one. It involved most of the exhibits, engaging student-groups as well as groups with parents or teachers. The only two exhibits where a behavioural combination like the above was not observed were GIS-Ohaaki and the Geyser. For all the other exhibits it was the most likely behaviour observed. This combination was noticed with viewing times between 30 seconds and 350 seconds.

Combination: Looking, Reading, Hands-on and Talking (L, R, H, T) – 11% (between 80 and 170 seconds)

This combination of behavioural activities was observed with groups only and was also one of the more prevalent combinations. The minimum viewing time that was observed was 80 seconds. This combination was observed at four different exhibits.

Combination: Looking, Hands-on, Reading and Hands-on, Talking (L, H, R + H, T) – 9% (between 124 and 325 seconds)

This combination of behavioural categories was common among groups of students and was twice observed with the exhibit Buck'n'Ham Palace. It was distinguished from the previous behavioural category (L, R, H, T) because students were re-doing their activity but supported now by instructions that they had read from the label. This observation was made with exhibits Continental Jigsaw, the Buck'n'Ham Palace and the Wave maker.

Combination: Looking, Reading, Hands-on, Reading and Hands-on, Talking (L, R, H, R + H, T) – 11% (between 124 and 325 seconds)

This was a combination of all listed categories, including separated activities like reading and hands-on activity, which were also observed combined at a later stage. Within this group was a large number of students who were either accompanied by teachers or their parents. For this observation combination there seemed to be a certain sequence of behaviour, which might be related to an accompanying adult's domination of the behaviour structure within the groups.

### 4.2.8 SUMMARY: BEHAVIOURAL CATEGORIES

The five behavioural criteria are applied to those observations where students stopped for an exhibit. The longer spent time with an exhibit, the more activities were likely to be involved.

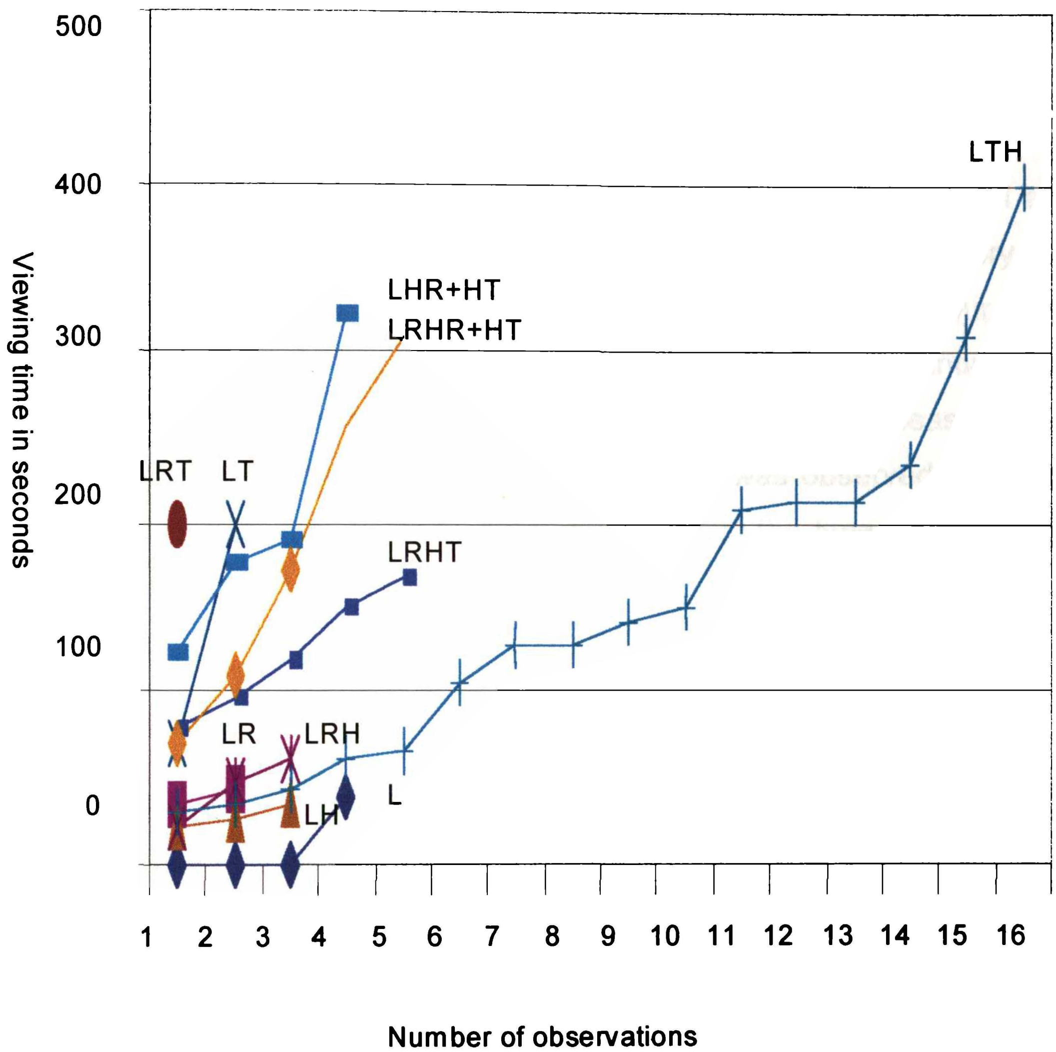



**Figure 11:** Behavioural categories and viewing time (L = Looking, R = Reading, T = Talking, H = Hands on, R + H = Reading and Hands on)

Figure 11 shows that behavioural criteria of Looking only or Looking combined with either Hands-on or Reading would never exceed viewing times of 50 seconds (measured maximum: 43 seconds). The combination of Looking and Talk on the other hand showed minimum times of 72 seconds up to 197 seconds. This implies that activities that include talking may enhance the time spent with an exhibit. The majority of observations showed that when Talk was included viewing times were at least 50 seconds or more (except for three observations within the group

L, H, T). Talk would be therefore one of the most observed as well as one of the most time-enhancing factors. However, this category is associated with being group-related. The most observed behaviour was the combination Looking, Hands-on and Talk (L, H, T), accounting for 36% of all observations. L, R, T was observed as the least likely combination of criteria. However, in one case it was observed that the viewing time was 200 seconds which might mirror the time - enhancing effect of Talk.

### 4.2.9 CORRELATION BETWEEN THE BEHAVIOURAL CATEGORIES

By taking a closer look at the different categories some interesting comparisons can be made. The behavioural category "Looking" appears to be strongly linked with the category "Hands-on" and "Talk". Whereas combinations of "Looking" with either "Hands-on" or "No Hands-on" as well as the combination of "Looking + Talk" with "No Hands-on" always scored below the 10% margin.

| | Hands-on | No Hands-on |
|---|---|---|
| Looking | 7 % | 9 % |
| Looking + Talk | **36 %** | 4 % |

**Table 3:** Behavioural category: L-H-T

Table 3 shows subjects who were engaged in those three activities, two of which are highly active (T+ H), showed a huge increase compared to people who showed one or two behavioural criteria only.

| | Reading | No Reading |
|---|---|---|
| Looking | 4 % | **9 %** |
| Looking + Talk | 2 % | 4 % |

**Table 4:** Behavioural category: L-R-L+T

Even though there were three behavioural criteria combined (Looking – Reading – Talk) the percentage of people who were observed doing this was one of the lowest (2%). Table 4 shows that this combination was even exceeded by L+R only (4%) and L+T only (9%). One obvious reason for this is that the criteria "Talk" can appear only within groups. On the other hand, groups are, on average, more active than single subjects are. The mixture of a group activity-based behaviour like "Talk" combined with the more passive criteria "Reading" singles out a very small group of participants.

| | Group (Total 80%) | Single subject(Total 20%) |
|---|---|---|
| Looking + Talk | **4.4%** | not applicable |
| Looking + Talk + Reading | **2.2 %** | not applicable |
| Looking + Reading | 0% | **4.4%** |

**Table 5:** Behavioural category compared with group setting

Table 5 compares activities "looking", "talking" and "reading" of single subjects with group related behaviour and shows that only single subjects would look at an exhibit and read. They would not talk for reasons that were mentioned above. Groups were not observed to have only looked and read labels of an exhibit. Even though this observation might not be surprising there is a potential implication for the design of exhibits, in that people in groups prefer to talk to each other about the exhibit than to read about it.

The combination of "Reading" pause "Reading and Hands-on" and "Talk" describes a sequence of events. The observation showed that students would read labels from an exhibit, afterwards they would interact with the exhibit and would read while doing so. This activity was distinguished from "Reading" only, because it highlighted that in other cases students would do those activities one after the other (e.g., Student looks at exhibit then reads label and after that puts hands-on: L, R, H). However, all subjects that were observed with the combination of "Reading" pause

"Reading and Hands-on" and "Talk" were groups (student groups or students accompanied by teachers or parents).

When the activity "Reading" was correlated with "age" and "type of exhibit" it showed that "Reading" certainly depended on the age of a student. However, it was interesting to see for which types of exhibits students would read instructions and explanations and which not. The chart in Figure 12 only distinguishes between primary school (S1) and secondary school children (S2) and is based only on estimates. In four cases there were no records of students being observed reading labels of exhibits These exhibits were; River Flume (RIF), Rock Fall (ROF), Shaking Table (SHT) and Volcano (VOL). Observations showed that those exhibits triggered active interaction but never any "Reading" activity. One explanation could be that the purpose or function of the exhibit was so obvious that they didn't need to read. There were no statistically significant differences for exhibits in their viewing time, whether that time included a "Reading" activity or not.

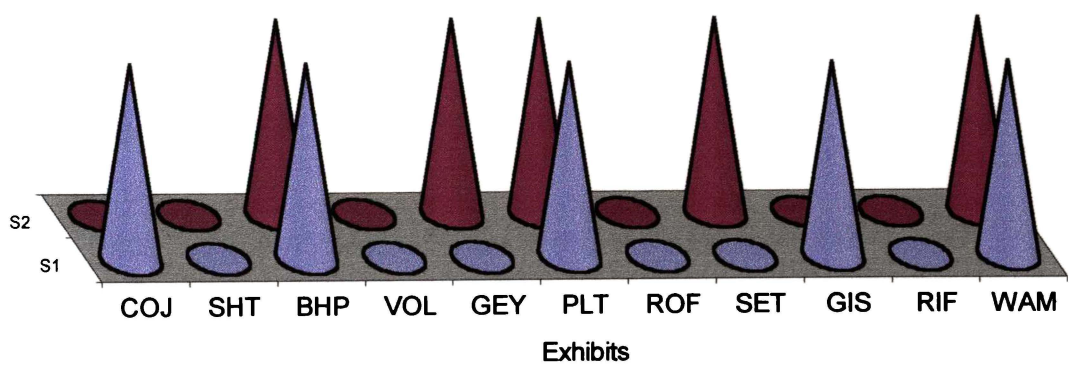



**Figure 12:** Reading of labels for Primary and Secondary School Students.

COJ –Continental Jigsaw, SHT - Shaking Table, BHP –Buck'h Ham Palace,
VOL –Volcano , GEY –Geyser, PLT –Plate tectonics ,
ROF –Rock Fall , SET –Settling tube , GIS –GIS-Ohaaki ,
RIF –River flume, WAM –Wave maker

The cones in the diagram stand for students that read exhibits (e.g.: cone = 'read', no cone = 'not read'). S1 = Primary school students, S2 = Secondary school students.

The chart shows that both students younger (S1) and older (S2) do read labels of some exhibits. This was the case for exhibits Buck'n'Ham Palace (BHP), Wavemaker (WAM) and the Mechanical Model of Plate Tectonics (PLT). For the following exhibits only older students read the labels: Settling Tube (SET) and Geyser (GEY). The models GIS-Ohaaki (GIS) and Continental Jigsaw (COJ) appeared to be read only by younger students. This was interesting to observe, especially because there did not seem to be any obvious reason for this observation (e.g. positioning of the labels). One reason might be that for the younger students the purpose of the exhibits Settling tube and Geyser were self-explanatory, however they may have had problems with understanding the purpose of GIS-Ohaaki and Continental Jigsaw. Older students seemed to read the labels for additional information on the subject, in particular if they had to fill in a worksheet. The following section examines a possible association between the age of the students reading labels on exhibits and the reading difficulty of the labels that were written for the exhibits.

"Readability" and "Exhibit" and "Age"

Using the "Noun Frequency Method" of Elley (1975) the instructions and labels for the exhibits were determined for their readability to specific age groups. Elley (1975) included a table to match the readability ratings with appropriate reading ages. Table 6 is adapted for this study and includes the ratings for the Earthworks exhibits.

| Mean Noun Frequency Rating | Approximate Age Range | Text for Earthworks exhibit |
|---|---|---|
| Below 3.2 | Up to 8.5 years | none |
| 3.2 to 4.0 | 8 to 9.5 years | none |
| 4.0 to 4.8 | 9 to 10.5 years | none |
| 4.8 to 5.2 | 10 to 12 years | SHT (5.07) |
| 5.2 to 5.6 | 11 to 13 years | GIS (5.23)<br>VOL (5.23)<br>WAM (5.33) |
| 5.6 to 6.0 | 12 to 14 years | COJ (5.95)<br>RIF (6.0) |
| 6.0 to 6.4 | 13 to 16 years | BHP (6.07)<br>ROF (6.33) |
| Over 6.4 | 15 years and over | GEY (6.76)<br>SET (6.88)<br>PLT (6.95) |

**Table 6:** Mean noun frequency rating for *Earthworks* exhibits

It is noticeable that none of the Noun Frequency scores are below 5, with the lowest readability score for the exhibit Shaking table (SHT) at 5.07. The highest score of 6.88 and 6.95 was found for the exhibits Settling tube (SET) and Plate Tectonics (PLT).

The table shows that according to the Noun Frequency Method rating there were no texts explicitly written for students younger than 10 years. These scores were compared with the behavioural category "Reading" and the age of the students. Table 7 compares the Noun Frequency rating and whether exhibits were observed being read or not. The two categories could be linked with 52 students (out of 124).

| Approximate Age Range based on Mean Noun Frequency Rating | Rated Text for Earthworks exhibit | Observed Reading Activity (Yes/No) | |
|---|---|---|---|
| | | Primary (S1) | Secondary (S2) |
| Up to 8.5 years | none | – | |
| 8 to 9.5 years | none | – | |
| 9 to 10.5 years | none | – | |
| 10 to 12 years | SHT (5.07) | no | no |
| 11 to 13 years | GIS (5.23) | Yes | No |
| | VOL (5.23) | No | No |
| | WAM (5.33) | Yes | Yes |
| 12 to 14 years | COJ (5.95) | Yes | No |
| | RIF (6.0) | No | No |
| 13 to 16 years | BHP (6.07) | Yes | Yes |
| | ROF (6.33) | No | No |
| 15 years and over | GEY (6.76) | No | Yes |
| | SET (6.88) | No | Yes |
| | PLT (6.95) | Yes | Yes |

**Table 7:** Reading activity compared with mean noun frequency rating

Older students were observed reading texts rated as more difficult. However, younger students chose to read labels even if they were rated above their age level.

Quite highly rated texts (age 13 to 15+) for the Buck 'n' Ham Palace (BHP) and the Plate Tectonics Model (PLT) exhibit were observed to be read by both the younger and the older students. Neither younger students nor older students read the lower rated text for exhibit Shaking table (SHT).

These findings suggest that the motivation for reading a label on a given exhibit is driven more by the agenda of the visitor (e.g., worksheet) and/or the visitor's perceived need to read the label to gain an understanding of the exhibit's purpose, rather then the reading level of the text. This is interesting particularly because although there is a lot of literature about labels (e.g., McManus, 1989) that reports about how to produce good labels, this study suggests that reading might be more triggered by how appealing an exhibit is rather then the label itself. A study by Diamond (1980, in McManus, 1992) found that adult and child groups were often observed not to read labels before they began to play with the exhibit and were using texts only as a "last resort" (p.171).

### 4.2.10 SUMMARY OF OBSERVATIONS AT EARTHWORKS

The observational data are the focus of this chapter. The behaviour of visitors at *Earthworks* had been categorised and described, together with the time they spent with exhibits.

Exhibits that were noisy like the Buck'n'Ham Palace or visually impressive like the Rock Fall exhibit attracted visitors' attention. Visitors stayed for longer periods of time with those exhibits. Compared to studies that tracked visitors viewing time with static exhibits (e.g., Geyer, 1995) this study showed that visitors would spend longer times with the interactive simulations at *Earthworks*. Viewing times for many exhibits were at least between 50 seconds and 150 seconds (six exhibits out of eleven) and four exhibits were viewed for at least 150 seconds. Those exhibits that were observed having long viewing times offered a lot of activity, which seemed to increase the holding power of the exhibit. Longer viewing times were usually achieved when visitors engaged physically with an exhibit as well as having conversation with each other. This was also the most observed behavioural combination.

Talk, a group dependent behaviour, always increased the viewing time compared with other behavioural combinations of the same number, e.g.: LT = 72 –197 seconds, LH = 20 – 35 seconds, LR =35 – 43 seconds. The combination L,H and T proved to be the most observed combination of behavioural activities with viewing times of up to 350 seconds.

Visitors were also observed reading instructions and explanations of exhibits. An assessment of the difficulty of the reading material showed that older students were more likely to read the more difficult texts however, younger students were also observed reading equally difficult text. An assessment of the texts showed that the written materials for the exhibits should have been too difficult to read for students under the age of ten, according to the Noun Frequency Method (Elley, 1975).

However, it appeared that the need to read the label of an exhibit at *Earthworks* may have been more driven by the agenda of a visitor and/or how well an exhibit could communicate its purpose. So, for example, students who were observed reading texts had worksheets to fill in and seemed to need information to do so. In other cases students started to read once they experienced difficulty with an exhibit and needed more information to continue with what they were doing.

## 4.3 INTERVIEWS WITH STUDENTS AND TEACHERS

### 4.3.1 INTRODUCTION

Students and teachers were interviewed to provide further data for the investigation into earth science simulations. Both students and teachers were interviewed in group settings. However, the format of the teacher interviews that led to a group discussion had slightly more flexibility, allowing the key issues to be raised and discussed more easily. The student interviews were more structured, the group size was smaller and photographs were used as stimulating tools. This section is, therefore, divided into *Interviews with students* and *Interviews with teachers*. Each of those two sections refers to the main objectives in these interviews, for example: 'Teacher experiences with Earth Sciences in a science centre' or 'Student recall without stimulus'. The focus of the analysing technique lies in the development of a theory (Strauss and Corbin, 1990; Creswell, 1998), which builds a story after the information was coded. Finally the sections conclude with a summary of the findings.

### 4.3.2 STUDENT INTERVIEWS

This section discusses findings from interviews with students. All participating students of the interviews had visited the *Earthworks* exhibition. The careful considerations given to interviewing children resulted in a special design of the interview procedure. The student interviews were divided into three parts: first the *Recall without stimulus,* then the *Stimulated Recall* and finally the *Exhibits versus real life images.* The interviews sought to determine what students could still remember from the exhibition and whether they were able to explain what the exhibits sought to portray as well as the students' interpretations of geological aspects. The following section makes extensive use of quotations from the students. This is because it gives a clearer picture of the students' ideas. This section concludes with a summary of the findings.

#### 4.3.2.1 Selection of participants

Students who visited the *Earthworks* exhibition at the venues in Hamilton or Palmerston North took part in interviews. The 47 interviewees came from primary and secondary schools, were from three different towns and were from five different classes. Trial studies that were conducted earlier with Year 6 students of a primary school suggested using focus groups as an interview format because it appeared to be a less intimidating situation for the students. The interviews took place between November and December 1996. There was a total number of fourteen groups and in most cases the group size was three. The interviews took place between three and four weeks after the class had visited the exhibition.

| Age | Female | Male |
|---|---|---|
| 8 years | 4 | 4 |
| 9 years | 5 | 4 |
| 10 years | 0 | 0 |
| 11 years | 7 | 2 |
| 12 years | 7 | 8 |
| 13 years | 5 | 1 |

**Table 8:** Age and gender data of students

Table 8 shows the age and gender distribution among student interviewees. The educational programme of *Earthworks* targeted Form 1-4 students (year 7-10) corresponding to the age group of 11 to 14 year olds (Hodder, 1997). Comparisons with the educational visitor numbers of the science centre venues EXSCITE in Hamilton and SCMM in Palmerston North showed that the exhibition was visited by 101 Primary and Intermediate schools and 34 Secondary schools. In respect of those numbers it seemed to be appropriate to include students representing Primary schools in the interviews.

#### 4.3.2.2 Recall without stimulus

Forty-seven students were asked which exhibits they could still remember from their visit at Earthworks.

This first part of the interview was conducted without any stimulating support (photographs). Typically students named all the exhibits they remembered and sometimes they would explain what they had to do with them or what the exhibits looked like.

| Exhibit | Percentage of non stimulated recall |
|---|---|
| Buck'n'Ham Palace | 100% |
| Wave maker | 79% |
| Geyser | 64% |
| Continental jigsaw | 64% |
| Volcano | 57% |
| Rock fall | 43% |
| River flume | 36% |
| Microscope | 36% |
| Earthquake Computer | 29% |
| Shake table | 21% |
| Settling tube | 21% |
| Hangi | 14% |
| Plate tectonics | 7% |
| GIS-Ohaaki | 0% |

**Table 9: Recall** without stimulus. The exhibits Microscope, Earthquake Computer and Hangi were not part of the group of exhibits that used simulations; therefore, they are not discussed subsequently. However, in order to show a complete picture of what students recalled at *Earthworks* they are included in this list of recalled exhibits.

Table 9 ranks each exhibit in terms of the proportion of students who recalled them from their visit at the earth sciences exhibition. This list includes also exhibits which are not further discussed in this study (Microscope, Earthquake Computer and Hangi), because they are not simulations. They were included in this first part of the interviews to give a full picture of what students recalled from their visit.

Buck'n'ham Palace 100% Recall without Stimulus

All 47 students participating in the interview recalled the Buck'n'Ham Palace. Twelve out of fourteen groups mentioned it first in the interview. Often students would describe how the exhibit worked, e.g.:

> I remember the earthquake cafe I think it was called, you got to pick what size of earthquake you wanted, and you sat in this thing and it started rocking, to show how serious the earthquake was (Girl, 12/ RW, 1*).

Students also referred to what they thought the exhibit was about, e.g.:

> And there's this earthquake house, and you press the buttons and it shakes, like the big New York [sic] earthquake and New Zealand earthquakes (Girl, 11/ RW, 3).

Comments like the above were made by students only twice, but they are clearly interpretations of the exhibit's purpose. However, mostly students would just simply recall the exhibit (eight out of fourteen groups), e.g.:

> The earthquake machine (Girl, 12/ RW, 10).
> The earthquake one (Girl, 8/ RW, 11).
> The earthquake house (Girl, 9/ RW, 12).

---

* The interviews were coded after they were transcribed. Coding key: (Gender, Age / Part of Interview, Number of Comment)

The Buck'n'Ham Palace was commonly the first exhibit that students recalled. Only twice was it recalled in second or third position. This indicates that this exhibit did leave a vivid memory from the students' visit to *Earthworks*.

<u>Wave Maker 79% Recall without Stimulus</u>

The Wave maker was the next most remembered exhibit. Students would often refer to it as an exhibit showing tsunamis (six out of eleven groups), e.g.:

> The tsunami (Boy, 12/ RW, 32).
> The tsunami thing (Girl, 11/ RW, 33).
> The water wave tsunami thing (Girl, 11/ RW, 34).

Students seemed to remember one of the demonstrations possible with this exhibit. However, even more often students referred to it as the 'wave thing' or 'the wave making machine'. Students also recalled what they were doing:

> The wave (Girl, 8/RW 36).
> The wave machine, you pushed down that lever and it made waves (Boy, 8/ RW 38).
> The water thing you have to push (Girl, 9/ RW, 39).

Other students emphasised what the exhibit was intended to demonstrate:

> There was this wave thing on and it shows the shape of the waves as they are going to the beach (Boy, 13/ RW, 37).

The Wave Maker was another exhibit that was remembered by many students, leaving vivid memories of the processes that were simulated.

Geyser 64% Recall without Stimulus

The Geyser was remembered by more than half of the students, e.g.:

> There was this geyser, and you pressed the button and you had to wait for three seconds, and when you went down below it you could see all the water boiling up, and on top the [tube] it would spurt out all the water (Boy, 13/ RW, 15)

This description of the purpose of the exhibit was quite detailed but otherwise the recalls were mostly confined to describing how the exhibit s worked.

Continental Jigsaw 64% Recall Without Stimulus

The Continental Jigsaw was also remembered by more than half of the interviewed groups. This exhibit is a good example that students would often try to explain the purpose of an exhibit or describe its features because they couldn't associate a name for it, e.g.:

> I remember that one where you had to build up the earth. What do you mean by build up the earth? It's like a jigsaw and you put on top of the half-globe (Girl, 11/ RW, 52).

This explanation shows what the student remembered which may not quite portray the intended purpose.

Volcano 57% Recall without Stimulus

More than half of the students also recalled the exhibit Volcano, e.g.:

> And the volcano and you put these things in it and you press them, it shoots out (Girl, 12/ RW, 67).

Students would typically describe this exhibit and refer to how it worked or what they had to do. In particular they mentioned that they had to put a plug in the vent and that it would 'explode' when the pressure was high enough.

> There was one where you pump up pressure and the volcano explodes (Girl, 12/RW, 72).

Every group that recalled the Volcano gave a short explanation of what they remembered of what they were doing with the exhibit. Clearly, one of the most memorable things was that foam balls 'erupted' once there was sufficient pressure build-up in the volcano.

Rock Fall    43% Recall without Stimulus

Rock fall, the stratigraphy exhibit, was recalled as a simple description of its appearance and what you had to do with it, e.g.:

> There was this thing, there was this wall and there was an outline, and you had to build it up (Girl, 13/ RW, 24).

Occasionally there was a more advanced portrayal supported that, e.g.:

> There was one where you had to build up the layers of like the plant life years ago, (Girl, 12/ RW, 29).

This exhibit was another good example of that which students gave more detailed descriptions of the look or function of the exhibit rather than just naming the exhibit as they did with the Buck'nHam Palace (the 'Earthquake machine'). Maybe the processes involved were perceived to be too complicated for using a simplified term, whereas 'Earthquake machine' may have been perceived as enough to explain what the exhibit was about.

River Flume 36% Recall without Stimulus

Only five groups remembered the exhibit River flume. Explanations varied in the degree of complexity. The comments that were made by students might also represent whether they actually spent time with the exhibit or whether they only had a look but were never actively involved.

> There was this thing where you had to build walls and stuff, and coves in the water and it made patterns in the water (Girl, 11/RW, 43).

This statement indicates that the student either put hands on the exhibit herself or observed others doing so, whereas

> Water went along a canal (Girl, 13/RW, 42).

This comment does not necessarily imply that the student was very much involved with the exhibit.

Shake Table 21% Recall without Stimulus

The exhibit Shake table was described by students who by their descriptions, seemed to have worked with it at the exhibition, e.g.:

> There was this thing and it had buildings on it and you sort of had to turn this handle and the thing would shake (Girl, 11/RW, 65).

Only three groups remembered the Shake table in this part of the interview. The explanations consistently indicated that the students who described it had also worked on them at the exhibition.

Settling Tube 21% Recall Without Stimulus

Three groups remembered the Settling tube from their visit to *Earthworks*.

> And this thing it had mud and stones down the bottom. And then you tip it up side down and all the mud comes down and all the water goes muddy. And then when you leave it for an hour or something like that the water will go all clear at the top and down the bottom will be mud, and the big stones fell down first, then the little stones and then the mud (Girl, 8/RW, 75).

The explanations were quite explicit and students described what they were doing with the exhibit.

<u>Plate Tectonics 7% Recall Without Stimulus</u>

The Plate tectonics exhibit was remembered only once and the description was also relatively vague, e.g.:

> And there was this thing it showed the pressure in the earth's core (Girl, 12/RW, 79).

GIS-OHAAKI 0% RECALL WITHOUT STIMULUS

The GIS-Ohaaki exhibit was the only simulation that was <u>not recalled</u> at all. None of the static display models or murals at the exhibition were recalled either.

#### 4.3.2.3 Summary: Recall without stimulus

All simulations except one were remembered from the *Earthworks* exhibition. A ranking (see Table 8) showed that the Buck'n'Ham Palace was remembered by all student groups and GIS-Ohaaki was not remembered at all. Each group recalled between two and nine exhibits from their visit. A comparison of the exhibits that were recalled by students with the floorplans of the exhibition halls and layout of the exhibition did not show any obvious relationship. It did not appear that there was any relationship between the main "traffic" ways through the science centre and student recalls. It seems that the exhibits were remembered because of the experiences the students had had with them.

The Buck'n'Ham Palace, although every student group remembered it, received the least detailed explanation about the function or the underlying purpose of the exhibit. Similar observations could be made for the exhibit Geyser and Wave maker. These simulations typically received a name from the students, which was used by most of the groups in a similar fashion. For example, the Buck'n'Ham Palace was labelled the Earthquake machine (six times), the Earthquake house (five times), the Earthquake cafe (one time), the Earthquake one (one time) and the Earthquake with the house (one time). Only four times could students explain what the exhibit was about. The exhibits Geyser (named: the Geyser) and the Wave maker (named: the Wave machine or the Tsunami machine) showed similar trends. This might suggest that the students found one term that would describe the purpose and appearance of the exhibit.

Most of the other exhibits received a lot more explanations about function and/or purpose and often gave the impression that students referred to experiences that they had made themselves, rather than recalling an exhibit they had just looked at. The same cannot be said from students who only stated they remembered the 'Earthquake machine' because this does not tell whether they just noted it from going past or whether they had only a look at them. However, one exhibit that only received a few comments was the Earthquake computer (not part of this study) where students explicitly referred to that they had only looked at it but had not operated it themselves.

#### 4.3.2.4 Stimulated Recall

Stimulated recall was the second part of the interview with students. The students were invited to look at photographs, which were taken at the Earthworks exhibition, showing the exhibits at the science centre that was relevant to the group. This information backs up the results obtained for some of the 'high impact' exhibits from section 4.3.2.2 like e.g., the Buck'n'Ham Palace. However, during the interviews it became clear that not all exhibits that were remembered in the first part were necessarily well described in the second part. Recall did not automatically translate to understanding of the concept that was portrayed, but was at times confined to describing the appearance of an exhibit.

<u>Buck'n'Ham Palace</u>

All fourteen groups commented on the exhibit Buck'n'Ham Palace. In this part of the interview students explained the exhibit in much more detail. More than two thirds of the explanations given described the processes that the simulation sought to portray, e.g.:

> That was the earthquake machine, and you had two different earthquakes a larger one and smaller one, and it shook the room, it shook how it would feel in an earthquake (Boy, 12/SRbh, 7).

Some of the students also gave their reasons why that exhibit had made such an impression on them e.g.:

> The earthquake house was the best, because you don't usually get to see earthquakes, so that you don't hurt yourself and anything, and it was really good (Girl, 12/SRbh, 15).

Explanations went further then merely descriptions of the exhibit:

> That was the earthquake house and you pressed the button and it showed you to simulate an earthquake (Girl, 12/SRbh, 9).
>
> And they simulated the Edgecumbe earthquake and there was another one, that was higher on the Richter scale, somewhere in America (Boy, 13/SRbh, 9).

The general impression that students gave during the interview was that a majority could describe in detail what their experiences were and how they interpreted them. However, five times out of fourteen, students referred to the exhibit Buck'n'Ham Palace with simplistic descriptions of the appearance of the exhibit only, which did not necessarily indicate whether they actually interacted with it themselves or whether they were only observers.

<u>Wave maker</u>

The Wave maker exhibit, which received the second highest recall rate in the first part of the interview, was again described by all fourteen groups. The exhibit was mostly described in terms of how it worked rather than in terms of the geological process it portrayed:

> Well you have to pull this thing and it makes the water go up (Girl, 9/SRwm, 13).

Descriptions of the Wave maker were improved with the support of the image, although they were mostly confined to how the exhibit worked. Four times students used the term "tsunami". However, throughout all the interviews no student referred to a tsunami as an earthquake-triggered wave, but related its cause more to the forces of wind.

> This one you had to push this lever down and it made these waves and there was sand underneath and if you push it hard and you do it for a long time it makes huge waves (Boy, 8/SRwm, 10).

> Was this the tsunami one, yes that's the tsunami, you pushed that there, it looks really big, yes and it was leaking when we were there (Girl, 11/SRwm, 4).
>
> *What are tsunamis – have you ever heard about them?*
>
> They are huge waves that have been built up by the wind, tropical cyclones, storms (Boy, 12/SRwm, 5).

The last comment suggests that the exhibit failed to communicate that the lever in the simulation, which produced waves, would stand for wind generated waves as well as waves that maybe generated from an earthquake or related events like underwater landslides. It did, however, show the students how the actions of waves accrete or erode material from the coast and along the ocean floor.

<u>Geyser</u>

Twelve groups gave explanations about the exhibit Geyser, however they were largely of a descriptive nature.

> This geyser, you pushed the button and it squirted water out (Girl, 12/SRg1)
>
> That was the geyser and you could push a button and you could go upstairs and you could watch it push or pump (Girl, 13/SRg, 2).

Only three times processes were reported that lead to the eruption of the geyser. Students often thought that pushing the button (exploitation button) would trigger the eruption. This might indicate a discrepancy of perceptions between designers and visitors, or might be caused by not everybody understanding what the word 'exploit' meant.

Plate Tectonics

The exhibit Plate Tectonics received explanations from all fourteen groups. Many of those comments were about the scientific idea that underlies the simulation, e.g.:

> I remember that the plates are moving together, sort of like how mountains were formed (Girl, 13/SRpt, 2).
>
> I know this, you turn this and it shows you, it opens up, it started overlap and an eruption happens if the plates go over each other (Girl, 12/SRpt, 3).
>
> Here you had to wind that handle, and they move together, to make the land move and it causes that volcano, when they push together (Boy, 12/SRpt, 4).

Seven times (out of fourteen) students specifically explained what they thought the exhibit 'showed to' them. In one particular case students even used specialised vocabulary appropriately, e.g.:

> It showed you the movement of plates and subduction of plates. *What does subduction mean?* It means going underneath (Boy, 13/SRpt, 9).

This observation was interesting considering it was one of the less frequently recalled exhibits in the first part of the interview (see table 8). This might be because perhaps the students 'knew' about plate tectonics before they came to the exhibition and it seemed to be a less novel idea to them. Maybe the design of the exhibit was less exciting than other exhibits found to be more memorable. However, the overall 'gestalt' of the simulation seemed to have succeeded in showing a sequence of processes related to plate tectonics.

Shake Table

The exhibit Shake Table also triggered recognition by all fourteen groups of it as a simulation.

> That was the earthquake one, was it the earthquake one, and you had blocks and in the trays were rocks and it would show how it would react in the earthquake (Girl, 13/SRst, 2).
>
> That was that thing that simulates earthquakes, and shows what happens when houses fall down, the shake table (Boy, 12/SRst, 9).

All explanations revealed that the students had worked with the exhibit and tried different possibilities.

> You had to make a landscape. And then you had to put buildings on there and you pressed the button and it made an earthquake. And you could see which ones held up the longest like the low ones on high ground or high ones on low ground (Boy, 9/SRst 13a).
>
> You had to try and see which buildings stays up the longest, like the short ones or the tall ones (Girl, 8/SRst, 13b).
>
> The small ones stayed up the longest, they made it through the earthquake unless you put them on a cliff or something (Boy, 9/SRst, 14).

In relation to the exhibit students referred to their own experiences which they then interpreted as the purpose of the simulation.

Continental Jigsaw

When students described the exhibit Continental jigsaw, six (out of thirteen) of the responses given were purely descriptive. The other half showed some appreciation of the concept behind the exhibit. The quality of the descriptions, however, pointed towards it as being a difficult concept to grasp.

> It's an earth and it's made and you pull it apart and you put it back together again (Boy, 8/SRcj, 11a).
>
> *What was it about?* It was when before cavemen, during cavemen and human being time (Girl, 9/SRcj, 11b).
>
> *What was the difference?* The first one was a lot of green in that the second was that green and the human being one was the darker green (Girl, 9/SRcj, 11c).

This type of answer indicates that students have difficulties with the concept of geological time portrayed in this exhibit. Time is confined to human existence and there is also an indication that the concept of plate movements is related to the idea of water being the driving force of the separation of the continents.

> *Were the puzzles different apart from the colour?* Yes I think so, cause I think the islands changed a bit, because of the water, each time it changed a bit (Girl, 9/SRcj, 11d).

Literature reports that 'deep time' is in fact 'the heart of geology' (e.g., Trend, 1998) and yet so difficult to understand because it is 'outside our ordinary experience' (Gould, 1987 in Trend, 1998, p.973). So by interpreting geological time within human existence, students attempt to make it more comprehensible.

One of the answers given also pointed towards a misconception about the internal structure of the earth.

> There was one where you had to build the Earth's core and Earth's layers around it. (Boy, 11/SRcj 9).

The exhibit did not appear to explain well enough what it showed once the puzzle pieces were taken down.

Rock Fall

Twelve groups recalled this exhibit when seeing the photograph. The exhibit Rock Fall was often associated with fossils and sedimentation.

> That was a big wall and you had to build up the fossils and the layers (Girl, 13/SRrf, 2).
>
> That was the world that you had to make and it showed all the different layers of the rock, and all the fossils, yes and the sediments (Boy, 12/SRrf, 6).

The comments suggest that the students recognised that the strata that had to be rebuilt showed different geological times. Layered rocks were often associated with change of time.

> You had to look at that picture then you had to build it up with the blocks (Girl, 8/SRrf, 11a). *What did it show?* It showed the earth or something (Girl, 8/SRrf, 11b). It showed all sorts of animals, it showed the prehistoric times (Boy, 9/SRrf, 11c).

About half of the students explained more about the processes that were portrayed by the exhibit. However, even though students were quite happy to use specialised vocabulary like fossil, sediment and prehistoric time it was not always quite clear how well they had understood what those words meant.

GIS Ohaaki

Eight student groups remembered the exhibit GIS-Ohaaki after they had seen the photograph but it was not recalled at all in the first part of the interviews. Some students did understand the purpose of the exhibit:

> Yeah I remember that one you had to follow that line, and it would go beep or something (Boy, 13/Srgo, 1a). *Do you know what it was about?* I think it followed water or something, I don't know (Boy, 13/Srgo, 1b).

This comment suggests that the boy actually described the correct meaning, but was unsure whether that he was correct. Apart from describing what the exhibit looked like, the explanations for what the students thought the exhibit portrayed suggested that the exhibit failed to communicate its underlying idea.

> Oh you scanned it, you rubbed over stuff and then you scanned it (Girl, 11/SRgo, 4a). Any idea what that exhibit was about?
>
> There were these areas of plate tectonics (Girl, 12/SRgo, 4b). Oh no that was something else (Girl, 11/SRgo, 4c). Oh maybe it was about how much soil was there and how much ash had fallen (Girl, 12/SRgo, 4d). Is it the layers under the ground (Girl, 11/SRgo, 4e). And there were little red dots around that place, they were volcanoes or something (Girl, 11/SRgo, 4f.
>
> The next one was tracking down the places where it's hot and where a fire could cause (Girl, 8/SRgo 5).
>
> I think it was the one where you put this handle thing down and it shows where roads or something like it has been (Girl, 9/SRgo, 6).

The students' explanations tend to suggest that they will try to construct a meaning for what they saw and experienced, whether it is correct or not. This example illustrates well the potential problems that arise if simulations cannot communicate the principal meaning of the exhibit.

River Flume

Only eight groups commented on the exhibit River Flume. All of the comments about the exhibit tended to be descriptive of its appearance and operation rather than an explanation of what it demonstrated.

> Oh yes, you had some rocks and had to keep the water up here (Girl, 13/SRrfl, 1).

Students described the operation of the River Flume, recalling their practical experiences with the exhibit:

> You had this tray and you could dam up that water, and you had rocks and other stuff (Boy, 12/SRrfl, 2).

However, half of those student groups commented that they recalled seeing the exhibit River Flume but said that when they visited the exhibition it was out of order. Their impression was thereforeonly based on having a look while passing by.

Volcano

Ten groups gave explanations about the exhibit Volcano. The photograph of the Volcano exhibit triggered the notion that the eruption happened because of the increased pressure from inside.

> Oh that's the volcano thing, the pressure from inside pushes the ball, you pumped it up and then it went bang (Boy, 12/SRv, 4).

Comments about the volcano exhibit were often connected with a local example, one of New Zealand's most famous volcanoes, Mt Ruapehu:

> This is the part where they showed Mt. Ruapehu and the ball pops out when it gets hot like the lava that is coming out (Girl, 9/SRv, 9).

However, it appeared that students were not always quite sure whether the upcoming lava, heat or air (like in the exhibit) caused the pressure release.

> *What makes the ball pop out?* The pressure, you had to swirl a handle around, you had to pump a pump and it build up the air pressure and it popped the ball (Boy, 9/SRv, 9b). *What makes a Volcano erupt?* The lava pressure under a thin layer at the top, the thin crust or a thin crack where it has to get through (Boy, 9/SRv, 9c).

The following comment shows that the simulation appears to induce a misleading notion, that an eruption is triggered by air pressure.

> That's the air pressure in the earth's core, there's volcanoes and geysers and you pump it up and all goes up into the air (Boy, 13/SRv, 5).
>
> You pull this thing and the ball goes up (Girl, 9/SRv, 10a). *Why did the ball go up?* To show what the lava does (Girl, 9/SRv, 10b). *Yes, but why?* You just pump it up (Girl, 9/SRv, 10c). Until the volcano erupts because its hot (Boy, 8/SRv, 10c). And you have to pull the pump and the ball flies out because of the air (Girl, 9/SRv, 10d).

Comments like the above might suggest that while simplified versions of reality are used in a simulation it is as important to refer maybe in picture or text to the real situation. However, having made this suggestion it is also important to point out that this particular simulation was accompanied by picture and text material referring to New Zealand's latest volcanic eruptions. The interviews were conducted not long after the eruption of Mount Ruapehu, which increased the level of awareness about volcanic activity. In hindsight, the student's statements might simply refer to their explanation of how the *simulation* worked, but not a real volcano.

Settling Tube

The exhibit Settling Tube communicated its intention rather well. Nine groups commented on this exhibit. Students described the process by which coarser particles settled first and the process of sedimentation.

> It's a tube and it's full of water with sand on the bottom. And you turn it upside down and then you turn it back and then you watch it and then you can see that the big rocks come down first and then the small rocks were on the top (Girl, 9). It's when the heavy sand comes down pretty quick. But the fine sand stays in the water which makes it dark and mud and by the time it comes back down it will be probably twelve o'clock at night or something (Girl, 9/SRstu 8).
>
> That's the sediment mixing (Boy, 11/SRsrtu, 3a). You can see what goes to the top and what goes down to the bottom (Girl, 12/SRstu, 3b). It falls down like sediment (Boy, 11?SRstu, 3c). *Which particles fell down first?* The heavy ones (Girl, 12/Srstu, 3d).

It appears that the 'simple' design of this exhibit allowed it to communicate its message quite clearly. The exhibit was associated with sedimentation and each of the nine groups who commented on it described correctly the processes involved. The success of this simulation might also be related to its being an observation that a majority of the students might have made themselves before e.g.: stepping into a mud puddle. Therefore students felt comfortable with the concept.

### 4.3.2.5 Summary: Stimulated Recall

The second part of the interviews showed two kinds of answers given by the students, those that described the overall look or 'gestalt' of a simulation and those that explained what the exhibit sought to portray based on the practical experiences the students had had. Typically the purely descriptive explanations referred to the overall appearance of an exhibit, which could be done by passing by and having a look at the exhibit. Those types of answers either did not mention the students' own experiences or mentioned explicitly that they only had a look but did not get more involved (e.g., River Flume, Continental Jigsaw). Other exhibits were clearly described based on the experiences students had made when operating them. Students would then refer explicitly to activities they undertook while they worked the simulation. This observation was made, for example, with exhibits Settling Tube and Buck'n'Ham Palace.

When students were given a photo to stimulate their recall it was noted that they would use it to construct a meaning for the simulation. The reasons for succeeding or failing to interpret the correct meaning (according to the designers' intentions) seemed to be due to a variety of factors. Some exhibits may not have been as straightforward as others. Recalls of simulation Plate Tectonics for example referred to a variety of processes, that may have been well displayed by the design of the exhibit, whereas explanations about the exhibit GIS- Ohaaki appeared to be confused and unsure.

Some explanations also gave rise to the suspicion that the exhibit might have been misleading about some of the processes involved, which would be correct as long as it applied to the simulation but incorrect when referring to the real process (e.g., involvement of air pressure to simulate volcanic eruption). However, this conclusion is not sustainable because it is not clear whether students were referring to the exhibit or the real process.

#### 4.3.2.6 Exhibits versus real life images

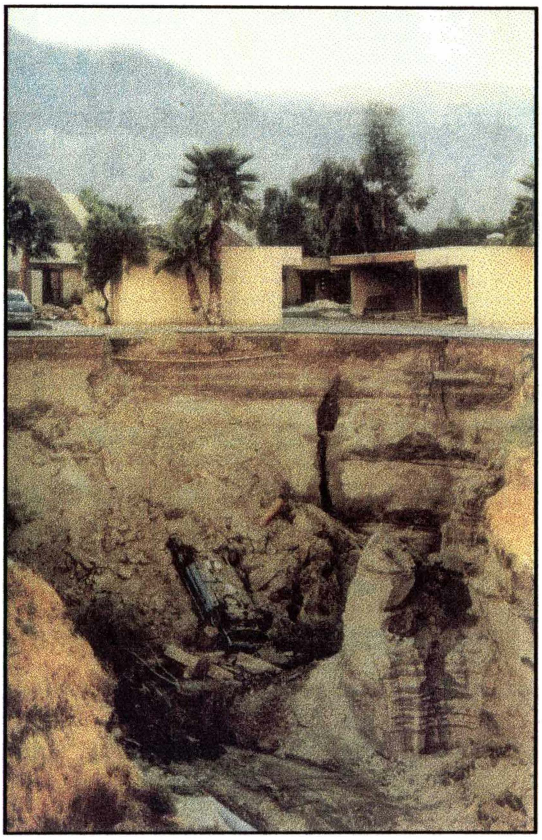
Students were asked to find photographs of real life situations and match them with the three favourite exhibits of their choice. Six exhibits were chosen in total. It was envisaged that the photographs would give insight into the students' perceptions of how they would judge and interpret certain geological situations.

Buck'n'Ham Palace

The Earthquake machine was the exhibit that was chosen by most students as their favourite exhibit (chosen by 11 groups out of 14). An overwhelming majority of students chose the photographs 12, 13 and 14 to go with this exhibit. Two of those photographs (Photograph 13 and 14) featured the effects of mass movement caused by landslides and one photograph showed four-story buildings damaged by an earthquake (Photograph 12). When students were asked to explain their selections, they would usually say that they would consider this to have happened during an earthquake.

**Photograph 12:** Earthquake damage. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 18.19)

**Photograph 13:** Landslide. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 1.2)



**Photograph 14:** Landslide. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, p.231)

In a further step students were asked to explain how an earthquake happens. In most cases they related the cause to the movement of tectonic plates, e.g.:

*Why does an earthquake happen?*

At the bottom of the earth there are these two plates and they move together (Girl, 12/ RLlem, 2a).

Yes, and they push together or they cross each other and then they push together (Boy, 13/RLlem, 2b).

Students were asked what the cause was for an earthquake. Typically the answer was related to the shaking of the ground, which was caused by the movement of tectonic plates:

*What makes the ground shake?*

Cause of the movement of the tectonic plates (Boy, 12/RLlem, 12a).

*Why do the plates move?*

Because of the pressure from underneath, (Boy, 12/RLlem, 12b).

This suggests that participants knew about ideas of plate movement and subduction:

The plates that scrape against each other, they bang into each other and sort of missing each other (Girl, 12/Rllem, 14c).

Yes, one goes up over the other (Girl, 11/Rllem, 14d).

They did appear to feel quite comfortable with the concept that the plates were not static, due to "magma that is underneath and makes the plates always moving" (Girl,12/Rllem, 17d). Convection "the earth underneath is really hot and pushing" (Boy, 12/Rllem, 20) - was an idea that several students mentioned.

Students were also asked why they thought they knew about concepts like plate movement and subduction:

*Why do you think so?*

Because of the layers you see, they are being pushed up (Girl, 12/Rllem, 19b).

These answers actually tell about what students think the cause for that particular process is. An answer as to why they would think that way could be because that is what their teacher told them, or maybe because they guessed from the appearance of the exhibit.

They also applied the notion of destructive plate boundaries, e.g.:

> Cause the plate tectonics went down and got burned up in the magma (Girl, 11/RIlem, 29).

It was interesting that students used the term plate tectonics so frequently and it appeared that they used it as a terminology for plates (no distinction between continental and oceanic):

> That's along a fault line (Boy, 12/RIlem, 33a).
> *What's a fault line?*
> The plate tectonics (Boy, 11/RIlem, 33b).
> Yes, on each side are the plate tectonics (Boy, 12/RIlem, 33c).

Throughout all conversations with the students it became clear that they felt confident in explaining plate movement and they used many terminologies and ideas that are often described by geologists and are evident in geology textbooks which actually have an older audience as their target (e.g., Press and Siever, 1994; Hamblin and Christiansen, 1998).

With the photographs of real life situations in their hands the students felt confident to talk about the concepts of earthquakes and plate tectonics. Sometimes students would directly relate the photograph back to the exhibit

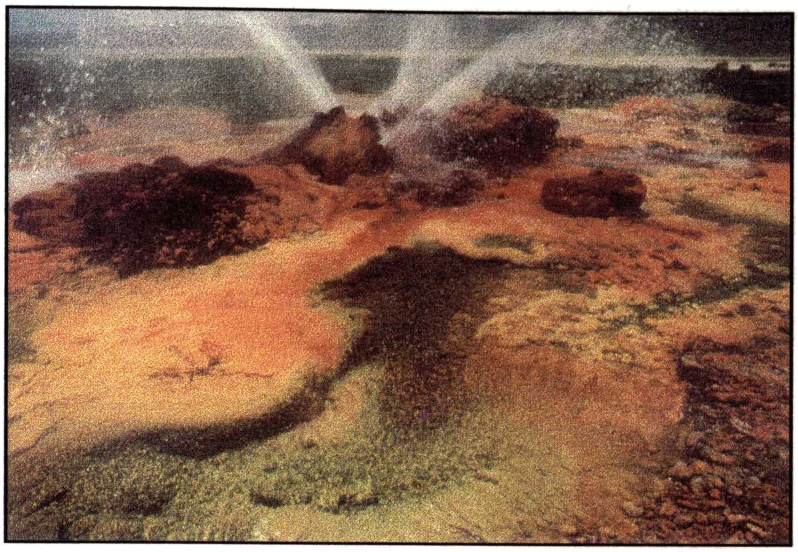
> Being in there [the earthquake machine] would be just like being in one of those buildings [photo] when an earthquake has happened (Girl, 13/RLIem, 6a).

Students interpreted the photographs based on their understanding of the situation. These interpretations seem to be their framework of understanding, which were enhanced by their experiences with the simulation.

Geyser

The most preferred selection of photographs to associate with the exhibit Geyser were photographs 15, 16 and 17. Two were photographs of steam vents in different locations caused by geysers (15 and 16) and photograph 17 showed hot water running over sinter terraces.

**Photograph 15:** Geothermal field. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 22.15)



**Photograph 16:** Geyser Hot Springs. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 5.26)

**Photograph 17:** Travertine deposits. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 12.23)

Again, students were first asked to explain their selection.

> On the photographs you can see geysers and hot springs and the geysers is just like what we saw there (Girl, 13/RLIg, 9).

And you find a lot of geysers with hot springs, and yes this one is a geyser, and this one there is some hot water coming up and there was some steam coming up with the geyser as well (Girl, 13/RLIg, 10a).

However, in two instances photograph 18, featuring typical volcanic products, obsidian, pumice and ash was selected to go with the geyser exhibit:

**Photograph 18:** Pyroclastics. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 4.5)

That one is a volcanic rock, obsidian (Boy, 13/RLIg, 1).

Yes and that one is pumice (Girl, 12/ RLIg, 2.

And that one must be... ash (Boy, 13/ RLIg, 3).

Obsidian is hard like glass (Girl, 12/RLIg, 4a).

*Why did you choose this to go with the geyser?*

Geyser are usually formed around a volcanic area (Boy, 13/RLIg, 4b).

Volcanism was directly related to geothermal activity. When asked for a reason, students would comment on a geyser being hot and coming from "underground". The inner earth was usually described as being hot because of magma that sits under the plates.

Students were further asked to explain how a geyser functions:

> Cause it is coming from underground. And there is a lot of heat, and friction from the plates. And there's a lot of heat, and that warms the water up, so when it gets to the surface the water on the surface is cold because of the air, and the hot air isn't trapped there and can move away not to heat the water up (Girl, 13/RLlg, 10c).

Steam was associated with pressure release:

> *Why do you see all that steam?*
> It's just letting off all that pressure from like the water bubbling up under the ground, and that's why he is letting all that pressure out (Girl, 12/RLlg, 17).

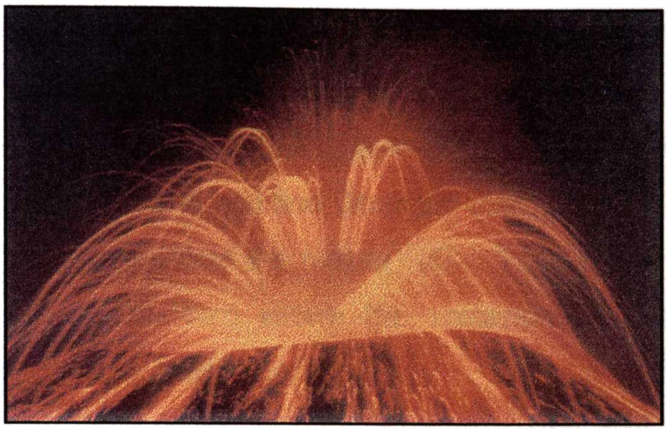
The idea that the interior of the earth is hotter appears to be a common thought. When asked why not every spring water was hot despite coming from "underneath" students replied:

> *If you think of normal springs, why aren't they hot as well?*
> Oh they are just not close enough to the magma to get heated up (Boy, 12/RLlg, 21c).

These answers gave the impression that the students felt comfortable with the notion that underground water can be heated by a nearby magma chamber.

<u>Volcano</u>

For the exhibit Volcano students choose mostly photographs 18 (volcanic rocks), 19 and 20, (volcanic eruptions). The photograph showing volcanic rocks, photograph 18, reminded students of own experiences.



**Photograph 19:** Lava Shower. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 5.13)

**Photograph 20:** Lava stream. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, p.91)

They are volcanic rocks (Girl, 11/RLIv, 1).

Like when they dry up, because first it's lava and then it's dried up (Girl, 11/RLIv, 2). *How do you know they are volcanic rocks?*

Because we learned about it, like at Lake Taupo* there is heaps of pumice around it and you find Obsidian (Girl, 11/RLIv, 3).

I got some pumice from the Mount* (Girl, 11/RLIv, 4).

And there is Obsidian where the volcano spit it all out (Girl, 11/RLIv, 5). *And what's that?*

That's just like the ash, like Mt. Ruapehu* that was just erupting (Girl, 11/RLIv, 6).

Reasons why a volcano would erupt were often related to pressure build-up. Students described the interior of a volcano, having a vent:

It's got that thing down the middle, like a hole in it (Girl, 11/RLIv, 11).

A tube, a hollow tube (Girl, 11/RLIv, 12).

Students described volcanoes also to be layered and having side-vents:

And its got lots of little things coming out the side, it's got the different layers (Girl, 11/RLIv, 13).

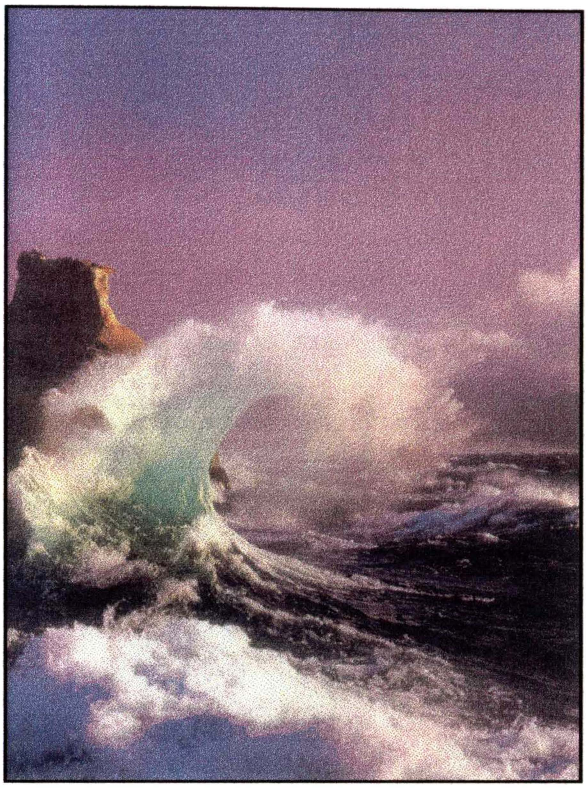
Explanations for why eruptions happen were sometimes related to earthquakes. More often pressure build-up as well as an increase of gas, was said to be responsible for melting rocks and consequently the reason for a volcanic eruption. The notion of air pressure being the driving force for a volcanic eruption was not used in this part of the interview despite its mention in the previous part.

---

* Three volcanoes in the North Island of New Zealand: Lake Taupo a caldera, Mt. Maunganui, a rhyolitic, dome-shaped volcano, by locals often called "the Mount" or "Mount Mauao" and Mt Ruapehu an active andesitic volcano.

Wave Maker

For the exhibit Wave maker students mostly chose photographs 21 and 22, featuring a breaking wave at the coast and ripples in the sand.



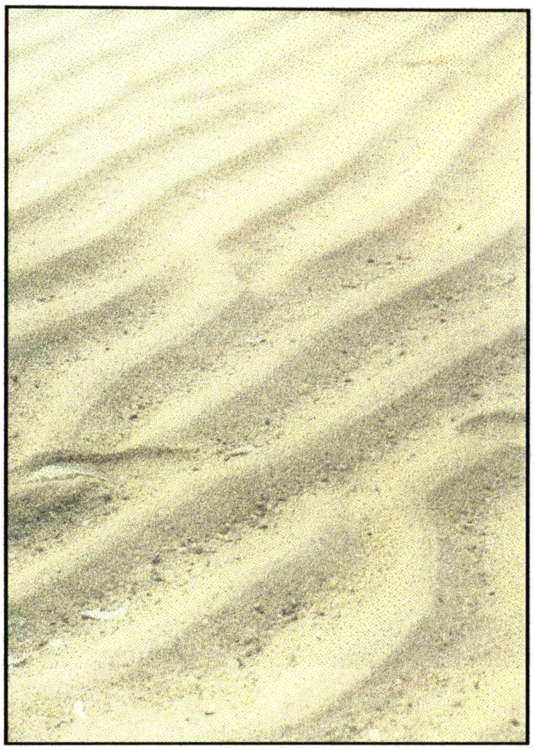
**Photograph 21:** Wave. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, p.369)

> In the sea, when a big tidal wave comes, it crashes to the land (5), (Girl, 13/RLIwm, 1).
>
> That's sand and it's at the beach and it shows different surfaces that changes with the waves (Boy, 12/RLIwm, 8).

Students were happy to talk about the erosional and accretionary effects of waves on the land.

*How do the waves affect the land?*

Heaps of waves affect the land, that's how they form cliffs and beaches, cause they take the sand from here and they take it back (Boy, 9/ RLIwm, 15b).



**Photograph 22:** Sand Ripples. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 7.10)

Connections were also made with tsunamis. However, it appeared that the mechanisms that generated tsunamis were unclear.

*How do you get big waves?*

Its pressure at the bottom of the sea (Girl, 12/RLIwm, 7b).

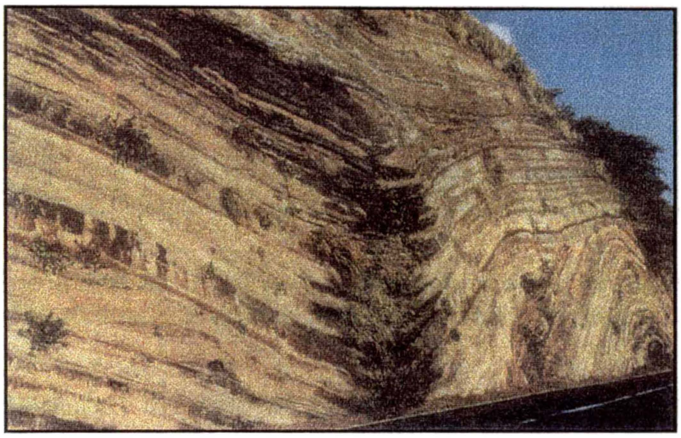
*How does that work?*

Oh maybe the plate tectonics they come up and that pushes the water (Girl, 12/RLIwm, 7c).

This statement could be interpreted as being caused by an earthquake. However, it seems this comment might merely represent a construction of ideas based on the content of the interview. A similar impression that students were unsure was given in the earlier part of the interview when students referred to tsunamis being wind-generated waves.

Continental Jigsaw

Three groups chose as one of their favourite exhibits Continental Jigsaw. They chose photographs 23 (layers of ash deposits), 24 (a meandering river) and 25 (folded rock layers).



**Photograph 23:** Ashflow sheets. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 5.24)

**Photograph 24:** Meandering river. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 13.9)

They explained their choice as:

> And it's sort of there's another slab of earth on top and something caught in between and the other bits are all fallen away and it sort of left a mark here [talking about photograph 25](Girl, 11/RLIcj, 1).

**Photograph 25:** Folding. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 10.3)

One student said that the photos showed "what the earth is made of" (Girl, 11/RLIcj, 4).

Students then tried to relate these photographs back to the exhibits. Their comments were often connected with the concept of plate tectonics.

> *How do you relate that [photograph] with the exhibit?*
> It shows that the plates are moving all the time (Boy, 12/RLIcj, 21b).
> They are shifting (Boy, 11/RLIcj, 22).
> They are floating on molten rock (Boy, 12/RLIcj, 23).
> They are going very slowly, and then every 100 years or so they change completely (Boy, 12/RLIcj, 24).

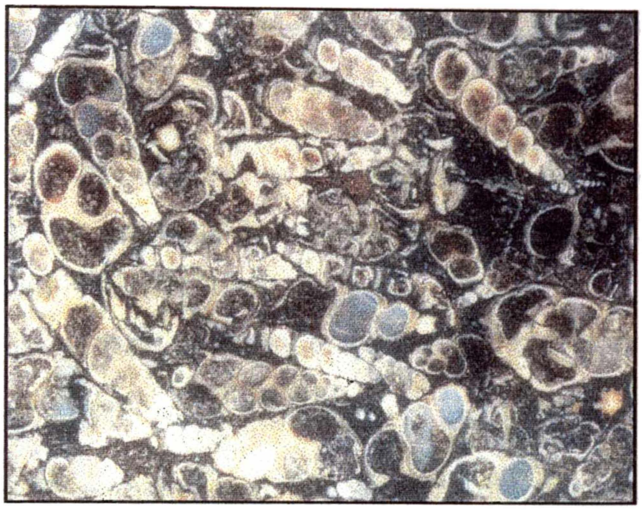
It appears that the layers in the rock were interpreted to be the plates. Student understandings of geological times were again related to human existence.

> *You remembered there were three jigsaws?*
> They were like the nineteenth hundreds (Girl, 11/RLIcj, 13).
> I only remember the last layer (Girl, 11/RLIcj, 14).
>
> *Why were there three jigsaws?*
> To show the different times of what the world looked like before (Girl, 12/RLIcj, 15).
> *Why did the world look different?*
> Because the plates, the plates move (Girl, 11/RLIcj, 16).
> And it broke up, all of the continents (Girl, 11/RLIcj, 17).
> And then the plates they move every 10 million, I mean, yes every 10 million or something like that, but they have moved only a couple of centimetres or something like that, cause it was also on the computer (Girl, 12/RLIcj, 18)

Interpretations are based on own experiences and understanding, which are then applied to this new situation. Typically 'common sense' interpretations are applied, but the understanding of the real length of time for earth's history appears to be problematic for students.

Rock Fall

For the exhibit Rock fall students often chose photographs 23 (layers of ash deposits) and 26 (fossils).



**Photograph 26:** Fossiliferous limestone. A photograph provided for "stimulated recall" during student interviews (Press and Siever, 1994, figure 7.20)

> The first one has got fossils in it (Boy, 12/RLIrf, 1).
> Yes, fossils and shells (Boy, 12/RLIrf, 2).
> The jigsaw actually showed you what happened, in there, with fossils and coal (Boy, 12/RLIrf, 3).

This conversation showed again associations of what was seen at *Earthworks* with photographs of actual geological situations.

> That is, you can see all the layers, it looks you cut the earth and you have got all the different lines (Girl, 12/ RLIrf, 17).
> I am trying to think of that word, its like a leave print, oh yes fossil, that's what they would be fossils (Girl, 12/ RLIrf, 19c).

Students often used the term "fossil", so they were asked to explain what it meant.

> *What is a fossil?*
>
> It's a remain trapped in rock or earth or something, something that's old (Girl, 13/ RLIrf, 21b).

It was interesting that students would often refer to a fossil of being a mould of the real thing, which might indicate their own experiences with plaster casts, which are often used for an example of 'fossil-making' in textbooks.

> Little imprints in the rock, or big things, like fossilised dinosaur bones, they are not actually bones they are actually just a print in the rock (Girl, 11/RLIrf, 19e).
>
> It's more like a copy, but they are actually the real thing, but they formed to rock (Girl, 11/RLIrf, 19f).

This last statement suggests that this student did associate the term fossil not with being simply a mould but some kind of organic trace that has been buried by natural processes, and subsequently permanently preserved. When asked why one would find shells there, students would reply:

> Would it probably be because some people say the sea used to be like over land and it might have washed stuff up and then all the land build up over the shells (Girl, 11/RLIrf, 19b).

This suggests a level of familiarity with the idea that areas must have been inundated by water. Students seem to feel comfortable using the concept of deposition of sedimentary material.

#### 4.3.2.7 Summary: Exhibits versus real life images

This final part of the interview looked at how students would judge a given situation and relate that to their experiences when they visited *Earthworks*. Students now had the opportunity to tie some of the ideas together that were mentioned earlier. So, for example, the Buck'n'Ham Palace was associated with photographs of destroyed buildings. Processes that led to such events were explained to be the movement of the plates.

Explanations for the cause of that movement were said to be the upwelling of magma and the subsequent movement of crust that lies on top. Most of the students were confident to apply all these notions to their interpretations. However, some of the explanations also showed that students inappropriately applied ideas that they had been taught (e.g., either by the exhibit or by a teacher) like plate tectonics. Ideas like plate tectonics were used to interpret events that happened for other reasons and were on much smaller scale like e.g. stratigraphic sequences. Geological time appears to be another difficulty and seems to be always related to human existence. Impressions of wrong interpretations of the cause of volcanic eruptions (air pressure) obtained from the second part of the interview were not sustained for those groups who chose to talk about it in this part of the interview.

### 4.3.3 SUMMARY OF STUDENT INTERVIEWS

This chapter describes data collected from interviews with students. The student interviews show how much of the information presented at *Earthworks* the students still knew and what sort of information that was. In addition, students were asked to interpret images of real geological settings and try to relate them with the *Earthworks* simulations.

Table 10 rates the interviews into recognition, description and understanding of geological processes. It shows that some simulations like the Buck'n'Ham Palace seemed to be highly effective. All children remembered it from their visit. They were explicit in their descriptions of how the exhibit worked and what it was about. Showing the students photos enhanced their descriptions. The Buck'n'Ham Palace was also one of the exhibits students chose as the best at *Earthworks*. They felt very confident explaining their ideas about why earthquakes happen and used comfortably theories like plate tectonics and concepts like heat convection and subduction.

| **Exhibit** | **% Recall Without Stimulus** | **Quality Of Student Response** | | |
|---|---|---|---|---|
| | | Without Stimulus | Stimulated Recall (Exhibit Photo) | Stimulated Recall (Real Photo) |
| Buck'n'Ham Palace | 100 | *** | *** | *** |
| Wave maker | 79 | ** | ** | *** |
| Geyser | 64 | * | ** | *** |
| Continental Jigsaw | 64 | * | ** | ** |
| Volcano | 57 | ** | ** | *** |
| Rock Fall | 43 | ** | *** | *** |
| River Flume | 36 | * | * | |
| Shake Table | 21 | ** | *** | |
| Settling Tube | 21 | ** | *** | |
| Plate tectonics | 7 | * | *** | |
| GIS-Ohaaki | 0 | | * | |
| *Inferences from student responses:* * recognition only; **recognition and description of exhibit; *** recognition , description of exhibit and some understanding of geological process exhibit portrays | | | | |

**Table 10:** Student responses to *Earthworks* exhibits

Throughout the interviews it appeared that not every simulation achieved the same results. One of the observations was that explanations about the exhibits were either descriptions of the appearance of the exhibit (recognition) or students' descriptions of experiences students had made with the simulations (recognition and description). So, for example, the Wave maker was the second most remembered exhibit, but descriptions were mostly confined to how the exhibit worked. Explanations about what the exhibit was about did improve with looking at the photo. This improvement could also be explained because the students tried to construct an explanation while they looked at the photo.

When students were commenting on the exhibit Wave Maker they often used the term "tsunami". However, they did not know the real meaning of it. Students interpreted geological situations very well, but certain areas seemed to be repeatedly problematic, like geological time. Typically students would relate it to human existence.

Stratigraphic sequences were sometimes interpreted as being the (continental or oceanic) plates. This finding might suggest that students are confident about the general theory of plate tectonics but have difficulty in applying it to a real geological setting. Exhibits like the Settling Tube were very well described and the students had a good understanding of what it was about. They also felt very confident to talk about volcanism, applied local knowledge and obviously referred that to their experience at the exhibition. In some cases it appeared that the exhibit Volcano misled students to think that volcanic eruptions are triggered by air pressure like the simulation at *Earthworks.* However, at later stages of the interview that impression was revised when students referred to volcanic eruption being triggered by pressure release due to gas production and upwelling hot magma.

Group interviewing can trigger a chain of responses. The interviews repeatedly demonstrated that a student who seemed to have had experiences with the exhibit wanted to tell of those experiences, even if somebody else was merely describing their impressions of the same exhibit. In summary of the above *Earthworks* left the students with a very vivid impression, which they applied to enhance their interpretation of geological events.

### 4.3.4 TEACHER INTERVIEWS

The interviews provided information about experiences and/or expectations with science centres and experiences and/or expectations with geo-science education. The participants of the group interviews were later invited to participate in questionnaires. Statistical information like the types of schools participants came from, was taken from the questionnaires and included in this section.

*Experiences and expectations of teachers with earth sciences* in a science centre are presented in section 4.3.4.2. *Experiences and expectations with geo-science education* are shown in section 4.3.4.3. They represent a combination of a narrative summary and actual quotes that aim to illustrate the views of the participants in their own words. Statistical representations have only been used where appropriate and have been omitted for the findings from the interviews as they were conducted in a group format which does not allow separate identification of each individual's viewpoints (Anderson, 1990).

#### 4.3.4.1 Selection of participants

Teachers that came for a preview of the exhibition were invited to take part in a group discussion. A total of 37 teachers accepted that invitation. Four separate discussions took place at the EXSCITE Science Centre in Hamilton between 22 July and 24 July 1996. Participants were encouraged to take the opportunity and discuss various issues about out-of-school activities. As the groups were self-selected, no particular inferences could be made on issues like whether the distribution of teachers from different school types, areas, years of experience or gender was representative. All of the participating teachers volunteered also to participate at a later stage in questionnaires (chapter 4.3), which provided the statistical information below (see Table 11 and 12).

| Gender distribution | Number of participants | Percentage |
|---|---|---|
| Female | 19 | 51% |
| Male | 15 | 41% |
| No answer | 3 | 8% |

**Table 11:** Gender distribution in group interviews

The gender distribution above shows a slight majority of female attendees. This does not represent a true picture of the gender balance in the teaching profession which is, depending on the level and subject, more female biased. Possibly male teachers may have been more attracted to the exhibition or to participating in the questionnaires.

| School types | Number of participants | Percentage |
|---|---|---|
| Contributing School (Y1-6) | 3 | 8% |
| Full Primary (Y1-8) | 7 | 19% |
| Composite School (Y1-13) | 1 | 2% |
| Intermediate School (Y7-8) | 5 | 14% |
| Form 1-7 (Y7–13) | 3 | 8% |
| Form 3 – 7 (Y9–13) | 18 | 49% |

**Table 12:** Distribution of school types

The distribution of school types in the interviews is very similar to the distribution of school types in the questionnaires (chapter 4.4), but with a slightly higher number of participating teachers from Form 3-7 Schools. Table 12 shows a strong representation of teachers responsible for year 7-10 teaching – the target group of the exhibition (Hodder, 1997). The school types the teachers were representing were not separately identified during the interviews. Since the pool of participants was the same only for the Hamilton location, this was a good crosscheck for consistency of the voluntary samples.

#### 4.3.4.2 Experiences and expectations with earth sciences in a science centre

Experiences from teachers with outside-the-classroom-activities were from either visiting Science Centres like EXSCITE[1], ventures like the 'Telecom Road Show' or the 'ECNZ[2] Caravan'[3]. The last two differ somewhat from the philosophy of fixed Science Centres and were described to have some advantages. Such travelling exhibitions are non specific in coverage of science topic. They were reported to typically portray a wide variety of science and technology and were said to create enthusiasm and improve children's attitude to science and technology. Some of the drawbacks were that the presentations did not always fit with what teachers were doing at the time. Although a lot of activities were stated as excellent, teachers claimed that often too many children had to rush through the exhibition because there was not enough time and too many students, with high noise levels as an additional frustrating element.

---

[1] "EXploration in SCIence and TEaching", the Science Centre in Hamilton, NZ

[2] Electricity Corporation of New Zealand, Sponsor of educational programmes

[3] These 'road shows" are collections of exhibits that invite interaction and experience of a range of phenomena like, electricity, magnetism, optics etc.

> The Road Show [Telecom Road Show] has got excellent activities, but it's too much for a two hour tour and too many children are pushed through. (60/A/3)
>
> The Road Show doesn't fit into the curriculum, but you have to be flexible. (61/A/C)

Teachers had had opportunities to visit Science Centres in the past. They considered Science Centres as places where a lot could be seen and that the experience was perceived to be of value.

> It is a valuable experience and best in combination of class preparation and the visit. (40/A/2)

Teachers also mentioned that they thought the experience was beneficial, especially for younger students and if it was possible to fit it into the curriculum it could be used to maximum effect.

> It is very beneficial for ages 9-11 because of all the work we put into it before [we visit] and then comes the practical part. (59/A/1)

Teachers from rural schools who found it harder to visit a science centre would still try to do a trip each year to a nearby site of geological importance: Mount Tarawera for volcanism was a specific example cited. The inference here is that the experience is more important, than what the experience is.

Teachers stated that the support from parents and caregivers for a visit at a science centre often depended on the age of the students. Their experience was that parents considered that by secondary level outings would 'disturb' their children's education.

> Parents like to see school trips. (7/B)
>
> Their [parents] perceptions change when they are in secondary school, because the students education could be disrupted. (23/B)

If the centre's program is curriculum-targeted teachers were better able to justify these visits, which increased the level of support. Also, parents' support was often linked to the cost. Provided there were not too many trips each year, many parents would support teachers to go on school trips with their students.

> The parents' support depends on the cost. (35/B)

Planning was one of the major concerns for teachers. The amount of organisation was often dependent on whether the school was located close to the facility to be visited or not. Rural schools found it much harder to organise costly trips, which would sometimes require an overnight stay. Primary schools were considered to have fewer problems because teachers would usually only have to organise for one class. Teachers stated that they needed to know about a coming event well in advance (between one term and one year) in order to organise it.

> If you plan long-term you can included it into the curriculum. (34/C)
> It is hard to get to the exhibition when living in the country. (14/C)
> The co-ordination of actually getting out is difficult. (20/C)

The planning would involve co-ordinating whether and how the program could be fitted into the curriculum, determining whether the program was worthwhile, informing parents about the program and its cost, and organising transport and overnight accommodation, if necessary.

Following is a summary of the points that teachers made in the discussion regarding their experiences and expectations with earth sciences in a science centre. The summary also includes how often teachers made those comments:

- Twenty-three teachers said that the experiences they had had came from visiting science centres, science and technology road shows as well as field-excursions.
- Six teachers said that road shows were stated as being useful for generating a good attitude towards science but the themes were very broad.
- Ten teachers said that science centres were perceived to be of value and offered good experiences for students.
- Five teachers said that visiting a science centre was most effective if it was accompanied by pre and post visit preparations.
- Three teachers said that rural schools found it harder to include out-of-classroom experiences like going to a science centre and more often chose field-excursions.
- One teacher said that parents of secondary school students perceive that outings may disrupt the students' education.
- Five teachers said that parent support depends on the cost involved.
- Eight teachers said that they would envisage long term planning to guarantee that the curriculum could be targeted in the preparation.

#### 4.3.4.3 Experiences/expectations with geo-science education

In this discussion issues are highlighted that relate to science centres and to geosciences that arose in the interviews. Although it might seem more appropriate to separate expectations and experiences of science centres generally and geosciences specifically it was not possible as participants frequently mentioned them in relationship to each other. The interviews occurred before the visit to Earthworks, therefore these are preconceptions.

Teachers believed that students would need to *'see'* something in order to understand earth science concepts. In their explanations it appeared that 'to see' was associated with 'to experience'.

> Earth science is a very visual thing. (51/1/3)
>
> We try to do a lot of hands-on activities in this area. (43/2)

Comments were made that students would often learn more from looking at slides than reading textbooks. This might suggest that teachers perceive visual stimulation as more useful than reading information. This argument begs the question of whether students learn more by being visually stimulated or whether it enhances their attitude towards science, itself perceived by teachers as learning. Some teachers were quite surprised at the amount of interest of the students in earth sciences. Although experiences were mixed, particularly about how much information students would actually get from the explanations provided in a science centre, teachers hoped for an overall positive experience. Teachers' beliefs were that a practical stimulation would take students forward towards understanding, e.g.,

> Students will pick up at the level they can manage at the time. (50/A/1)

Teachers said that the experience in a science centre was very beneficial for students aged 9 – 11 years. Older students were perceived to be less convinced about the amount of 'new' information with which they could be provided at a science centre.

> Excellent experience for younger students, older students tend to think there is nothing there for them. (66/A/1)

In order to prepare students sufficiently, teachers said that science centre programs needed to be well advertised in order to give sufficient information as well as enough time so that classes could be prepared for the experience. Better advertising would allow the visit to be linked to the curriculum implementation that had been planned for the school or class.

They pointed out that the science centre was a valuable experience for them and worked best in combination with preparation before the visit. Independent studies with their students might be added or it might even be possible to make a connection with other curriculum areas. In a few cases the exhibition was planned as part of a follow-up of previous fieldtrips.

> With many children you count on the experience and hope they picked up something and maybe add independent studies or even connect with another curriculum area. (72/1/2)
>
> We had an emphasis on rocks last year we went to a limestone quarry, we had a geologist with us and went fossil hunting, this will follow it up. (49/A/2)

Teachers said that they themselves found the idea of an earth science exhibition very exciting, and that it would stimulate children's interest. The exhibition was expected to be a valued experience, because it highlighted a particular curriculum area. In addition, teachers also preferred bringing students to one place that covered a range of earth science topics rather than going to a number of places to cover the same issues.

In summary, the points that teachers made regarding their experiences and expectations with geoscience education are listed below.

- Three teachers said that they perceive earth sciences as a 'visual' subject.
- Twelve teachers said that they expect an overall impression from going to a geoscience exhibition, where students pick up information at their level, but most of all enhance their attitude.

- Five teachers said that they expect students to have most of all a practical experience from visiting a geoscience exhibition at a science centre.
- Three teachers said that they expect younger students to be most impressed by new information, older students are perceived to be harder to enthuse.
- Three teachers said that advertising in advance would allow teachers to plan pre-and post activities like field trips.

### 4.3.5 SUMMARY OF TEACHER INTERVIEWS

Teacher interviews revealed information about their experiences and expectations with science centres and geoscience education. The main comments that were made by the participants were:

*Planning* was a common difficulty of out-of-school activities. It often depended on the support they received from their schools and the parents. Key concerns were whether an activity was well advertised, how expensive it was and how to organise the visit and fit it with the curriculum. Parent support for visiting a science centre was stated to be less at secondary school level and depended on the cost involved.

Teachers' *experiences* with science centres or related road shows were overwhelmingly positive. It was perceived to be of value and offered good experiences. As a minimum effect they perceived it would enhance students' attitudes towards science. The experience at a science centre was mentioned to be very useful if it was combined with preparation and follow-up activities.

Teachers' perception of how students would achieve an *understanding* in earth science highlighted the value of practical experiences. Field trips, hands-on activities or even slide shows were said to be useful as it was said to be a very visual topic. Science centres were perceived to offer a wide variety of activities where students could select information at their own level but mostly enhance their attitude towards earth sciences.

*Expectations* for visiting *Earthworks* were that teachers could bring their students to one site that features various aspects of earth sciences. This was said to be easier than going to various places to cover the same range of topics. *Earthworks* was expected to give students a learning experience which could be subsequently developed through field trips or other pre and post visit preparations.

## 4.4 QUESTIONNAIRES

### 4.4.1 INTRODUCTION

This section presents data from and about teachers that was collected by using questionnaires. Surveys were conducted before a visit to Earthworks (pre-questionnaires) and after a visit (post-questionnaires). The section is divided into Part A – statistical information, which provides an insight into the sample profile, as well as comments on teachers' confidence in teaching earth sciences. This part also includes the earth science topics that participating teachers taught during the past year.

Part B reports on the background knowledge the teachers had in earth sciences. The data presented includes results from a multiple-choice test and drawings of a volcano that teachers made. The pre-questionnaire was intended to obtain information about teachers' experience in teaching earth science and their formal training in the subject as well as teachers background knowledge in earth science. The post-questionnaire aimed to provide information on changes in the knowledge or understanding that may have resulted from the teachers' visit to *Earthworks*.

After collecting the data, the questionnaires were immediately filed and coded in a relational database using Microsoft Access. [This program enables comparison of different categories of information.] The information was coded to facilitate data comparison. However not every question could be reduced to a code number. Some of the open-ended questions were not reducible in a convenient way for computer analysis. A coding frame (Cohen and Manion, 1994) had to be developed for these type of questions after the completion of the questionnaire.

The results of a post-questionnaire are then compared to the previous questionnaires. The section finishes with a summary.

### 4.4.2 PART A – STATISTICAL BACKGROUND INFORMATION

This section shows information gathered that forms a statistical background. Information includes gender, the school types, years of teaching experience, teacher qualification and whether those teachers had training in earth science by additional pre-service or in-service courses.

#### 4.4.2.1 Sample profile

As a minimum sample size researchers recommend having at least thirty respondents if the data are being used for some form of statistical analysis (Cohen and Manion, 1994). One hundred and fifty six teachers volunteered for this study. The participants came from four New Zealand cities, two in each of the North and South Island. Participants in the survey were either self-selected or nominated by their schools. Of the sample, the majority (63%) of participants were female, 34% were male and 3% did not specify (see Table 13). When asked about their years of teaching experience, nearly two thirds of teachers who came to a preview of the exhibition were women with 10 to 20 years of teaching experience. The majority of male teachers had taught for 20 to 30 years. The next highest groups represented were teachers with up to 5 years of experience for both genders. The group of teachers with 5 to 10 years experience and those who had been teaching for over 30 years were amongst the smallest groups.

| Gender | female | male | unknown |
| --- | --- | --- | --- |
| (n = 156) | 63% | 34% | 3% |
| Years of Teaching Experience | | | |
| 0-5 | 15 % | 8% | - |
| 5-10 | 10 % | 5% | - |
| 10-20 | **26%** | 6% | 1% |
| 20-30 | 8% | **14%** | 1% |
| more | 4% | 1% | 1% |

**Table 13: Summary** of sample profile

Teachers came from 7 different school types:

- Full Primary School (Years 1 to 8),
- Contributing School (Years 1 to 6),
- Composite School (Years 1 to 13 in one school - which may mean that there will be sometimes children of different academic years in the one class - often referred to as a Composite Area School),
- Form1-3 (Year 7-9),
- Form1-7 (Year 7 –13),
- Form 3-7 (Years 9 to 13) and
- Intermediate School (Years 7 & 8 only).

The distribution of school types as a percentage is shown in Figure 13.

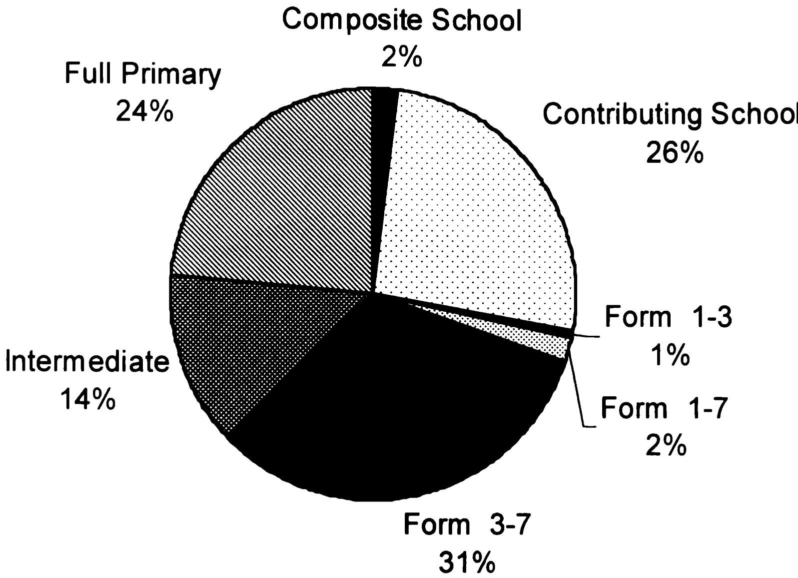



**Figure 13:** Distribution of school types in percentage.

Teachers were further asked about their formal training (Figure 14). Of all teachers, 32% had qualifications of a Bachelor of Science, whereas 22% held the Diploma of Teaching. Other qualifications that were held were Bachelor of Education, Bachelor of Arts, Bachelor of Social Sciences, Master of Science, Master of Arts, Master of Social Sciences and one Doctor of Philosophy in Education. 19% of all teachers stated that they had had pre-service training in earth science and a further 13% said that they had in-service training in the subject area. Typically the teachers with Bachelor degrees in science had passed geology papers either as pre-or in-service course. Within the group of teachers with a Diploma in Teaching (22%), only 3% had pre-service training and another 3% had in-service training in this subject.

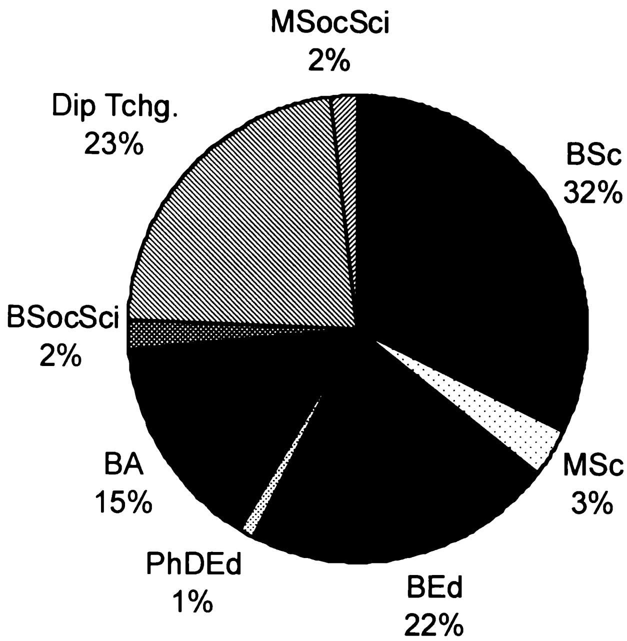



**Figure 14:** Teachers' formal qualification

The teachers' qualifications were compared with the school level they were teaching. The qualifications were arranged into three main areas: education, social sciences and science. The teachers' highest finished degree was used with an emphasis on science, e.g.: when teachers stating that they had a Bachelors degree in Art and Science they were put into the group of 'Bachelor of Science'. The level of schooling was organised into two groups: Year 1 to 6 and Year 7- 13. They made a general distinction between primary and secondary schools. Teachers were then arranged into those groups with which they would do the majority of their teaching, e.g.: Full Primary (Y1-8) assigned to 'Teaching year 1-6' in Table 14.

| Qualifications: | Teaching Year 1-6 (n = 72) | | Teaching Year 7-13 (n = 84) | |
|---|---|---|---|---|
| Education | Diploma in Teaching | 39% | Diploma in Teaching | 16% |
| | Bachelor of Education | 31% | Bachelor of Education | 14% |
| | | | Doctor of Philosophy in Education | 1% |
| Social Sciences and Arts | Bachelor of Arts | 20% | Bachelor of Arts | 7% |
| | Master of Arts | 4% | Master of Social Sciences | 1% |
| | Bachelor of Social Science | 1% | | |
| Science | Bachelor of Science | 4% | Bachelor of Science | 54% |
| | | | Master of Science | 6% |
| | No answer | 1% | No answer | 1% |

Table 14: **Teacher** qualification compared with the level of schooling

Table 14 shows that more than half of the teachers teaching Year 7 to 13 have a degree in Science, whereas the majority of teachers of the Year 1 to 6 teachers have their degrees in Education. The group of year 7 to 13 teachers also has a higher proportion of higher degrees (Master and Doctor of Philosophy).

#### 4.4.2.2 Teacher confidence

Teachers were asked to rate their confidence of teaching Earth Science to their students on a Likert scale from 1 to 5. On this scale 1 indicated very confident and 5 not confident. Only two participants chose not to answer this question (Figure 15).

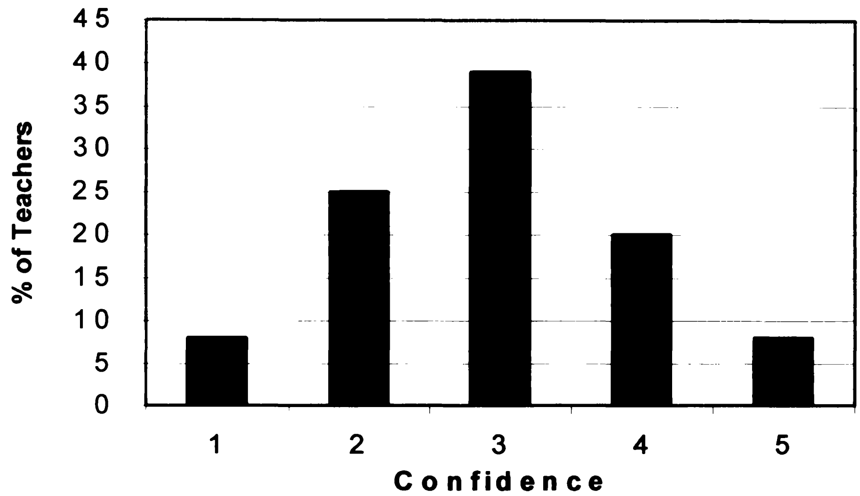



**Figure 15:** Teacher confidence

When asked for a reason for their confidence ranking, it became clear that the teachers' overall opinion was that background knowledge whether obtained through professional training or personal interest, enhanced confidence in teaching earth sciences. Comparisons of the rating for confidence with the qualification of the teachers or the years of teaching experience did not show any significant correlation. Each confidence group had a similar distribution of qualifications. A comparison of teachers' confidence with the years of teaching experience showed that each group had a similar trend of confidence rating. This general trend was that no matter how long teachers had been working in their profession the majority of teachers would place themselves into confidence group 3. Interestingly, the questionnaire showed that teachers with less than 5 years of teaching experience and teachers with more than 30 years of teaching experience had the highest proportion for not being confident. (Rating 5: 17% of all teachers with less than 5 years experience and 10 % of all teachers with more than 30 years of Teaching experience.). There is a clear association between confidence rating and the comments made, as shown in Table 15.

| Participant Code | Confidence ranking | Comment on confidence ranking |
|---|---|---|
| SS77 | 1 | I have various physics, geography and geology papers in my degree. |
| 0512 | 1 | My previous education and my natural interest lends to the subject. |
| PC08 | 2 | I spend time collecting resources and developing programmes. |
| 5491 | 2 | Geology in the degree and I enjoy the subject. |
| RJ41 | 3 | No real qualification, but very interested. |
| LM82 | 3 | I like and enjoy teaching it, but background is very light. |
| PN49 | 4 | Unfamiliar with the subject, hard to teach in multi-level class. |
| 7478 | 4 | Personal knowledge is limited. |
| RB56 | 5 | Not enough experience, lack of knowledge, lack of confidence to teach. |
| MN55 | 5 | Not studied, no interest. |

**Table 15: Examples** of confidence ranking and comments

Table 15 shows typical comments that were made by teachers representing their confidence group. One teacher with a low confidence (D19, rank #5) felt that this might affect the students' interest in earth sciences: "While children often find this a fascinating area to study I inhibit this enthusiasm through poor understanding myself." On the other hand, a more confident teacher commented (C92, rank #2): "Both children and I have found earth science topics fun and fascinating."

Often the awareness of the availability of resource material appeared to be associated with the level of confidence, as is shown in Table 16.

| Participant code | Confidence rank | Comment on confidence ranking |
|---|---|---|
| DISS | 2 | Plenty of books available. |
| H10 | 3 | Hard to find interesting, easy, practical activities. |
| C77 | 4 | Lack of teaching resources. |

**Table 16:** Examples of confidence ranking and the association of availability of resource material.

The result for category 'Lack of teaching resources' is particularly surprising. A quick search of the New Zealand Ministry of Education's web site shows that by comparison with other curriculum strands the number of resources for 'the Planet Earth and Beyond' strand published by Learning Media is quite large (Hodder and Otrel-Cass, 2000). This perception of not having enough resource material may be related to the fact that is in comparison to the other strands, Planet Earth and Beyond is new and teachers are likely to be less familiar about the availability of teaching materials. Comments associated with the confidence rating showed that the group with the most positive confidence rating mostly expressed that they felt so because of their professional training and that they enjoyed teaching the subject. Teachers who rated themselves as 2 on the confidence scale mentioned similar reasons as the first group, but also based their confidence on having enough resource material. Participants from the group with confidence rank 3 mentioned that they felt interested but weak on the content knowledge. Teachers who rated themselves with the number 4 or 5 stated often that there were no teaching resources and one teacher mentioned that there were also no training courses available.

Comparisons of the confidence rank and the qualification did show that all the teachers that mentioned a lack of resource material did not have qualification beyond undergraduate status. Further they had not had pre-service or in-service training in this area. Similar studies on teacher misconceptions in earth sciences (e.g., King, 2000) show that poor background knowledge is one of the main reasons for lack of confidence.

#### 4.4.2.3 Teaching earth science

Teachers were asked to identify all the earth science areas based on the 'Planet Earth and Beyond' strand of the science curriculum that they had taught during the past year (Figure 16).

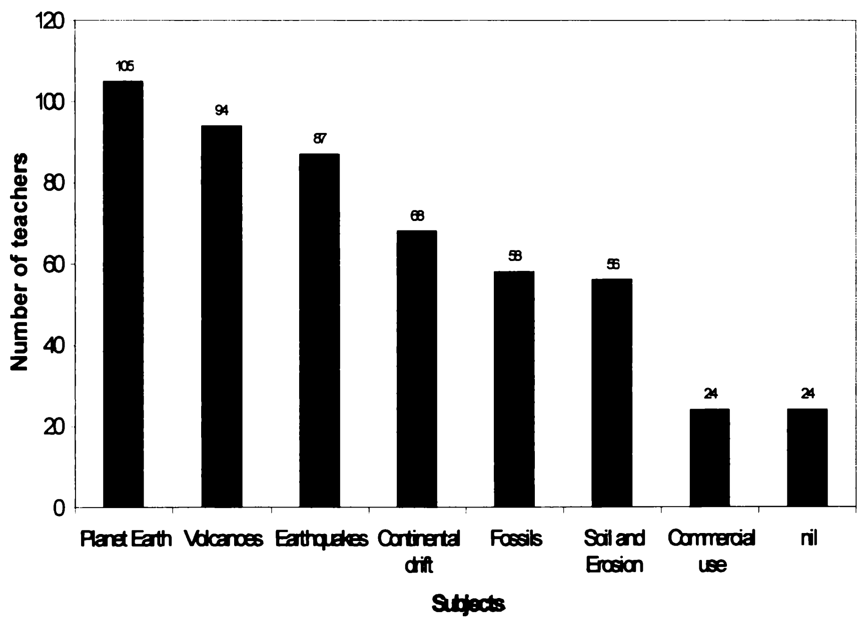



**Figure 16:** Earth science subjects that were taught by teachers during the past year

The topics earthquakes (56%), volcanoes (60%) and earth as a planet within the solar system (67%) were taught by more than half of all teachers. Topics that were taught by fewer teachers were fossils (37%), soil and erosion (23%) and commercial use of earth's materials (15%).

Fifteen percent of all teachers stated they had not taught any of those earth science areas during the past year. Planet Earth and beyond topics were however taught by 67% of teachers. This strand covers a wide range of topics other than earth science and is included at Level 1 (new entrant) up to Level 8 in the science curriculum. Volcanoes (taught by 60% of teachers) corresponds with level 4-6 (upper primary to junior high school) of the curriculum. The same applies to earthquakes (taught by 56% of teachers). Topics like fossils, soil and erosion and commercial use of earth materials are included in topics from level two to level eight. In this analysis the topics in the 'Making sense of Planet Earth and beyond' strand of the New Zealand science curriculum, are compiled from 'sample learning context', 'possible learning experiences' and 'assessment examples' (Ministry of Education, 1993).

The ranking of topics in figure 5, resembles that found in American newspapers and popular magazines, where natural hazards predominate (55%), followed by fossils – particularly dinosaurs (22%) and 'trendy' topics of global warming and climate change (12%) followed by minerals (8%) (Springer, 1997). This shows a relationship to the topic awareness of teachers that might be driven by their exposure to topics in books or other media. A comparison of topics that were stated by teacher with the levels to which they correspond in the curriculum shown on the table overleaf:

| | | Planet Earth and Beyond | Volcanoes | Earthquakes | Continental Drift | Fossils | Soil and Erosion | Commercial Use |
|---|---|---|---|---|---|---|---|---|
| 1 | Earthquakes | | | ● | o | | | |
| 2 | Floods | | | | | | ● | |
| 3 | Fossils | | | | | ● | | |
| 4 | Dinosaurs | | | | | o | | |
| 5 | Minerals | | | | | | | |
| 6 | Global Warming | o | | | | | o | |
| 7 | Volcanoes | | ● | | | | | |
| 8 | Greenhouse Effect | | | | | | | |
| 9 | Human Evolution | | | | | | | |
| 10 | Groundwater Pollution | | | | | | | |
| 11 | Plate tectonics | | o | o | ● | | | |
| 12 | Glaciers | | | | | | | |
| 13 | Ice Ages | o | | | | | | |
| 14 | Landslides | | | | | | o | |
| 15 | Groundwater | | | | | | | |
| 16 | Seismic activity | | o | ● | | | | o |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

**Figure 17:** Comparison of geological hit-list (Springer, 1997) with topics that teachers taught during the past year. Close correspondence of exhibits to topics is shown as closed symbols; exhibits inferred to correspond less closely with topics shown as open symbols.

The comparison with Springer's list is interesting, although a straight comparison with American papers and magazines can only be indicative because it might imply that the New Zealand Print Press features similar articles. Nonetheless, hazardous themes are often of great interest to the public. For example, volcanic eruptions of New Zealand volcanoes have featured extensively in recent years' newspapers in New Zealand, and often feature in earth science books at introductory levels. Thus, it is not surprising that teachers are likely to decide to include this topic. By comparison, there has not been much about commercial use of earth materials that has hit the papers. No corresponding study has been done in New Zealand but it can be expected to be similar to the United States experience except for that in the time between 1995-96, when one of New Zealand's active volcanoes Mount Ruapehu, erupted and received extensive and prolonged media coverage.

### 4.4.3 PART B – BACKGROUND KNOWLEDGE

In this part of the questionnaire the background knowledge of teachers was assessed. This was done in two different ways, firstly by a multiple-choice test and secondly by drawing a picture.

#### 4.4.3.1 Multiple-choice test

Teachers had to state whether particular earth science and astronomy statements were 'true' or 'false'. If they were unsure they could also choose to tick either 'never heard' or 'not sure'. Only two participants chose not to complete this section of the questionnaire. Two thirds of all participants (76%) ticked between 4 and 7 correct boxes (out of 8) in the multiple-choice section. The outcomes of the knowledge test were compared with data from the statistical part of the questionnaire, like school type or years of teaching experience. Teachers who scored highest typically came from secondary schools (Form 3-7 schools) and from year 1-6 primary schools. Teachers with lower scores generally came from full primary schools and intermediate schools.

In the next part of the multiple-choice section teachers were asked about the locations of volcanoes in New Zealand in the past and the likelihood of future eruptions at the same location. Interestingly there were regional differences in knowledge of this topic. (see Table 17) Teachers in the South Island had better knowledge about both their local volcanic history and that of New Zealand overall than their colleagues in the North Island.

| | Knowledgeable about volcanism in: | |
|---|---|---|
| Resident in: | North Island | South Island |
| North Island | 95% | 62% |
| South Island | 100% | 92% |

**Table 17: Knowledge** about New Zealand's volcanism

The multiple-choice test was also compared with the confidence scores of teachers, so that often teachers who stated earlier that they did not feel confident teaching earth sciences also had overall low scores in the knowledge test.

### 4.4.3.2 Volcano drawings

Teachers were asked to draw a volcano and label its features. A point was given for each of the following features (either in the drawing or as a written explanation): volcanic cone-form, magma chamber, internal plumbing (e.g., from magma chamber to vent), involvement of water or gas, correct layering of erupted material (e.g., parallel to the flanks of the cone). Thirteen teachers decided not to attempt this question.

The following table lists the percentage of teachers with the number of correctly drawn volcanic features.

| Number of correct features (*N*) | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Percentage of participants who drew or explained *N* features | 26 | 35 | 21 | 8 | 1 |

**Table 18: Volcanic** features

Often volcano drawings would show a cone with internal plumbing; additional features were then typically either a magma chamber or correct layering. Only eight percent of the participants drew four features and only one percent included any involvement of gas or water. This outcome indicates a rather limited understanding of volcanism by teachers and was disconcerting considering that earlier in the questionnaire 60% of all teachers had stated that they had taught volcanoes during the past year (see Figure 16).

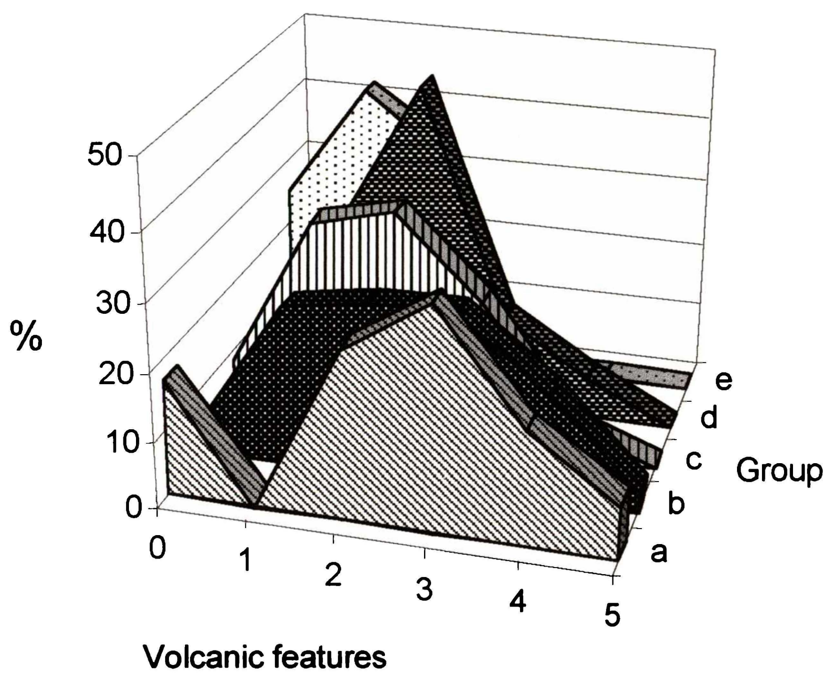
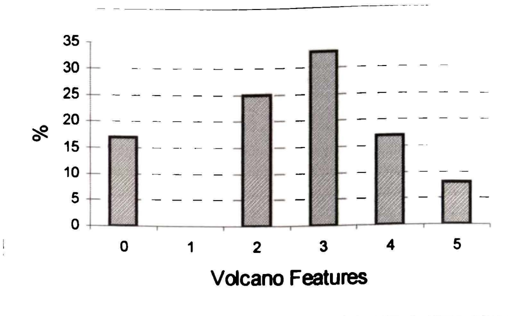



**Figure 18:** Confidence and Volcano Drawings (group a = confidence 1 group b = confidence 2, group c = confidence 3, group d = confidence 4, group e = confidence 5; confidence from 1 (highest) to 5 (lowest).

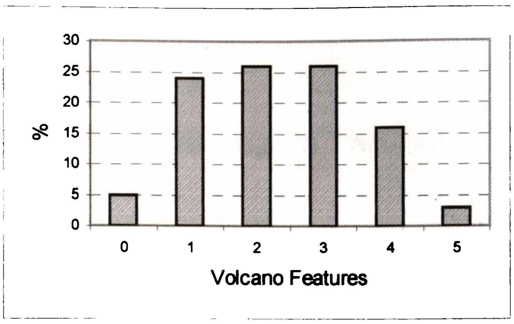
A comparison between the confidence (perceived knowledge) and the volcano drawings (actual knowledge) did show that more than 50% of teachers who had low scores in the drawings were amongst the very low confidence group. This relationship could be traced with every other confidence group (see Figures 18 and 19).

This is supportive of Gobert's (2000) suggestion that a correctly drawn diagram will function as a support for further integration of concepts, whereas a incorrectly constructed diagram will produce a barrier for further understanding.

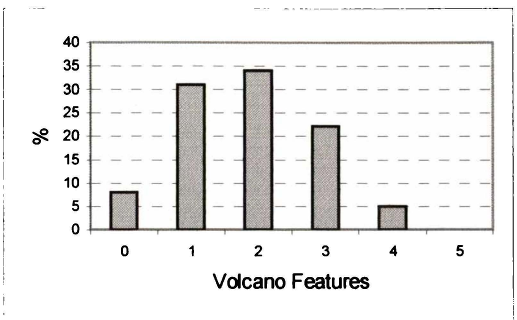
Group a
Confidence Rank 1



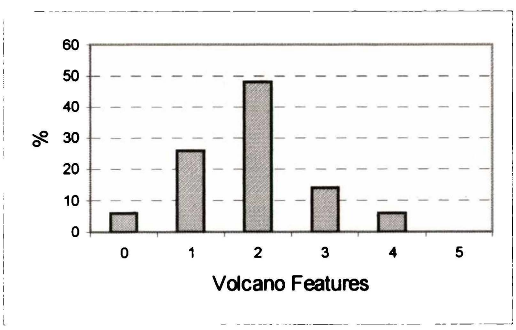

Group b
Confidence Rank 2




Group c
Confidence Rank 3




Group d
Confidence Rank 4




Group e
Confidence Rank 5

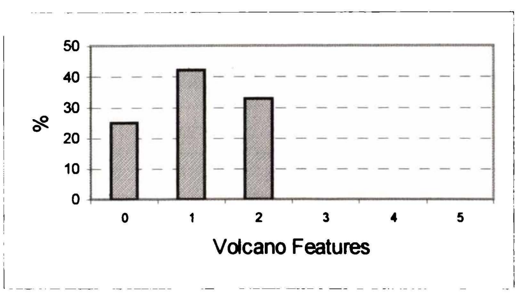



**Figure 19:** Comparison of Volcano Drawings and each Confidence group (group a = confidence 1 group b = confidence 2, group c = confidence 3, group d = confidence 4, group e = confidence 5; confidence from 1 (highest) to 5 (lowest).

Calculating a weighted average of the number of the volcano features and comparing this with the confidence ranking showed a statistically significant result. The weighted average calculation was done as follows:

$$Av = x_{(\%fo)} * f_0 + x_{(\%f1)} * f_1 + x_{(\%f2)} * f_2 + x_{(\%f3)} * f_3 + x_{(\%f4)} * f_4 + x_{(\%f5)} * f_5 / \sum$$

Where:

Av = Weighted Average for a confidence rank

$X_{(\%fn)}$ = Percentage of participants drawing 'n' number of volcano features

$F_n$= 'n' number of volcano features

$\sum$ = sum of x for a confidence rank

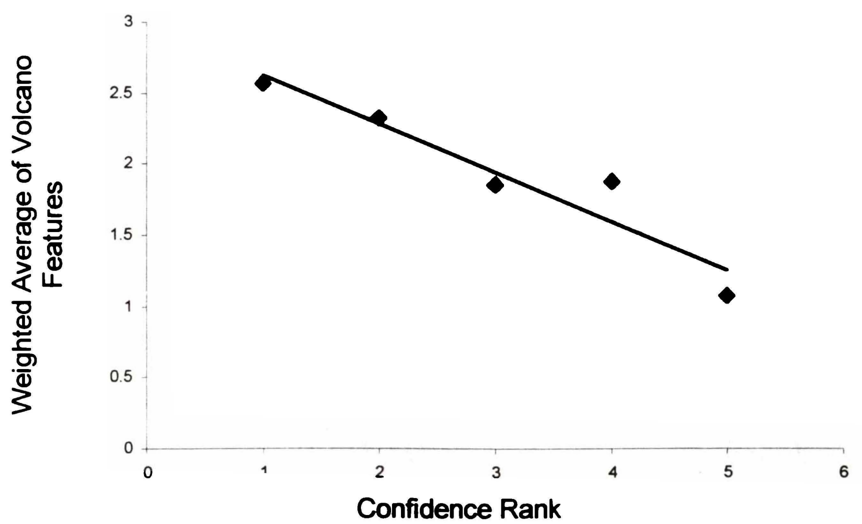



**Figure 20:** Comparison of weighted average of the number of volcano features with the confidence ranking.

The linear regression of the volcano features and confidence rank in Figure 20 shows a statistically significant trend of better volcano drawing results with increased confidence. This result supports the findings discussed earlier and highlights the relationship between confidence and knowledge.

### 4.4.4 POST-QUESTIONNAIRES

#### 4.4.4.1 Introduction

For the post-questionnaires the participants in the pre-questionnaire activity were contacted after the exhibition had moved to another venue. Seventeen percent of the contacted teachers responded in this round. While the number of replies that participated in the post-round of questionnaires was not very high (26 participants) and therefore not suitable for statistical analysis it still gave some valuable ideas about teachers' perceptions of the exhibition. The post-questionnaire had the same layout and contents as the pre-questionnaire, except that it included some additional questions about how teachers perceived the exhibition and what impact it had had on their teaching of earth sciences.

#### 4.4.4.2 Post-Questionnaire: Confidence in teaching Earth Science

The majority of the teachers who responded to the post questionnaires ranked their confidence for teaching earth science at 1 or 2 (the two highest scores). The explanation teachers gave for their confidence ranking showed that teachers felt more positive about the subject earth science after their visit to the science exhibition, for example, Subject PQ8 and PQ10, both confidence 2 stated this:

> Confirmed prior knowledge opened new areas for investigation. (PQ8)
>
> Yes, greater understanding of macro processes that are seen at a local scale. (PQ10)

A majority of teachers stated that the teachers' workshop in conjunction with the exhibition helped them considerably for example, Subject PQ9 and PQ15, both at confidence rank 2 had this to say:

Not only the exhibition, but the workshop presenting the information in a different way, and making the resources, were particularly valuable. (PQ9)

Pre visit talk was the most helpful. (PQ15)

The teacher's reported on the exhibits that were perceived as having been of good value in the following ways for example:

Showed principles clearly and simply, and when they worked. (PQ4)

Large scale effect, very visible – *[geyser].* (PQ8)

Size and simplicity were the leading factors of good value exhibits, named by the majority of teachers

Disappointment was expressed whenever exhibits were not working and when the exhibit was too complicated, for example:

River Flume- not enough sand. (PQ 7)

I was very disappointed, there were no AV displays or pictures, no rock samples and hardness testing; something, that primary kids could relate to. (PQ 13)

One respondent (Code PQ13) shows that teachers came with certain preconceptions of what the exhibition would show. In this instance the teacher felt that Earthworks was not suitable for the younger audience envisaged by the designers.

Unfortunately, very few of the participants of the post-questionnaire used the personal code they selected in the pre-questionnaire so that a direct comparison of pre- and post-data was not possible. The few teachers that did use the same codes were amongst the group of teachers with high confidence (rank 1 or 2) in the pre-questionnaires. Their rank was generally unchanged by the Earthworks experience. Only one respondent showed an increase in confidence ranking towards feeling more confident (change from 3 to 2).

It can be assumed that the teachers who participated in the study were already reasonably highly motivated towards earth science. Thus the study may not be a fair representation of the teachers' nation-wide. Furthermore, given that the group that participated for the pre-questionnaires was also self-selected there is a strong suggestion that this group was more motivated towards geoscience and science and technology centres. It might be therefore reasonable to infer that within the science education community overall, the knowledge of geoscience and enthusiasm for interactive science centres will be lower than reported here.

#### 4.4.4.3 Post-Questionnaire: Earth Science knowledge

The results of the knowledge part of the questionnaire were very good. When asked about the volcanism in the past and the likelihood of volcanism in the future it was noticeable that a lot of the participants were now better informed about volcanism, both in the North Island and South Island. When asked to draw the internal structure of a volcano, many teachers drew three or more volcanic features and on average the explanations showed an improved understanding of volcanic processes. As mentioned in section 4.3.4.1 it was not possible to make a direct comparison of the data from the pre and the post-questionnaires. The good results in the post-questionnaire may be because of any or all of the following:

- only teachers replied who felt confident and scored high in the pre-questionnaire
- after the exhibition teacher felt 'inspired' to look up more information

- teachers did learn more about the things they were asked in the pre-round after they did the teacher workshop and had seen *Earthworks*.

### 4.4.5 SUMMARY

In this section data that were collected by using pre-and post-questionnaires were presented. One hundred and fifty six teachers participated and answered questions concerning their teaching background and confidence in teaching earth sciences as well as taking a knowledge test. Only twenty-six teachers replied in the post-round. The results showed that teachers came from different types of schools and had various types and levels of qualifications. Their confidence in teaching earth science typically increased with the amount of formal training they had in this area. Nevertheless, in spite of the variance in knowledge and confidence, more than half of all teachers had taught various earth science subjects, usually on hazardous themes like volcanoes and earthquakes.

These findings were compared with topics that are popularised in United States print media (Springer 1997) and showed a similar order. Most of the topics that teachers had stated they had taught in the previous year are represented in the science curriculum from level 1- 8; some topics correspond to areas from level 4-8. Topics that were only taught by few teachers were represented at all levels of the science curriculum. This comparison lead to the belief that the selection of earth science topics might be more related to Springer's (1997) 'hitlist' of popular earth science topics than to their representation in the science curriculum.

In the knowledge test teachers did overall quite well passing with 50 to 70 % correct answers. Typically teachers from secondary schools scored higher in the knowledge test. The confidence rating did also correlate with the knowledge test. However, drawings of volcanoes often showed only 2 to 3 features and only a small percentage of teachers were able to draw volcanoes with 4 or more characteristics. This contrasted with the finding that 60% of all teachers said that they had taught volcanoes in the past year. The number of features that were drawn also correlated with the confidence ratings.

The small number of replies of the post-questionnaires nevertheless indicated an improved awareness and attitude towards earth sciences. The exhibition and the teacher workshops were said by respondents to have had a positive effect on their knowledge and attitude. These findings are also supported by research in the UK that showed that teachers had very poor background knowledge in earth sciences and gained confidence by attending earth science workshops (King 2000). In addition, when it is considered that the participants were largely self selected, it is inferred that the teachers who replied represented a group of more motivated teachers. The confidence and knowledge of teachers overall is likely to be considerably less than this study suggests.

## 4.5 DOCUMENT ANALYSIS

### 4.5.1 INTRODUCTION

The document analysis section critically reviews written information to establish the background philosophy from which exhibition developers approached the project. Three documents were examined to elicit the designers' and developers' way of interpreting earth science ideas and how they thought these ideas could be represented in the *Earthworks* exhibits. This section begins with an introduction to the three documents that were analysed. The following part will discuss answers to particular questions that were chosen to review the documents. A summary concludes the section.

### 4.5.2 THE DOCUMENTS

Three sources of information were examined:

I. *Earthworks* – a guide to the exhibition; Peter Hodder, Department of Earth Sciences, University of Waikato.

This document included technical details but it was mostly devoted to explaining the educational background of the exhibits. The explanations were subdivided for each exhibit into: 'Scientific idea', 'How the exhibit works' and 'Educational aspects'. The author was the director of the project and was substantially involved in the development of *Earthworks*. The document was intended both to be a record of the purpose of the exhibit, and to be available to teachers attending the exhibition.

II. *Earthworks Maintenance Manual*; Catherine Iremonger, Project Manager, Exscite Science Centre, Hamilton.

This document was written by the project manager of *Earthworks* to facilitate the installation and continued operation of the exhibition from a technical standpoint. Every exhibit was described and the descriptions were subdivided into: 'Design', 'Layout', 'Power requirements', 'Electrical Specifications', 'Material Specifications', 'Maintenance' and the 'Summary of the Display'. This document also included a Condition Report for each exhibit.

III. *Earthworks – the teachers guide;* Peter Hodder, Anne Hume, Andrew Jenks and Julia Peters, Department of Earth Sciences, University of Waikato, Occasional Report No.20, ISSN 0110-0947.

This document was prepared by a Teachers Advisory Group (TAG) as supportive material for teachers who visited *Earthworks*. It concentrated on classroom activities and information that were linked with the *Earthworks* exhibits. This could be used for preparation (i.e. pre-visit) or post-visit activities. Each section referred to the *Earthworks* exhibits and to the curriculum links, before supplying background information and activities.

### 4.5.3 THE DATA

This was a study of communication: the communication of the exhibition providers with different audiences - teachers, visitors or other museum personnel. By evaluating already written material the observation of the communication became indirect. A sampling technique described by Babbie (1992) was used to determine about which or whom descriptive and explanatory statements are to be made (see section 3.5.4). This technique required that the data were divided into units of observation and units of analysis (Babbie, 1992, p.314). Furthermore, three questions were chosen to assess the research question of this study of how earth sciences are portrayed in the interactive science exhibition Earthworks (see Figure 21).

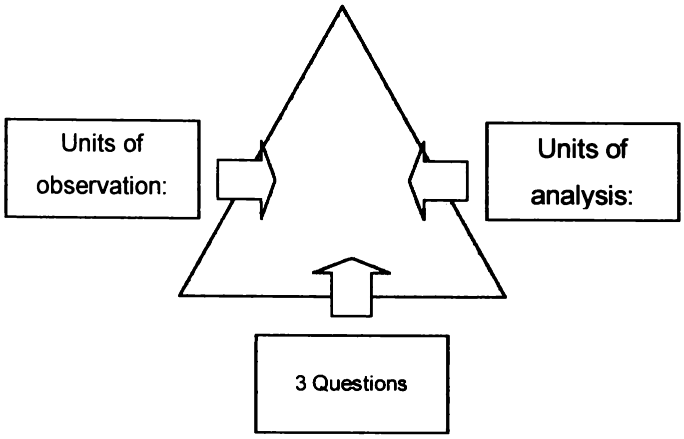



**Figure 21:** Information triangle for the Document Analysis

Each exhibit (*unit of observation*) was reviewed in each document (*unit of analysis*) for the following query:

- What were the main aims of the exhibits?
- What ideas did the exhibition providers seek to present?
- How did the exhibition designers achieve it?

Each of the documents had a different focus and was written for a different purpose. While one document (Document 2) concentrates on technical issues another one (Document 1) discussed the educational background. The third document (Document 3) was obliquely related to the exhibits, putting them in a wider educational context and thus was a very different type of document. However, they were all concentrating on the units of observation – the exhibits. To answer the questions that were selected, the documents were reviewed without comparing them with each other.

#### 4.5.3.1 The purpose of the exhibits

This first question investigates what the designers and developers reported in the documents as the most important features of the exhibits. The documents were evaluated on the main aims of the exhibits. This is important because it illustrates the objectives of the simulations. Findings are later compared with comments made by students and teachers and this gives insights into the exhibition developers intentions and how the visitors perceived them.

The main aim that the Earthworks exhibits envisaged was to "show the physical principles behind some of the processes that have shaped and continue to shape the surface of planet Earth" (Document 1, Hodder p.1). For example in the Mechanical Model of Plate Tectonics participants could simulate the movement of the sea-floor by manually cranking the heat convection.

Many of the exhibits showed geological aspects that are impossible to observe in reality because they are inaccessible due to scale, location or time. These included a subduction zone (Mechanical Model of Plate Tectonics), the consequences of plate tectonics (Continental Jigsaw) or internal and underground plumbing of a geyser (Geyser).

Simulations and models were also often smaller, simplified representations of real life situations, e.g.: the River Flume and the Wave Maker.

The other aim of the exhibits was to invite interaction. This varied in the degree of interaction: ranging from group activities like the re-assembly of a stratigraphic column (Rock Fall) or the diverting and damming of water (River Flume). Simpler demonstrations concentrated on showing a single geological process. For example, the exhibit Volcano represents a simplified demonstration of a scientific principle (viz., that an eruption is a result of pressure build-up). Some of the exhibits invited participation in an experimental investigation, with controlled variables and measurements that could be taken to answer 'What if?' questions (i.e. different materials and shaking frequencies for the exhibit Shaking Table). Some of the exhibits focused primarily on the impact of the experience (Buck'n'Ham Palace). For those exhibits additional material should give an opportunity for experimentation and inquiry.

#### 4.5.3.2 The presentation of the earth science exhibits

Even though the exhibition was designed to appeal to a wider audience, it was designed with the learning needs of Form 1-4 students in mind. The underlying ideas of the exhibition providers on how earth science concepts should be presented were investigated. *Earthworks* needed to reflect the requirements of the learning strand 'Planet Earth and Beyond' in the New Zealand science curriculum. For example:

> Earthwork exhibit - Volcano:
> It demonstrates the relationship between gas pressure in the magma reservoirs and the explosivity of eruptions.
>
> Curriculum link:- Strand – Planet Earth and Beyond:
> Investigate the composition of planet Earth and gain an understanding of the processes which shape it.
> Strand – Making sense of the Physical World: explore and establish trends, relationships and patterns involving physical phenomena.
> Strand- Making sense of the Nature of Science and its relationship to technology: gain an understanding of personal, community and global implications of the applications of science and technology.
> (Hodder et al., 1996, p. 32-33)

Bearing the curriculum links in mind, the exhibits concentrated on central geological concepts like the concept of plate tectonics (Mechanical Model of Plate Tectonics), the reconstruction of the super continent Pangea and the Laurasian and Gondwana fragments into which it split (Continental Jigsaw), river systems from the hydrological cycle (River Flume) or geothermal systems (Geyser). The exhibits were to appeal visually and reflect the central geological concept. For example:

> Earthworks exhibit - Settling Tube;
> The display showed the different settling rates of different sized particles. The settling of particles through a water column depends on their size, shape and density. In general, the larger and heavier particles will settle out first, followed by the finer grained ones. The effects of currents and water turbulence moderate the whole process, which are themselves affected by the water depth and closeness to shore.

In this case visitors could invert a large cylindrical tank which would cause the water to mix up. The different settling rates for the materials in the tank could be viewed. Although the idea being portrayed was quite simple, it was appealing to both adults and students within because it was large and therefore visually impressive and easy to operate. While processes that the Earthworks simulations portrayed were based on those suggested by the national science curriculum, the transformation from curriculum statement to exhibit was based on the ideas, understanding and experience of the designer team. So for example the science curriculum states as a possible Learning Experience for Making Sense of Planet Earth and Beyond at Level 3: "Making a model volcano to illustrate its character (Ministry of Education, 1996, p.113)". The transformation into the idea of how to portray this process in a simulation was then subjected to what designers considered to be effective.

#### 4.5.3.3 From conceptualisation to presentation

The analysis of how exhibition providers presented their ideas showed the transformation of concepts into workable exhibits. In order to show geological processes exhibits had to be able to show change. In some cases the change and end result were pre-designed in so far that the visitor could not make any alterations. For example the Mechanical Model of Plate Tectonics:

> A tank that sits on a table with the dimensions of 1.2 m x 0.3m x 1.2 m. The display inside the tank sits on two conveyer belts one of which is also connected with a handle on the outside. By moving the handle in either the one or other direction the conveyor belts moved either towards each other or apart. On top of the conveyor belt were sheets of rubber foam mounted such that they would crumple up when colliding. The tank was painted to hide the internal mechanics and to display the internal structure of the Earth. On the right side of the tank was a rubber foam montage that depicted an upfolded mountain chain.

By manipulating the exhibit it would show a simplified version of a constructive and destructive plate boundary. The person handling it could not control the changes that the exhibit showed, it was, therefore limited in the extent of explanation it could give. The decision of how the exhibit worked depended also on whether it was a magnification of a process (e.g., Settling Tube) or a scaled down version of reality (e.g., Geyser). When the exhibit was operated on behalf of the visitor (either for reasons of safety or other reasons) other means had to be designed to make the exhibit interactive. This was achieved in various ways. For example, although the exhibit Shaking Table used a motor to provide the shaking at various frequencies, the visitor could alter this frequency. In addition, the visitors could choose which ground material to use (e.g., wet sand / dry sand) and different sized "buildings". The landscape could also be altered (flat/hilly) by putting the ground material in the desired formation.

Other exhibits were far more restricted in the type and extent of interactions that were possible. The Geyser for example, involved a complex heating arrangement, which could not be handled manually for safety reasons. However this exhibit included some possibility for interaction in so far as it included a push button that depleted hot water. This was intended to show how commercial use of geothermal resources and affected the interval between and the intensity of the Geyser's eruption.

Other exhibits were purely mechanical. The Wave Maker, for example, included a paddle at one end of the water filled tank and a graded beach at the other end. Moving the paddle could generate waves and the slope of the beach could be altered by manually moving the sand in the tank.

Some exhibits like Rock Fall or Continental Jigsaw that invited group activity used game playing incentives (playing puzzle). Rock Fall even augmented this role playing approach by supplying hard hats and showing the cliff face at a near-life size. The students were invited by the instructions to re-build the broken down cliff face and identify (like geoscientists) the different layers in the strata.

A lack of time meant that no formative evaluation was conducted. This would have assessed whether the designers' aims were achieved before the exhibition started. Wizevich (1993) described such a study as an opportunity "...to obtain information on the ability of each exhibition component to communicate as intended" (p.9). While the exhibition was touring some of the exhibits had to be adapted to withstand the physical wear and tear, but no substantive changes were made.

### 4.5.4 SUMMARY OF DOCUMENT ANALYSIS

This section presented data that were produced by conducting a content-analytic study of three documents. Three questions were identified that investigated the research question of how earth sciences are portrayed in the interactive science exhibition *Earthworks.* The three documents were systematically sampled by reviewing each exhibit's description. The first question identified the main aims of the exhibits, which were firstly to show physical principles of geological processes and secondly to invite visitors to participate. This aim seemed to be often realised in the exhibition by simulations like Plate Tectonics or the Geyser. However, the simulations did not always offer a simplified version of reality but had to use analogues to operate the simulations. For example the exhibit Volcano had to use air pressure to initiate an eruption. The second question asked what ideas the exhibition providers were trying to portray.

*Earthworks* was designed to reflect the learning needs of Form 1-4 students, as described in the Planet Earth and Beyond strand of the New Zealand science curriculum. *Earthworks* also sought to show geological concepts that are central to earth sciences. Ideas that were portrayed in the exhibition were therefore highly affected by the ideas that are specified in the national science curriculum. The designers' team adapted these ideas based on their own experience and understanding to shape the final version of the *Earthworks* simulations. The third question was concerned about how those aims and ideas were put into practice. The review showed that the exhibits varied in the degree of interaction, depending on the scale of process they were representing, whether they were engine powered or mechanical models and whether they invited group activity. This process of development seemed at least to some extent based on trial and error. No formative evaluation was conducted to assess the suitability of the exhibits before it was put in place. While the exhibition was touring some exhibits had to be adapted to withstand wear and tear they experienced.

## 4.6 SUMMARY OF THE PRESENTATION AND DISCUSSION OF THE DATA

One of the more complex tasks of this study was to achieve a complete description of the presentation and reception of earth science simulations at science centres in New Zealand. This study endeavoured to accomplish this by obtaining data from different perspectives. In this way not only was the information from different sources, but each source of data was interrogated in a different way. This led to the even more complex issue of comparing the data and organising it into a meaningful relationship.

During the observations at *Earthworks*, time and behaviour of visitors was the focus. Although this does not seem to differ from the approach of other studies (e.g., Wizevich, 1993), the key difference in this study was the focus afforded to the interaction between the visitor and the exhibit. During the observation, an exhibit, which was selected on the criterion of being a simulation, was observed for a minimum of three minutes and if nobody stopped to view it, another exhibit was selected. The observation concentrated on recording and if possible specifying the type and sequence of behaviour that could be observed. Compared to studies that tracked visitors' viewing time with static exhibits (e.g., Geyer, 1995) this study showed much longer viewing times with the interactive simulations.

Some key issues that stood out in the observation were that firstly, visitors were attracted to visually and acoustically impressive exhibits. Comparisons that were made with the 'interviews with students' showed that in fact, exhibits which were on a lower level of interactive style still achieved a high impact based on their visual and audible characteristics. Secondly, factors that increased the duration of the engagement with an exhibit were physical engagement and talk. In fact the activity 'talk' generally dramatically increased the time that visitors spent with an exhibit. Thirdly, the activity 'reading' was observed to be generally motivated by the agenda of a visitor. Typical agendas were for example, that a student had to fill in worksheets or if a student did not know how to operate an exhibit. The reading activity was not dependent on the difficulty of the text.

Interviews produced data, which showed the experiences of students and teachers with the *Earthworks* exhibition. The interviews with the students which were conducted several weeks after their visit, did not differentiate between that information gained at *Earthworks* and the information that had been 'updated' by post visit work at school or at home. The reliability of these data came from the diversity of the students, being from different schools and from different places. This allowed this study to make conclusions about the impact of '*Earthworks*'.

The answers students gave regarding the simulations could be distinguished between exhibits which were remembered only on their visual qualities (recognition only) and those which were remembered from the experiences the students had made (recognition and description). This observation may be also classified as body memory (Brooke, 1994) and is a mixture of cognitive and affective experiences. The need to give a meaning to situations became clear when students were looking at photographs of the exhibits and even if they were not clear about the purpose of the exhibit they would still try to construct an explanation. Comments by students that they had looked at a certain exhibit but had decided that it was less interesting, implies that the same process happens in a new situation where a subject quickly constructs a meaning and decides whether it is worth while pursuing. This may be the case for the 14 % of visitors that were observed not to stop for an exhibit and may also account for visitors (9%) who were characterised to have looked at an exhibit but left shortly after that.

Findings were that highly simplified simulations, like the Plate Tectonics exhibit showing the subduction of plates and rifting, achieved their purpose very well in explaining the meaning of the underlying concept. The near life size simulation of stratigraphic sequences, even though it involved students in long engagement (up to 350 seconds, see section 4.2.5) was at times misinterpreted as showing plates rather than strata. A possible solution to that problem might be a simulation that shows the gradual build up of strata and the deformation processes before students work on the three dimensional strata puzzle.

Concepts that concerned 'geological time' were in general difficult for the students, and were, typically, related to human existence. Overall findings were that concepts were well understood if they were well communicated and put into perspective.

For some exhibits it appeared that the point of interaction was not always clear nor was the relationship was with reality explained well enough. So for example, the exhibit 'Plate Tectonics' was interpreted by most students to present the action and consequence of manually moving the plates, while the exhibit s intended to show the plate movement in nature driven by heat convection. By comparison, the lever that was used to move the water in the exhibit Wave Maker was interpreted for the real life situation of a tsunami by students as the product of the wind. The inference is then that certain exhibits did not make a clear enough bridge from the demonstration to the natural phenomenon. Recording the time students spent with the exhibit was not sufficient information to draw any reasonable conclusions regarding the quality of the exhibit.

Teachers who were invited to interviews expressed their views on visiting science centres with their classes. They expressed concerns about the planning of out-of-school experiences, but said that they had overwhelming positive experiences visiting those places with their students. They commented on the importance of practical experiences in earth sciences. Further that they perceived earth sciences to be dominated by visual learning. They also liked the idea of going to a science exhibition featuring various earth science concepts. Programmes that are curriculum targeted allow . them to plan and fully include out-of-school activities into their science programme.

The interviewed group of teachers was part of a much larger group of teachers who participated in questionnaires. The results of that study showed that teachers' confidence teaching earth sciences was dependent on the amount of formal training they had received. Nevertheless, many had taught earth science topics at school, with a particular preference for hazardous themes like earthquakes and volcanoes. This preference for hazardous themes might well be correlated with the selection of students' choices of their most favourite exhibits from the student interviews ranking earthquake, geyser and volcano exhibit as their three favourite exhibits.

Teachers' overall high score in a knowledge test was not replicated when they were asked to draw the internal structure of a volcano. This seems to indicate a lack of visualisation of spatial as well as causal component processes. There are also studies which suggest that wrongful completed diagrams act as barriers for deeper understanding (Gobert, 2000).

In the document analysis three questions were posed and three documents were analysed. The questions aimed to find out firstly, what the main aims of the exhibits were, secondly what ideas the exhibition providers tried to portray and lastly, how those aims and ideas were put into practice. The analysis showed that the exhibition providers' aim was to produce mostly interactive exhibits, which would concentrate on portraying the physical concepts of geological processes. The exhibition designers wanted to address the learning needs of Form 1-4 students and based the educational requirements on the Planet Earth and Beyond strand of the New Zealand science curriculum. The designers' team adapted these ideas based on their own experience and understanding to shape the final version of the *Earthworks* simulations.

By comparing the findings with the other investigations in this study it was shown that there are sometimes discrepancies between the designers ideas on how to represent a concept and actually producing a workable exhibit. Difficulties were experienced when the exhibits' design did not portray clearly enough what part of the concept the participants' interaction stood for. The provider's concepts included some of the requirements of the Science Curriculum, adapted to the needs of New Zealand science centres and also clearly reflected the needs and wishes that teachers expressed in the interviews. However the designers' ideas did not give any particular regard to typical misconceptions in earth sciences, nor did they reflect during their planning stage on any pre-exhibition evaluations, which often is a cost-related decision of science centres.

The overall impression from the interviews, the questionnaires and the observations was that the design of the *Earthworks* exhibits was a success in so far that certain exhibits were extremely effective in teaching earth science concepts and students and teachers were quite enthusiastic and had positive attitudes towards earth sciences.

Chapter 5

# DISCUSSION, CONCLUSIONS AND IMPLICATIONS

## 5.1 INTRODUCTION

This final chapter of the thesis presents the major findings of this study. It discusses the research questions and concludes in relation to the literature presented in Chapter Two. This chapter highlights the findings from this study and is the main body of argument based on what had been presented in previous sections.

Each of the following sections discusses a research question in the context the findings and the literature. This chapter will conclude with some possibilities for future research in this area and the potential implications for teachers, their students and exhibition providers (section 5.5).

## 5.2 AN EARTH SCIENCE EXHIBITION

> *Research question 1:*
> *How does an exhibition that portrays earth sciences influence the audience's perception about the subject?*

New Zealand science centres belong to the big group of multifunctional museums. These include science and technology museums, open-air museums as well as castles and zoos. This is in contrast to the classical museum, which presents specialised areas and targets similarly specialised visitors for example, art museums (Geyer, 1995; Eisenbeis, 1972). Different exhibits that present science and technology concepts and additional attractions like restaurants, shops or playground are typical for the multifunctional character of science and technology centres. Geyer (1995) described the finding that visitors of those museums do not experience a 'cognitive dissonance', which is explained, as the necessary background knowledge that the classical type museum requires.

One philosophy behind the science centre is, that there is no preparation necessary before visiting. This is one of the reasons why science centres are sometimes regarded as places of entertainment offering education as a by-product (Friedman 1996).

*Earthworks* – the exhibition, was designed to be exhibited in New Zealand science centres. It was set up as a travelling exhibition that toured through New Zealand between 1996 to 1998. In contrast to permanent exhibits, Danilov (1982), characterises travelling exhibitions as those that are often derived from the need for temporary exhibitions to build attendance, raise funds, obtain publicity, attract members, fill voids in permanent exhibits, inform the public on important or interesting topics, provide a community service and sometimes just to fill space. Such exhibitions can range from simple poster displays up to a set of workable exhibits. The quality of travelling exhibitions has therefore been described as variable (Danilov, 1982).

The New Zealand situation shows that, in addition to the above characteristics the need for travelling exhibitions is particularly strong for the community of small science centres, which have to ensure return visitors. In addition, New Zealand science centres have put considerable emphasis and efforts into attracting school groups. School visits ensure that exhibitions are used during weekdays and off-peak periods as well as encouraging students to return with their parents at other times. Changing exhibitions covering a range of themes play a vital role in ensuring that visitors are encouraged to return every time the exhibition changes. From this need for returning visitors a particular kind of exhibition derived from a funding scheme by New Zealand's Ministry of Education "Learning Experiences Outside The Classroom" (LEOTC).

### 5.2.1 A SPECIALISED EXHIBITION

The funding scheme, "Learning Experiences Outside The Classroom" is provided by the New Zealand Ministry of Education. LEOTC, for which the proposal for *Earthworks* qualified, required that the learning experience target the learning outcomes for earth science laid out in the New Zealand Science Curriculum. So, for example, Level 3 of the New Zealand Science Curriculum notes: " Students can investigate the major features, including the water cycle that characterise the Earth's water reserves." (Ministry of Education, 1996, p.112) and it continues on Level 4: "Students can investigate major factors and patterns associated with weather.." (p.114) and for level 5 it states: " Students can investigate and describe processes which change the Earth's surface of time at local and global levels.' (p.116).

In addition to designing new interactive exhibits relating to earth sciences, the designers of *Earthworks* borrowed existing simulations that were used for teaching at the Department of Earth Sciences at the University of Waikato and adapted them for use at the science centre. In deciding to make use of those simulations, namely the River Flume and the Wave Maker, their potential of teaching earth science concepts with the addition of being interactive and visually appealing were key prerequisites. Those exhibits directly addressed the achievement objectives as described in the Science Curriculum and were highly suitable for the purpose of the exhibition. Both exhibits portrayed earth science processes by using a simulation, which is a common tool for the tertiary teaching of earth science concepts and this philosophy has been adapted for the majority of exhibits. However, the classification of simulations is a new one and this method of teaching scientific concepts has been referred to as scientific models (Harrison and Treagust, 2000).

Meeting the requirements for funding, e.g., targeting the learning outcomes as described in the curriculum, was chiefly resolved during the design phase of *Earthworks*. The result of this was that the exhibition is rather specialised. Science centres do target the school curricula when they advertise their programmes to schools, however this rarely happens during the design phase of the exhibits (Wizevich, 1993). LEOTC funded programmes have changed that. With the requirements for LEOTC funding, designers of out-of-school activities are required to target the school curricula, a benefit to the draw card of credibility is that teachers can make use of those new resources.

The specialisation has meant that areas that had been identified as important concepts to teach by the Ministry of Education were presented by using the philosophy of presentation by science centres. The result was an exhibition that presented earth science concepts for year seven to year ten students and their teachers. The *Earthworks* exhibits were specifically designed to cater to for a selected audience, while retaining a general appeal in keeping with the attraction that science centres have on visitors due to their multi-functionality.

This focus on a target group is quite contrary to the broader approach of science centres catering for the general public. This specialisation further meant that teachers were able to make the visit to the science centre part of their teaching strategy. Although this selected presentation is in sharp contrast to the general description of science centres, it is nevertheless becoming common practice for many New Zealand science centres.

Furthermore, *Earthworks* presented an area of the National Science Curriculum with which many science teachers were unfamiliar. A previous investigation reported similar findings (Hume, 1997) but this study showed that the unfamiliarity of some teachers with earth sciences, in the worst cases, led to avoiding teaching this subject altogether. It also appeared that with a lack of formal training in earth sciences there seemed to be a proportional decrease in the awareness of resource material. Teachers who had less training felt less competent in this area and often perceived earth sciences as an unattractive science area. Some teachers were surprised about the positive attitude their students had towards this science area and noted it highlighted their lack of understanding in earth sciences.

Going to the science centre for the purpose of learning new information meant that some teachers, at least, had undergone a change from their traditional way of science teaching. Visiting the science centre also gave both teachers and students a break from their usual learning environment, which is an important attribute of New Zealand's LEOTC scheme.

### 5.2.2 A SPECIAL AGENDA

This study incorporates information obtained from both teachers and students. From this study there are several factors that influence the perceptions about this particular earth science exhibition.

First was the specialised character of the exhibition. Being curriculum-based in its earth science content, teachers' expectations were that *Earthworks* could be part of their teaching strategy in this subject. This focus in content presentation allows teachers to include it into their planning of earth science units. Further, it allowed them to include earth sciences even if the teachers' formal training in earth science is not that good because the environment provided allows the teachers to gather information for themselves. This suggests that teachers make use of informal learning situations like *Earthworks* and that they support the development of new resources and make use of new resource material that is provided for them. Teachers expected *Earthworks* to be experience driven, including hands-on participation. The special agenda allows exhibition providers to target schools more specifically.

Secondly, expectations varied considerably in relation to the amount of formal training teachers had in earth sciences. Teachers who were well trained in earth sciences were interested to visit with their students but they did not envisage *Earthworks* their sole unit on earth science. Teachers who indicated that they were less well trained in this area were hoping for an opportunity to gain more understanding themselves. However, this expectation was based not only on visiting the exhibition but also on participating in teacher workshops and receiving additional teaching material. There is strong evidence from this study and elsewhere (e.g., Trend, 2000) that the amount of formal training teachers have is directly linked to their confidence in teaching an area, and their awareness about teaching strategies and resources in the area and the quality of their engagement. Insecurity is linked to avoidance of new knowledge and understanding. An informal resource like a science centre may provide a non-threatening environment, particularly for such teachers.

Thirdly, teachers' expectations varied, depending on their previous experiences with science centres. Teachers who had had experience with other exhibitions that presented one theme or subject had greater expectations than, for example, those who had seen "road shows", which were wide-ranging in their coverage of science topics. Teachers who had experience from road shows mentioned that they were only expecting a change towards a more positive attitude towards earth sciences.

The students on the other hand were enthusiastic in their descriptions about their experience and attempted to use the information they acquired to interpret geological events as described in section 4.3.2. Teachers had also reported that they were surprised about how interested their students were in earth sciences. The students' perceptions of each exhibit were strongly linked with both the level of communication of the exhibit and with the social group structure of their companions. Exhibits that were not viewed for long periods of time during the observational phase of the study were either not recalled or were only recalled without reporting on the underlying meaning of the exhibit.

Observations in this study also showed that the degree of interaction was highly dependent on the social group setting. Students who viewed exhibits on their own showed fewer interactions than those who were included in student groups. The different learning environment offered both a science and social experience.

The reason for visiting a science centre for the teachers and their students however, was quite different from the 'usual' science centre (or museum) visitor, described in international contexts (for example, Geyer, 1995; Klein, 1984), as they visited with an educational agenda. Rennie and McClafferty (1996) report that the agenda for a museum visit is one of the factors that determines the outcome of the visit; consequently, comparisons of studies about general museum visitors have to be treated with caution.

Furthermore, many overseas science centres allocate a relatively small percentage of their exhibition space to changing exhibitions, whereas New Zealand science centres often provide up to 50 % of the total exhibition space. For teachers in New Zealand the changing exhibition is often a motivating factor in the decision to go to a science centre. By comparison, visiting a themed exhibition in other countries might just be an add-on to the overall experience.

*Earthworks* portrayed earth science concepts based on a specialised design plan and targeted a selected audience. The selected audience was aware of that background and had, therefore, specialised expectations. This is quite contrary to the motivation of museum visitors as described by Geyer (1995). Her characterisation of visitor motivation is that visitors come because of a more general and rather unspecific interest in nature, as well as 'sight seeing' and also as a social experience for children. The intention of *Earthworks* to serve a target group influenced the teachers', and subsequently the students', perceptions about the experience. This put a strong focus on the content of the exhibition and the students were enthusiastic about their experience and well aware what their visit was about. However, even though *Earthworks* targeted a specific age group of students, it seemed to be successful with students who did not fall into the specified age group.

## 5.3 THE *EARTHWORKS* EXHIBITS

> *Research question 2:*
> *Can simulation based models teach a non-specialist in earth science the functionality of the real system?*

The exhibits represented the central product of the *Earthworks* project. They were the means to communicate information from the designers to the visitors. They embraced the philosophy of science centres to be interactive and in addition incorporated the specific target areas outlined in the New Zealand Science Curriculum.

Since the project was specialised it required a combination of expertise for its realisation. This team consisted of earth scientists, teachers, exhibit builders (to translate concepts into exhibits), and educational researchers (to assess whether they had done it effectively). Wizevich (1993) describes the development of exhibitions using a museum communication system. Such a system examines the flow of designer intentions and a highlight of Wizevich's (1993) study was the influences from the outside and from within before the designer's intentions are realised. She identifies developers and curators to be "typically scientists or other academically – oriented professionals" (p.211). However, due to the lack of communication of the designing teams in the Wizevich study, the exhibits were complex in their presentation and often reflected the multiple viewpoints of their designers in their presentation. Such viewpoints are highlighted in this study as the aims of the *Earthworks* exhibits:

- The exhibits aimed to incorporate the New Zealand science curriculum.
- The exhibits aimed to be interactive 'science centre' presentations.
- The exhibits aimed to represent earth science concepts.

From the educational point of view earth science concepts were portrayed by concentrating on the 'processes' rather than 'results' and by the fact that it took a different approach to other more common out of class activities in earth sciences like fieldtrips (Hodder and Otrel-Cass, 2000). It has been discussed that there are often discrepancies between exhibits concentrating on either offering educational tools or experiences however, as Wizevich (1993) reports, those categories are mostly separated during the design stage of exhibits. The LEOTC criteria demanded that the designing team of *Earthworks* combined education and experience.

### 5.3.1 SIMULATIONS AT *EARTHWORKS*

This study investigated the meaning of simulations as related to this exhibition. Eleven out of the fifteen interactive exhibits at *Earthworks* were identified as simulations. This distinction was based on three criteria of Towne (1993). They offered exploratory learning, by using a model in an open-end discovery. Nottis (1999) stresses how difficult it is to teach non-observable earth science concepts, agreeing with Gilbert et al. (1982) who attribute the lack of observability to conceptual problems. Nottis (1999) proposes using analogies to circumvent this problem of observability and this raises the question of the familiarity of the learner with the analogue that is being offered (Newton 1996). Harrison and Treagust (2000) explain that scientific modelling is part of everyday science teaching practices, but that teachers are often unfamiliar with the kind of models they offer. They also state that teachers should know the concepts they are teaching before they make use of a model. Gobert (2000) identifies different types of models in earth sciences, which this study refers to as mental models, which differ in the degree of causal and dynamic understanding. Harrison and Treagust (2000) also propose that concepts, particularly those that are concerned with more abstract ideas, should be taught by multiple models. This allows the students to realise that models are not reality and enhances their own ability to make use of models to represent sophisticated scientific processes. An exhibition with multiple models serves this purpose well. Using simulations to overcome the lack of observability appears to be less confusing, particularly if the process of information delivery is uncontrolled as is the case in a science centre.

Exhibits that are simulations, particularly in the science centre environment, integrate educational aspects with the experiential parts of the exhibits. Each exhibit had its own complex issues to cover. Each *Earthworks* exhibit imposed different aspects of conceptualisation while maintaining the general aims for the exhibition. This integration is one aspect of exhibit development that has been noted to be missing previously (Wizevich, 1993).

Observations in this study revealed different behavioural criteria for the simulations. *Time* - Graf and Treinen (1983) describe that dynamic or participatory exhibits are mostly defined by an increase in time spent with them by visitors compared with static exhibits. This is caused by the exhibits being approachable and able to be manipulated. The authors also pointed out that participatory exhibits are responsible for a change in *behaviour* and such change and types of behaviour can be used to infer the effectiveness of an exhibit.

### 5.3.2 CRITERIA FOR SUCCESSFUL EARTH SCIENCE EXHIBITS

Time and behaviour were selected as ways of describing the exhibits. Simulations at *Earthworks* showed long times of engagement (up to 420 seconds). The exhibits with the longest viewing times (above 250 seconds) were the Continental Jigsaw, Rock Fall and the Wave Maker. Those exhibits were always observed to trigger at least three different behavioural criteria, one of which was always 'hands-on' activity. Exhibits with short viewing times had typically only one or two behavioural criteria.

Interestingly, interviews with students showed that although the exhibits mentioned above were amongst the five most remembered, Buck'n'Ham Palace and the Geyser were in this group as well. Buck'n'Ham Palace was always observed with long viewing times (between 124 and 176 seconds) and four behavioural criteria. The Geyser had viewing times between 72 seconds up to 200 seconds but only two behavioural criteria.

One of the reasons Geyser tended to be in the top rank of remembered exhibits could be the reason described by Geyer (1995): an increased attention for exhibits offering acoustic or optical signals. While the exhibit offered only a very limited amount of active engagement the impressive size (3.5 metres high) and the display of erupting hot water made it a very memorable exhibit. Comparing observations with information from interviews showed that exhibits like River Flume and the Continental Jigsaw which had long viewing times, were recalled and sometimes a description of the exhibit was added, but no notable understanding of the underlying concept was given by the students.

To interpret these findings, the aims of the exhibits had to be compared with the data from the observations and the interviews. All of the above mentioned exhibits were attractive in their physical appearance: they all had a strong attraction power. However, as discussed, time spent alone is not a reliable indicator for the effectiveness of an exhibit. In addition, they all showed a variety of behavioural criteria during the observational phase. Nevertheless, during the interviews it appeared that those exhibits did not communicate their aim as well as these behavioural criteria might imply: students were unsure about what the exhibit was about.

The underlying scientific idea for those exhibits was complex. For example, the River Flume's scientific concept was to show erosion and the movement of mass in a river system, the results show that this exhibit did not communicate this purpose. Students' interpretations tended to suggest the exhibit's purpose was to show the effects of damming. Similar observations were made for GIS-Ohaaki and the Continental Jigsaw exhibits, whereas exhibits like the Buck'n'Ham Palace communicated its purpose extremely well.

In this study the ability of communicating an exhibit's aim was not affected by whether or not the accompanying texts were read or whether the texts were written for the appropriate age range. Reading was most often observed as an additional activity, often after a student was already actively engaged with an exhibit.

This investigation showed that monitoring time and the behavioural criteria were valid but limited ways to collect information. Additional information, however, that was produced through interviews gave more insight and showed that time and behaviour on their own were not sufficient instruments to judge the impact of an exhibition.

Students, who for the purpose of this study were classified as non-specialists, interpreted the geological situation very well. They often related their explanations to their experiences at *Earthworks* and applied several earth science concepts correctly. Some concepts, like geological time, appeared to be more difficult and were interpreted with more familiar concepts like human existence. This supports overseas studies on this issue (Trend 2000). These findings show that a successful exhibit depends on various factors which Rennie and McClafferty (1996) describe as the Interactive Experience Model (modified after Falk and Dierking, 1992). This model highlights three aspects the Physical, Social and Personal Context.

> The Physical Context is embodied in the exhibits and the physical setting in which they are displayed, and the Social Context refers to interactions between the visitors and others at the museum. The Personal Context is important in terms of the visitor's age, sex, and personal characteristics and preferences. (Rennie and McClafferty, 1996, p.64)

This description shows the dynamics that are involved in the success of an exhibit and that each context influences the other.

## 5.4 THE RECEPTION OF *EARTHWORKS*

> *Research question 3:*
> *Did students and teachers perceive their visit to a science centre featuring earth science simulations enjoyable and what did they remember, after a considerable amount of time?*

The results of this study clearly showed that students had very good recall even several weeks after their visit. In many cases they could not only remember the exhibits at their visit but were also able to explain what they had experienced and some students were even able to apply their knowledge to new situations. Learning clearly took place in the cognitive as well as the affective area. The literature does not always support this level of learning in such situations (e.g., Wellington, 1989; Flexer and Borun, 1984). It is important to look closely at the background of each study, wherein visits to exhibitions were described as being less well structured than a class lesson and therefore failed to succeed in the cognitive area (Borun and Flexer, 1984). It is recognised that those results came from a study at a big science museum offering a multitude of exhibits, lacking the focus and aim of *Earthworks*.

### 5.4.1 BODY MEMORY AND MENTAL MODELS

In this study it was apparent that, even if students were not able to explain the underlying concept of the exhibit their memory was often one of sensations. Solomon (1980) refers to the importance of understanding a concept by 'feeling it'. Brooke (1994) describes it as the "body memory" and says that understanding of a concept is often a result of having both cognitive and affective experiences.

By using the environment of a science centre and featuring interactive exhibits that appeal visually and physically *Earthworks* was perceived by the students in this study as an interesting and pleasurable experience. The principal concept of science centres as providing an enjoyable and participatory setting stimulated an affective reception of *Earthworks*. The different philosophy for the design of the exhibits added the necessary structure for a cognitive experience.

The responses in this study also showed that students and teachers reflected on their experiences, often starting with the overall impression, whether that was dominated by the visual impact, noise or the physical experience they made. Outcomes of the interviews with the students suggest that the simulations they have worked with at *Earthworks* functioned as mental models, which they used to interpret new situations. The ability to correctly interpret a new situation depends, then, on how transferable that mental model is. The new situation has to be compared with the mental model and then articulated. Newton (1996) elaborates this point, explaining several situations that can cause the model to fail, but highlighting that failure of understanding stems from a defective mental model. By providing simulations to teach earth science concepts, the designers offered a conceptual structure that will aid students to form a mental model. The transformation of a concept to understanding depends on how successful the simulation is and on the knowledge and skills of the student or visitor.

The study showed that three to four weeks after their visit, almost all children that were interviewed remembered in great detail what they had seen and experienced. However, the exhibition did not always provide a simulation that succeeded in communicating a clear picture of the concept it was designed to show.

## 5.5 TARGETING NEW ZEALAND

> *Research question 4:*
> *What is the New Zealand perspective on earth sciences in science centres?*

Research associated with this study showed that owing to the small population in New Zealand, science centres need to have return visitors to be financially viable. Changing exhibitions are a key to that. By targeting specifically schools with specially designed programmes, science centres aim for children to visit first with their schools and to come back later with their families. The LEOTC initiative proposed funding to providers of out-of-school activities and allowed new initiatives to take place. The *Earthworks* project framed their programme with the New Zealand school curriculum in mind which was intended to enable teachers to include those activities into their teaching agenda. This initiative was a reflection of the changing needs for science education and earth sciences in particular. One of those changes was the revision of the New Zealand Science Curriculum (Ministry of Education, 1993) and the introduction of earth sciences as one of the new 'learning strands'.

*Earthworks* was a response to this change firstly as it offered a themed exhibition targeting specific curriculum areas and it also provided a new resource to teachers in this field. This investigation showed that teachers were often poorly trained in earth sciences, and whenever they lacked the knowledge they also expressed having not enough confidence to implement it. Drawings produced by the teachers also showed that they were at times lacking the causal and dynamic understanding that are involved in earth science processes. This supports similar findings from international studies. Interestingly, teachers who had received formal training in earth sciences were aware of available teaching resources and felt very confident to teach the subject.

From this study it appeared that the *Earthworks* project addressed the apparent need for teaching resources in earth sciences as well as serving the needs of science centres in New Zealand.

## 5.6 CONCLUSIONS

The diversity of these data provided rich information for the description of an innovative earth science teaching tool. Comparisons of the different data improved the meaning of the interpretation and in some cases even changed it. By comparing time data with observations and data that came from interviews, the time factor did loose in importance. This revelation was a discovery that was unintended, but nevertheless very interesting for further studies. The impact and potential of models and simulations teaching earth science concepts in a science centre is thought to depend on various factors:

*The theoretical framework that the design of the exhibits is based on.*
For *Earthworks* the guideline was the New Zealand science curriculum, which gave the exhibit providers as well as the teachers some direction as to what the exhibition would be about. It may have allowed the teachers that were more familiar with earth science concepts to include and prepare their students for a visit, and may have allowed those who were less familiar to rely on the exhibition being an appropriate teaching tool to update their own knowledge and assist in educating their students. This framework also may have helped the designers to focus on how certain curriculum objectives can be translated into a workable exhibit.

*The ability of the simulation to effectively communicate earth science concepts.*
Students like scientific models and it is a common teaching tool. For the simulation to achieve its full potential it has to show A) a simplified version of reality, B) show processes that are non-observable under normal circumstances to explain processes involved, C) allow interaction in so far that the participant can vary the result. It allows the participant make hypothesis and test them. D) The simulation should be very clear

about the role of the participants. Their interaction has to be explained and brought into relationship with reality. E) Multiple simulations of varying degree of concreteness touching on the same or similar concept will allow the participant to view the concept from different angles and support the learner's discovery that simulations are only representations of reality but nothing more. It also teaches about the complexity of scientific concepts and may be effectively used to produce a sequence of representations of particularly difficult concepts. However, it needs to be noted that students can also experience difficulties with models and that they should be used as a teaching aid (Gobert, 2000).

*The visitor will always make assumptions of what an exhibit is about.*

The results of the study showed that students would usually try to find a meaning for something they see and make a judgement whether it is worth while pursuing. For this reason this study strongly suggests formative evaluations of exhibits because discrepancies between what the designers intended to do and what the visitors actually perceive might differ substantially.

*Recognition and understanding might happen at various levels.*

The recognition of a concept that is displayed by using a simulation may happen in a similar sequence to that of learning to read. It often starts with simplistic pictures, the first visual impact that brings meaning to the collection of letters that make up a word. Active engagement widens that experience and might result in an effective impact. If the visitors engage further and re-test their experiences they might make the cognitive step to understand the process that is displayed. Another aspect is that some exhibits do not seem to achieve their objectives, which might be because the conceptual models of the designers embed more theory than novices will be familiar with. This difficulty can be circumvented by testing the models with visitors, before they go on display.

*Reading of additional information depends on the agenda of the visitor.*

The findings from this study suggest that the motivation for reading a label on a given exhibit is driven more by the agenda of the visitor. This study supports literature reports that visitors do read labels (e.g., McManus, 1989) albeit selectively, and this study suggests that reading might be triggered more often by how appealing an exhibit is rather then the label itself.

This study showed that simulations have the potential to provide a useful tool to teach earth science concepts in the environment of a science centre. The description of simulations however, was superimposed on the exhibits that were produced for the *Earthworks* exhibition. This analysis might allow future designers to incorporate the educational and the experiential aspects of the exhibit more effectively, this inference has implications for ongoing research and is discussed below.

## 5.7 IMPLICATIONS OF THIS STUDY FOR FUTURE RESEARCH

The multitude of data that was gathered in this study provided rich information and it also opened up new areas that need to be further investigated. The following discussion is divided into key areas and might be of interest for any of the following groups.

### Implications for Science Centres

Several aspects have been discussed that are of relevance to science centre staff or external bodies who are doing research in this environment. This study did not discuss the question of designing simulations for earth science applications. An appropriate next step could be an exhibition based on simulations developed at the design stage.

This investigation also highlighted that science centres and other-out-of school situations are learning environments of great potential, however they are constantly undergoing change. Evaluation methodologies need to evolve with those changes. What might have been a useful description of a successful hands-on exhibit at the Exploratorium (Hein, 1987) may not be appropriate for a specialised exhibition like *Earthworks* in the New Zealand setting in the late 1990s. International differences also appear to be of great significance, as well as the differences between science centres in small communities or big cities.

Future research might also explore the specific role of the tacit learning by concentrating on the impact of the "physical experience" in the process of learning at a science centre, and the role of science centres as new out-of-school resources for teachers.

**Implications for teachers**

This study showed that students enjoyed their experience and that they also gained understanding from it. Teachers themselves reported positive feedback from their visit. This research aimed to show that 'models' and in particular 'simulations' are useful tools to teach novices. This may be a strategy that can be adapted by teachers and institutions to improve their capacity, and need not be at substantial cost. Teachers might also benefit from an exploration into how to encourage students to modify and test the simulations.

**Implications for further Geo-science Education Research**

It is quite clear from research and the results of this study that certain aspects of geo-science, like geological time, were hard to teach at the exhibition. Future research might look at this specific concept for geoscience education in the science centre environment, which appears to prove difficult in various other teaching situations (e.g., Trend 2000; Trend, 1998).

Parlett and Hamilton (1972, p.21) write: "When an innovation ceases to be an abstract concept or plan... it assumes a different form altogether." It is the translation of such a plan that is of interest for evaluations of this kind and it is important for the researcher to select appropriate ways to investigate them. The style of methodology is crucial and will have major implications on any outcomes. Future research could explore the findings from this study from a different methodological perspective.

Finally, as geoscience education becomes more concerned about the identification of effective ways of teaching the subject, science centres using simulations offer the possibility of an educational, informative and fun exposure to core concepts for students and the wider public. This would also offer possibilities for biology, chemistry and other subjects, which are traditionally dealt with less often in science centres.

## 5.8 FINAL COMMENT

This research was sparked by two issues: firstly how to teach earth science concepts and secondly to record and report on the multitude of factors that contribute to the success or failure of educational strategies at a science centre. Even though this research concludes that simulations are a most useful tool to teach earth sciences in particular, it should not be forgotten that this is just one tool and others can be equally important in their own way. The problematic issue of visualisation in earth sciences might be greatly reduced by simulations but learners still need to make the translation into interpreting the real life situations. For this they will need a substantial theoretical understanding which they can apply. It has been described that prior knowledge can enhance the ability to develop a more sophisticated understanding of earth sciences and the construction of models can enhance cognitive processes (Gobert, 2000). This is particularly the case for all those who are involved in teaching situations, whether they design educational tools or teach students.

This study has contributed to the understanding of the complexity of learning environments like science centres. In doing so it has examined both the development and the product of earth science learning in science centres, and focused on the use of simulations as a very important process and integral part of earth science learning (Gobert, 2000; Harrison and Treagust, 2000). It has been shown that it is necessary to consider a range of factors that influence the interpretation of such situations. This study has also shed new light on how to describe and therefore, design and evaluate simulations in a science centre. It has been argued that simulations are a useful tool for teaching earth science concepts. This study also highlighted the difficulty of understanding earth science concepts due to a lack of observability.

This study advocates the view that simulations can assist in learning, but to a limited level, determined by the simulation design. Simulations act like a cyclist's learner's wheels: one has to detach them at some stage to become confident in cycling.

## APPENDIX 1

**Observational Protocol**

1/ Observation number: ☐

2/ Exhibit:

| | | |
|---|---|---|
| 3/ / Date: | | |
| 4/ Day: | | |
| 5/ Time: | Start: | Stop: |
| 6/ Gender/Number | male | female |
| 7/ Social Group: S5 S10 SG5 SG10 ST5 ST10 SP10 (circle one option) | | |

**Observational criteria:**

| **Criteria:** | √ | **Comments** |
|---|---|---|
| 8/ Looking | | |
| 9/ Reading | | |
| 10/ Hands-on | | |
| 11/ Reading and Hands-on | | |
| 12/ Talk | | |

## APPENDIX 2

### Interview Protocol for Interviews with Students

1/ Interview Group: ☐

| | | |
|---|---|---|
| 2/ / Date: | | |
| 3/ Day: | | |
| 4/ Time: | | |
| 5/ Gender/Number/Age | male | female |

**Key for exhibits:**

1 = Buck'n'Ham Palace, 2 =Volcano, 3 =Geyser, 4 =Shaking table, 5 = Settling tube, 6 = Continental Jigsaw, 7 = Wave maker, 8 = Plate tectonics, 9 = Flume, 10 = GIS Ohaaki, 11 = Rock fall

**Key for photographs:**

a = earthquake, b= landslide, c = landslide + car, d = layers of volcanic ash, e = layers of crystals, f = geyser, g = breaking wave, h = hot spring, i = meandering river, j = volcanic eruption, k = lava flow, l = sinter terraces, m = fossils, n = ripples in the sand, o = pyroclastics, p = folded layers

**Interview questions:**

**6/ Part one ( no pictures):** Introduction and explanation of the structure of the interview.

- What do you remember from your visit to the Earth works exhibition?

**Tick** which exhibits were remembered:

1 2 3 4 5 6 7 8 9 10 11

**<u>7 / Part two:</u>** Show students photographs of the exhibits at Earthworks.

➢ Please, explain what you remember from the exhibits?

**Tick** which exhibits were remembered:

1 2 3 4 5 6 7 8 9 10 11

**<u>8/ Part three</u>:** Ask students to choose the three exhibits that they liked best and let them choose real life photographs which they think represent what the exhibits explained.

**Tick** which exhibits were remembered:

1 2 3 4 5 6 7 8 9 10 11

**Tick** which photographs were chosen **(include number of the exhibit, example 2 a):**

a b c d e f g h I j k

l m n o q

# APPENDIX 3

## Interview Protocol for Interviews with Teachers

1/ Interview Group: ☐

| | |
|---|---|
| 2/ / Date: | |
| 3/ Day: | |
| 4/ Time: | |

**Interviews are conducted prior to workshops that are offered to teachers for Earthworks.**

- Introduce yourself and explain the study.
- Ask teachers whether they wanted to participate and that their participation is entirely voluntary.
- Take the time – interviews should not take longer than 15 minutes.

**Main questions for the interviews:**

1. Have you ever visited a science centre or similar institution with your classes before and if yes what were your experiences?
2. What do you expect from visiting a science centre featuring an exhibition on earth sciences?
3. What experiences have you had teaching earth sciences at school?
4. What do you consider as important teaching tools to explain earth science concepts?

**APPENDIX 4**

□□□□

**TEACHERS' VIEWS TOWARDS EARTH SCIENCE**
**- A QUESTIONNAIRE**

The attached questionnaire is designed to gain insight into how New Zealand teachers feel about teaching earth science and their empathy with the subject.

It is part of an wider study involving teachers and pupils which will be used as a way evaluating "EARTHWORKS" – the exhibition. It will also be used as a research for a PhD study surrounding the introduction of earth sciences with the New Zealand school curriculum.

The questionnaire is in two parts:
The first will ask you about your present teaching background and how you feel about earth science. The second part is a survey of the depth of knowledge of the subject which teachers already have. This is necessary to ensure that our future introduction of earth science to teachers is at a helpful level.

In order to protect confidentiality and to leave you free to answer fully we would like you to enter a combination of two letters and two numbers in the spaces provide at the top of the page. Please remember your code for future use. This is so that your response to any further research can be correlated at a later date.

**Thank you for your help.**

This questionnaire has been prepared by Kathrin Otrel-Cass of the Department of Earth Sciences, Waikato University, Hamilton. For any future questions please contact also Dr. Peter Hodder, Department of Earth Sciences, Waikato University, Hamilton

**Part A**

These questions are about yourself and your teaching experience.

1. Gender : Female ❑ Male ❑

2. How many years of teaching experience do you have?

❑ < 5 yrs.
❑ 5 -10 yrs.
❑ 10 -20 yrs.
❑ 20 -30 yrs.
❑ > 30 yrs.

3. At what type of school do you presently teach?

❑ Contributing School
❑ Full Primary School
❑ Intermediate School
❑ Form 3-7 School with attached Intermediates
❑ Form 1-7 School
❑ Form 3-7 School
❑ Composite (Area) School
❑ Special School
❑ Correspondence School
❑ any other, please specify:

4. Please, name your tertiary qualifications.

5. Name any **pre service** courses in **earth science** you have completed.

6. Name any **in service** courses in **earth science** you have completed.

7. Within the past year, which of the following topics have you taught?
(*Tick as many boxes as are appropriate.)*

- ❑ continental drift and plate tectonics
- ❑ commercial use of natural materials (i.e. roads, buildings, monuments, etc.)
- ❑ volcanoes
- ❑ earthquakes
- ❑ fossilisation
- ❑ soil and erosion
- ❑ planet earth and the solar system model
- ❑ none

8. How confident do you feel about teaching earth science?
*Please, rate your confidence in the scale 1 to 5 with a ring.*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| confident | | | | not confident |

9. Please, explain why you feel so about this subject.

| **Part B**<br>Please read the following very carefully before you tick one of the boxes. | Never heard | Not sure | True | False |
|---|---|---|---|---|
| **10. Gondwanaland (the supercontinent), comprised Australia, Antarctica, including New Zealand, India, Africa and South America.** | ❑ | ❑ | ❑ | ❑ |
| **11. The continental crust dives under the seafloor, this process is called Subduction.** | ❑ | ❑ | ❑ | ❑ |
| **12. Seafloor is created along the mid ocean ridge.** | ❑ | ❑ | ❑ | ❑ |
| **13. Moh's hardness scale grades minerals according to their hardness. No. 10, the hardest is corundum.** | ❑ | ❑ | ❑ | ❑ |
| **14. Fossils can be used to determine the age of rock strata.** | ❑ | ❑ | ❑ | ❑ |
| **15. The sun is a star.** | ❑ | ❑ | ❑ | ❑ |
| **16. Stars are planets in their early stages.** | ❑ | ❑ | ❑ | ❑ |
| **17. Erosion only happens to unprotected soil ( protection through bushes, trees, etc.).** | ❑ | ❑ | ❑ | ❑ |
| **18. Yellow brown earth is commonly derived from volcanic deposits.** | ❑ | ❑ | ❑ | ❑ |

| **19. Do you think that there are or were volcanoes in these places?** | Yes | No | Not sure |
|---|---|---|---|
| Auckland | ☐ | ☐ | ☐ |
| Rotorua | ☐ | ☐ | ☐ |
| Taupo | ☐ | ☐ | ☐ |
| Wellington | ☐ | ☐ | ☐ |
| Christchurch | ☐ | ☐ | ☐ |
| Dunedin | ☐ | ☐ | ☐ |
| | ☐ | ☐ | ☐ |
| **20. Do you think there might be volcanoes in these places in the future?** | | | |
| Auckland | ☐ | ☐ | ☐ |
| Rotorua | ☐ | ☐ | ☐ |
| Taupo | ☐ | ☐ | ☐ |
| Wellington | ☐ | ☐ | ☐ |
| Christchurch | ☐ | ☐ | ☐ |
| Dunedin | ☐ | ☐ | ☐ |
| | ☐ | ☐ | ☐ |

**21. Please draw a picture of a volcano in the box below that shows what you think it looks like inside. Please explain the features in the diagram as fully as possible.**

Thank you for your participation!

## APPENDIX 5

☐☐☐☐

# *EARTHWORKS*

## TEACHERS' VIEWS TOWARDS EARTH SCIENCE – A QUESTIONNAIRE

*Part 2*

As you will remember a couple of weeks ago you participated in a workshop associated with the EARTHWORKS exhibition where some of you filled in a questionnaire. This was designed to give an insight into how New Zealand teachers feel about teaching earth science and their empathy with the subject.

This is now part 2 of the study. This questionnaire is again in two parts: the first will ask you about your present teaching background – (because this survey is anonymous we must ask this again) – and how you now feel about earth sciences. The second part is then once more a survey of the depth of the knowledge of the subject which you have.

If you can remember your **personal code** of two letters and two numbers, please enter them at the top of the page so we can confidentially correlate data with the first survey.

Please post the questionnaire to the address shown below.

**We would appreciate your participation very much!**

**Thank you for your help.**

This questionnaire has been prepared by Kathrin Otrel-Cass of the Department of Earth Sciences, Waikato University, Hamilton. For any future questions please contact also Dr. Peter Hodder, Department of Earth Sciences, Waikato University, Hamilton

Please post questionnaires to:

***"Earthworks"***
**FREEPOST 423**
**Department of Earth Sciences**
**University of Waikato**
**Private Bag 3105**
**Hamilton**

**Part A**

These questions are about yourself and your teaching experience.

1. Gender : Female ❑ Male ❑

2. How many years of teaching experience do you have?
- ❑ < 5 yrs.
- ❑ 5 -10 yrs.
- ❑ 10 -20 yrs.
- ❑ 20 -30 yrs.
- ❑ > 30 yrs.

3. At what type of school do you presently teach?

- ❑ Contributing School
- ❑ Full Primary School
- ❑ Intermediate School
- ❑ Form 3-7 School with attached Intermediates
- ❑ Form 1-7 School
- ❑ Form 3-7 School
- ❑ Composite (Area) School
- ❑ Special School
- ❑ Correspondence School
- ❑ any other, please specify:

4. Did you attend an EARTHWORKS preview in:

- ❑ Hamilton
- ❑ Palmerston North

5. Which of the following topics have you taught since the teacher workshop about earthworks?
*(Tick as many boxes as appropriate.)*

- ❑ continental drift and plate tec tonics
- ❑ commercial use of natural materials (i.e. roads, buildings, monuments,etc.)
- ❑ volcanos
- ❑ earthquakes
- ❑ fossilisation
- ❑ soil and erosion
- ❑ planet earth and the solar system model
- ❑ none

6. How confident do you feel about teaching earth science?
*Please, rate your confidence in the scale 1 to 5 with a ring.*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| confident | | | | not confident |

7. Did the exhibition have any influence on how confident you feel about this subject. Please, explain.

8. Which exhibit(s) did you like the most and why?

9. Which exhibit(s) did you like the least and why?

| **Part B**<br>Please read the following very carefully before you tick one of the boxes. | Never heard | Not sure | True | False |
|---|---|---|---|---|
| **10. Gondwanaland (the supercontinent), comprised Australia, Antarctica, including New Zealand, India, Africa and South America.** | ❑ | ❑ | ❑ | ❑ |
| **11. The continental crust dives under the seafloor, this process is called Subduction.** | ❑ | ❑ | ❑ | ❑ |
| **12. Seafloor is created along the mid ocean ridge.** | ❑ | ❑ | ❑ | ❑ |
| **13. Moh's hardness scale grades minerals according to their hardness. No. 10, the hardest is corundum.** | ❑ | ❑ | ❑ | ❑ |
| **14. Fossils can be used to determine the age of rock strata.** | ❑ | ❑ | ❑ | ❑ |
| **15. The sun is a star.** | ❑ | ❑ | ❑ | ❑ |
| **16. Stars are planets in their early stages.** | ❑ | ❑ | ❑ | ❑ |
| **17. Erosion only happens to unprotected soil ( protection through bushes, trees, etc.).** | ❑ | ❑ | ❑ | ❑ |
| **18. Yellow brown earth is commonly derived from volcanic deposits.** | ❑ | ❑ | ❑ | ❑ |

| **19. Do you think that there are or were volcanoes in these places?** | Yes | No | Not sure |
|---|---|---|---|
| Auckland | ❑ | ❑ | ❑ |
| Rotorua | ❑ | ❑ | ❑ |
| Taupo | ❑ | ❑ | ❑ |
| Wellington | ❑ | ❑ | ❑ |
| Christchurch | ❑ | ❑ | ❑ |
| Dunedin | ❑ | ❑ | ❑ |
| | ❑ | ❑ | ❑ |
| **20. Do you think there might be volcanoes in these places in the future?** | | | |
| | ❑ | ❑ | ❑ |
| Auckland | ❑ | ❑ | ❑ |
| Rotorua | ❑ | ❑ | ❑ |
| Taupo | ❑ | ❑ | ❑ |
| Wellington | ❑ | ❑ | ❑ |
| Christchurch | ❑ | ❑ | ❑ |
| Dunedin | ❑ | ❑ | ❑ |

21. Please draw a picture of a volcano in the box below that shows what you think it looks like inside. Please explain the features in the diagram as fully as possible.

Thank you for your participation!

## APPENDIX 6

### RAW DATA

The raw data from Interviews, Observations, Questionnaires and Document Analysis is available on CD-ROM for secondary analysis.

Please, contact the Centre for Science, Mathematics & Technology Education Research at the University of Waikato, Private Bag 3105, Hamilton, New Zealand.

## REFERENCES


Alt, M.B. and Shaw, K.M. 1984. Characteristics of ideal museum exhibits. *British Journal of Psychology*, 75, p.25-36.

Anderson, G. 1990. *Fundamentals of Educational Research*. London: Falmer Press.

Arnold, P. Sarge, A. and Worral, L. 1995. Children's knowledge of the earth's shape and its gravitational field. *International Journal of Science Education*, 17/5, p. 635-641.

Ault, C.R. 1987. The Museum as Science Teacher. *Science and Children*, Nov./Dec. 1987, p.9-11.

Babbie, E.R 1992. *Unobtrusive Research, The Practice of Social Research*, 6th ed. Belmont, Ca.: Wadsworth.

Bacon F. 1627. *New Atlantis*. Rawley, London, p. 41-42

Barton, K.C. and Levstik, L.S. 1996. " Back when God Was Around and Everything": Elementary Children's Understanding of Historical Time. *American Educational Research Journal* , 33/2, p. 419-454.

Beer, V. 1987. Great expectations: Do Museums Know What Visitors Are Doing? *Curator*, 30/3, p. 206-215.

Beiers, R. and McRobbie, C. 1992. Learning in Interactive Science Centres. *Research in Science Education*, 22, p. 38-44.

Bell, B. and Gilbert, J. 1996. *Teacher development: a model from science education*. London: Falmer Press.

Bell, B.,Jones, A. and Carr, M. 1995. The Development of the Recent National New Zealand Science Curriculum. *Studies in Science Education*, 26, p. 73-105.

Bennet, T. 1995. *The birth of the Museum: history theory, politics*. London: Routledge.

Black, P. and Atkin, J.M. 1996. *Changing the subject- Innovations in science, mathematics and technology education.* Routledge: London.

Boisvert, D.L. and Slez, B.J. 1995. The relationship between exhibit characteristics and learning-associated behaviours in a science museum discovery space. *Science Education*, 79/5, p. 503-518.

Borun, M. 1977. *Measuring the immeasurable: A pilot studyof museum effectiveness.* The Franklin Institute Science Museum & Planetarium, Philadelphia.

Borun, M. and Miller, M. 1980. *What is in the name? A study of the effectiveness of explanatory labels in a science museum.* The Franklin Institute Science Museum & Planetarium, Philadelphia.

Borun,M. and Flexer, B.K. 1984. The impact of a class visit to a participatory science museum exhibit and a classroom science lesson. *Journal of Research in Science Teaching*, 21/9, p. 863-873.

Borun, M. Massey, C.and Lutter, T. 1993. Naïve Knowledge and the Design of Science Museum Exhibits. *Curator*, 36/3

Broadfoot, P. 1988. Educational research: Two cultures and three estates. *British Educational Research Journal*, 14/1, p. 3-15.

Brooke, H. 1994. *Playing and Learning in an Interactive Science Centre: A study of Primary School Children.* Special Diploma ion Educational Studies, University of Oxford.

Buckley, B.C. 2000. Interactive multimedia and model-based learning in biology. *International Journal of Science Education*, 22/9, p. 895-935.

Butler,S.V.F. 1992. *Science and Technology Museums.* Leicester University Press.

Cameron, D.F. 1971. The Museum, a temple or the forum. *Curator*, 14/1, p. 33-40.

Carr, M.A. 1997. *Technological Practice in early childhood as a dispositional milieu.* Ph.D. Thesis, University of Waikato.

Coe, J.C. 1986. Towards a coevolution of zoos, aquariums and natural historymuseums. In: *American Association of Zoological Parks and Aquariums.* Annual Proceedings, 1986, p. 366-376.

Cohen, L. and Manion, L. 1994. *Research methods in Education.* 4th ed. London, New York: Routledge.

Creswell, J.W. 1994. *Research design: Qualitative and quantitative approaches.* London: Sage Publications.

Creswell, J.W. 1998. *Quality Inquiry and Research Design: Choosing among five Traditions.* London: Sage Publications.

Danilov, V. 1973. Science/Technology Museums come of age. *Curator*,16/3, p. 183-219.

Danilov, V. 1975. Science museums as education centers. *Curator* 27/3, p. 173-188.

Danilov, V. 1982. *Science and technology centers*. The Massachusetts Institute of Technology.

De Vaus, D.A. 1991. *Constructing questionnaires. Surveys in Social Research*. London: Allen and Unwin.

De Wet, A.P. 1994. Integrating Field Observations with Physical and Computer Models in an Introductory Environmental-Geology Course. *Journal of Geological Education*, 42, p. 264-271.

Delamont, S. 1992. *Fieldwork in Educational Settings: Methods, Pitfalls and Perspectives*. Falmer Press, London.

Denzin, N.K. 1970. *The research act in sociology: A theoretical introduction to sociological methods.* The Butterworth Group, London.

Department of Education 1987. *The Curriculum Review.Report of the Committee to Review the Curriculum for Schools.* Wellington: Government Printer.

Department of Education 1988. *Draft National Curriculum Statement: a discussion document for primary and secondary schools.* Department of Education: Wellington.

Department of Education 1989. *Science Syllabus and Guide. Primary to standard four.* Wellington: Government Printer.

Diamond, J. 1986. The behaviour of family groups in science museums. *Curator*, 29/2, p.139-154.

Dove, J.E. 1996. Student Teacher Identification of Rock Types. *Journal of Geoscience Education,* 44, p. 266-269.

Duerr, C. 1992. *Biologieunterricht im Museum.Oekologie und Umwelterziehung in Museen im deutschsprachigen Raum.* Untersuchungen zu neuen Tendenzen in Thematik und Praesentation mit einer Laengsschnittuntersuchung der Abteilung "Geologie" und "Landschaft und Mensch" im Museum fuer "Natur und Stadtkultur", Schwaebisch Gmuend. Frankfurt a.M.:Haag +Herchen Verlag.

Eason, L.P. and Linn, M.C. 1976. Evaluation of the effectiviness of Participatory Exhibits, *Curator* ,19/1, p. 45-62.

Eisenbeis, M. 1972. Elements for a sociology of museums. *Museum* 24, p. 110-119.

Elley, W.B. 1975. *Assessing the Difficulty of Reading Materials, The Noun Frequency Method.* New Zealand Council for Educational Research, Wellington.

Falk, J.H. 1982. The use of time as a measure for visitor behavior and exhibit effectiveness. Roundtable Reports. *Journal of Museum Education*, 7/4, p.10-13.

Falk, J.H. 1983. Time and Behavior as Predictors of Learning. *Science Education,* 67/2, p. 267-276.

Falk, J.H. Koran, J.J. Dierking L.D.and Dreblow, L. 1985. Predicting Visitor Behavior. *Curator*, 28/4, p. 249-257.

Falk,J.H. and Dierking, L.D. 1992. *The museum experience.* Washington, Whalesback Books.

Fang, Z. 1996. A Review of Research on Teacher Beliefs and Practices. *Educational Research*, 38/1, p. 47-65.

Feber, S. 1987. Das Kindermuseum von Boston, In: Liebich, H. und W. Zacharias (Eds.): *Vom Umgang mit Dingen. Ein Reader zur Museumspaedagogik heute,* Muenchen, p. 58-59.

Feher, E. and Rice, K. 1985. Development of scientific concepts through the use of interactive exhibits in museums. *Curator*, 28/1, p.35-46.

Flagg, B.N. 1990. Visitors in front of the small screen. *What research says about learning in science museums.* W ashington D.C. Association of Science-Technology Centers, p. 21-24.

Fliedl, G. 1988. Verlorene Aufklaerung? Anmerkungen zur Geschichte des oestereichischen Museumswesens und zum Strukturwandel musealer Oeffentlichkeit. In: Fliedl, G. (Ed.): *Museum als soziales Gedaechtnis? Kritische Beitraege zur Museumswissenschaft und Museumspaedagogik*. Klagenfurter Beitraege zur bildungswissenschaftlichen Forschung, 19, p. 92-119.

Friedman, A.J. 1996. Vive la difference: Differentiating science-technology centres from other leisure time enterprises. *ASTC Newsletter*, 24/1, p.7-10.

Geyer, G. 1995. *Der Besucher im Naturkunndemuseum. Eine empirische Untersuchung im Haus der Natur, Salzburg.* Dissertation, Naturwissenschaftliche Fakultaet an der Universitaet Salzburg.

Gilbert, J.K. Osborne, R.J. and Fensham, P.F. 1982. Children's Science and its Consequences for Teaching. *Science Education*, 66/4, p. 623-633.

Gillies, P. and Wilson, A. 1982. Participatory Exhibits: Is fun educational? *The Museums Journal*, 82, p. 131-134.

Gobert, J.D. 2000. A typology of causal models for plate tectonics: Inferential power and barriers to understanding. *International Journal of Science Education*, 22/9, p. 937-977.

Gobert, J.D. and Buckley, B.C. 2000. Introduction to model-based teaching and learning in science education. *International Journal of Science Education*, 22/9, p. 891-894.

Graf, B. and Treinen, H. 1983. Besucher im Technischen Museum. Zum Besucherverhalten im Deutschen Museum Muenchen. *Berliner Schriften zur Museumskunde*, Band 4, Berlin.

Griffin, J. 1994. Learning to learn in informal science settings. *Research in Science Education*, 24, p. 121-128.

Griggs, S.A. 1990. Perceptions of traditional and new style exhibitions at the Natural History Museum, London. *ILVS Review*, 1/2, p. 78-90.

Haeseler, J.K. 1989. Length of visitor stay. In: Bitgood S. (Ed.) : *Visitor Studies: Theory, Research and Practice*, Volume 2, Proceedings of the 1989 Visitor Studies Conference, Jacksonville State University, p.252-259.

Hamblin, W.K. and Christiansen, E.H. 1998. *Earth's Dynamic System*. 8th ed., Prentice Hall, Upper Saddle River, New Jersey 07458.

Happs, J.C. 1982. Some aspects of student understanding of two New Zealand landforms. *New Zealand Science Teacher*, 32, p. 4-12.

Hardy,T. 1994, Towards creating effective learning environments for science teachers: The role of a science educator in the tertiary setting. *International Journal of Science Education*,16/2, p. 231-251.

Harrison, A.G. and Treagust, D.F. 1993. Teaching with Analogies: A Case Study in Grade-10 Optics. *Journal of Research in Science Teaching*, 30/10, p. 1291-1307.

Harrison, A.G. and Treagust, D.F. 2000. A typology of school science models. *International Journal of Science Education*, 22/9, p. 1011-1026.

Hein, G.E. 1987. The right test for hands-on learning? *Science and Children*, p. 8-12.

Hein, G.E. 1995. Evaluating teaching and learning in museums. In: Hooper-Greenhill, E. (Ed.): *Museum, media, message*. Routledge, London, p. 189-203.

Hensgens, J. Van Rosmalen, P. and Van Der Baaren, J. 1995. Authoring for simulation based learning. *Instructional Science*, 23, p. 269-296.

Hilke, D.D. 1989. The family as a learning system: An observational study of families in museums. In: Butler, B.H. and M.B. Sussman (Ed.): *Museum visits and activities for family life enrichment*. Washington D.C. p. 101-129.

Hodder, A.P.W. 1996. *Earthworks, a guide to the exhibition.* Occasional Report, 23, Hamilton: Department of Earth Sciences, University of Waikato, 22 p.

Hodder A.P.W. 1997. Science-technology centres and science education in New Zealand, In: Bell, B. Baker, R. (Ed.): *Developing the Science Curriculum in Aotearoa New Zealand.* Addison Wesley Longman, p. 144-155.

Hodder, A.P.W. and Hodder, C. 1997. Earth sciences in schools: Some implications for tertiary geoscience teaching. *Paper presented at the annual NZARE conference, Auckland, New Zealand.*

Hodder, P. Hume, A. Jenks, A. and Peters, J. 1996. *Earthworks: The teachers' guide*. Occasional Report, 20, Hamilton: Department of Earth Sciences, University of Waikato, 212 p.

Hodder, A.P.W. and Otrel-Cass, K. 2000, An Interactive, Process Oriented Geoscience Exhibition. *Journal of Geoscience Education*, 48, p. 46-56.

Hodge, D. Bursik, M. and Barcley, D. 1995. Simulation of Physical Processes in Environmental Geology Laboratories. *Journal of Geological Education,* 43, p. 453-460.

Hooper-Greenhill, E. 1994. *Museums and their visitors*. London, New York: Routledge.

Hooper-Greenhill, E. 1995. Museums and Communication: an introductory essay. In: Hooper-Greenhill, E. (Ed.), *Museum, media, message*: Routledge, London, p. 189-203.

Hudak, P.F. 1998. Visualizing Ground-Water-Flow Fields and Contaminent Plumes in an Undergraduate Hydrogeology Course. *Journal of Geoscience Education*, 46, p. 132-136.

Hudson, K. 1975. *A social history of museums.1980s. What the visitors thought.* London.

Hughes, J. 1990. *The interpretative alternative. The Philosophy of Social Research,* 2nd ed. London: Longman.

Hume, A. 1990. Earth Sciences Fellowship. *New Zealand Science Teacher*, 64, p. 23-25.

Hume, A. 1997. The status of earth sciences education in New Zealand schools, *Paper presented at the annual NZARE conference in Auckland, New Zealand.*

Imbeck, K. 1990. Spielend durch die Wissenschaft. *GEO-Magazin,* 1, p. 104-118.

Ingham, A.M. and Gilbert, J.K. 2000. The use of analogue models by students of chemistry at higher education level. In: Gobert, J.D. and B.C. Buckley: Introduction to model-based teaching and learning in science, *International journal of Science Education*, 13, p.193-202.

Iremonger, C. 1996. *Earthworks Maintenance Manual.* Exscite Science Centre, Hamilton.

Javlekar, V.D. 1989. Learning scientific concepts in science centers. In: Bitgood S. (Ed.) : *Visitor Studies: Theory, Research and Practice*, Volume 2, Proceedings of the 1989 Visitor Studies Conference, Jacksonville State University, p.168-179.

Jorgensen, D.L. 1989. *Participant Observation - A Methodology for Human Studies.* Applied Social Research Methods Series, Volume 15, Sage: London.

Kastens, K.A. Van Esselstyn, D. and McClintock, R.O. 1996. An Interactive Multimedia Tool for Helping Students "Translate" from Maps to Reality and Vice Versa. *Journal of Geoscience Education*, 44, p. 529-534.

Kelman, I. 1995. Responsive evaluation in museum education. In: Hooper-Greenhill, E. (Ed.): *Museum, media, message.* Routledge, London, p.204-212.

Kimche, L. 1978. Science Centers:A potential for learning. *Science*, 199, p. 270-273.

King, C. 1999. Improving the teaching of plate tectonics: teacher education by means of a scientific approach that deals with teacher misconceptions. In I.F.Clark (Ed.) *Proceedings of the Third International Geoscience Education Conference*, p. 68-71.

Kintsch, W. and Miller, J.R. 1984. Readability: A view from Cognitive Psychology. In: *Understanding reading comprehension*, International Reading Association, Inc. p. 220-232.

Klein, H.J. and Bachmayer, M. 1981. *Museum und Oeffentlichkeit. Fakten und Daten - Motive und Barrieren.* Berliner Schriften zur Museumskunde, Band 2, Berlin: Gebrueder Mann Verlag.

Klein, H.J. 1984. Analyse von Besucherstrukturen an ausgewaehlten Museen in der Bundesrepublik Deutschland und in Berlin (West). *Materialien aus dem Institut fuer Museumskunde*, Heft 9, Berlin.

Klein-Wisenberg, L. 1988. Zur Situation der Museumspaedagogik in Oestereich. In: Fliedl, G. (Ed.): *Museum als soziales Gedaechtnis? Kritische Beitraege zur Museumswissenschaft und Museumspaedagogik.* Klagenfurter Beitraege zur.

Klemm, F. 1973. Geschichte der naturwissenschaftlichen und technischen Museen. *Deutsches Museum, Abhandlungen und Berichte*, 41, Jg.Heft 2.

Koran,J. J. Foster, J.S. and Koran, M.L. 1989. The relationship among interest, attention and learning in a natural history museum. In: Bitgood S. (Ed.) : *Visitor Studies: Theory, Research and Practice*, Volume 2, Proceedings of the 1989 Visitor Studies Conference, Jacksonville.

Kowal, P.B. 1995. Earth Science Excursions. Finding geology field trips in real -life settings. *The Science Teacher*, April 1995, p. 31-33.

Kroen, M, Geyer, G. and Wagner, H. 1994. Zuckersuesses Eis durch Salz. Publikumsarbeit bei der Landesaustellung Salz in Hallein. *Neues Museum*, 3 / 4, p. 28-33.

Ladendorf, H. 1973. Das Museum - Geschichte, Aufgaben, Probleme. In: Deutsche UNESCO Kommission (Ed.):*Museologie*. Koeln: Verlag Dokumentation, p.14-21.

Larkin, J.H. 1981. Enriching formal knowledge: a model for learning to solve problems in physi cs. In J.R.Anderson (Ed.), *Cognitive Skills and their Acquisition,* Hillsdale, N.J: Lawrence Erlbaum Associates, p. 311-334.

Lee, D. 1993. Science in the New Zealand Curriculum: making sense of Planet Earth and beyond. *Geological Society of New Zealand Newsletter*, 103, p.1-2.

Lucas, A.M. 1991. 'Info-tainment' and informal sources for learning science. *International Journal of Science Education*,13/5, p. 495-504.

Manner, B. M. 1995. Field studies benefit students and teachers. *Journal of Geological Education*, 43, p. 128-131.

Marin, N. and Benarroch, A. 1994. A comparative study of Piagetian and constructivist work on conceptions in science. *International Journal of Science Education*, 16, p.1-15.

Matthews, M. 1995. *Challenging New Zealand Science Education.* Palmerston North: Dunmore Press.

McManus, P. 1987. It's the company you keep. *The International Journal of Museum Management and Curatorship,* 6, p. 263-270.

McManus, P. 1989. Oh, Yes, They Do: How Museum Visitors Read Labels and Interact with Exhibit Texts. *Curator,* 32/3, p. 174-189.

McManus, P. 1992. Topics in Museums and Science Education, *Studies in Science Education*. 20, p. 157-182.

McManus, P. 1994. Families in museums. In: Miles R. and L. Zavala: *Towards the museum of the future: new European perspectives.* Routledge, London, p. 81-97.

Mayer, V.J. 1997. Global Science Literacy: An Earth System View. *Journal of Research in Science Teaching*, 34/2, p. 101-105.

Melton, A.W. 1936. Distribution of attention in galleries in a Museum of Science and Industry. *Museum News*, 14/3, p. 6-8.

Mensch, P. van 1983. Natural History Museums - new directions. In: Reinwardt Academy (Ed.): Exhibition design as an educational tool. *Reinwardt Studies in Museology* ,1, p. 47-56.

Meyer, K.O. 1973. Die historische Entwicklung zum heutigen naturkundlichen Museum. In: Deutsche UNESCO Kommission (Ed.):*Museologie.* Koeln: Verlag Dokumentation, p.29-31.

Miles, R.S. 1988. Exhibit Evaluation in the British Museum (Natural History). *ILVS Review*, 1/1, p. 24-33.

Miles, R.S.and Tout, A. 1990. Holding Power: To choose Time is to Save Time. *What research says about learning in science museums*, W ashington D.C. Association of Science-Technology Centers, p.17-20.

Miller, E. 1973. *That noble cabinet: A history of the British Museum*, London: Deutsch.

Ministry of Education 1993. *Science in the New Zealand Curriculum.* Wellington: Learning Media.

Ministry of Education 1996. *Science in the New Zealand Curriculum.* Learning Media, Wellington.

Moffat, H. 1991. Museums and the National Curriculum, *Museums Journal*, May, p. 32-37.

Moscardo, G.M. 1988. Toward a cognitive model of visitor responses in Interpretive Centers. *Journal of Environmental Education*, 20/1, p. 29-38.

Munro, A. 1999. The long and rocky road: A look at Earth Science Education in New Zealand Secondary Schools, 1970 -2003. In: *Geological Society of New Zealand Inc. 1999 Annual Conference,* Geological Society of New Zealand Miscellaneous Publications 107A.

Newton, D.P. 1995. The Role of Pictures in Learning to Read, *Educational Studies*, 21/1.

Newton, D.P. 1996. Causal situations in science: A model for supporting understanding. *Learning and Instruction*, 6/3, p. 201-217.

Newton, D.P. and Newton, L.D. 1995. Using Analogy to Help Young Children Understand. *Educational Studies*, 21/3, p. 379-393.

Njoo, M. and De Jong, T. 1993. Supporting Exploratory Learning by Offering Overviews of Hyptheses. In: *Simulation-Based Experiential Learning*. D.M. Town, T deJong and H Spada (Eds.), Springer Verlag, Berlin Heidelberg, p. 207-224.

Norris, R.M. 1993. Field-Trip Crisis Large and Small. *Journal of Geological Education,* 14, p. 324-328.

Nottis, K.E.K. 1999. Using Analogies to Teach Plate-Tectonics Concepts. *Journal of Geoscience Education*, 47, p. 449-454.

Nuissl, E. 1988. *Bildung im Museum: zur Realisierung des Bildungsauftrages in Museen und Kunstvereinen*. Vorstand der Arbeitsgruppe fuer empirische Bildungsforschung e.V. (Ed.), Heidelberg, p. 41-175.

Oppenheimer, F. 1968. The role of science museums. In: Larrabee, E. (Ed.): *Museums and Education*. Washington D.C. p.167-178.

Orchiston, W. and Bhathal, R. 1984. Introducing the Science Centrum: A new type of Science Museum. *Curator* 27/1, p. 33-47.

Osborne, R. and Gilbert, J. 1980. A technique for exploring students' views of the world. *Physics Education*, 15, p. 376-379.

Park, E. 1993. Die groessten Museen in drei Tagen. *Globo Sonderheft "USA Highlights",* p.106-113.

Parlett, M. and Hamilton, D. 1972. Evaluation as Illumination: A new approach to the study of innovatory programmes. In: Hamilton, D. Jenkins. D. King, C. MacDonald, B. and Parlett, M. (Eds.): *Beyond the Numbers Game,* Basingstoke, MacMillan Education.

Peart, B. 1984. Impact of exhibit type on knowledge gain, attitudes and behaviour. *Curator*, 27/3, p. 220-237.

Perry, D. L. 1990. Designing exhibits that motivate. *What research says about learning in science museums*, Washington D.C. Association of Science-Technology Centers, p. 25-29.

Philips, D. 1994. It's Hands On. *Museums Journal*, May, p. 28-29.

Philips,W.C. 1991. Earth Science Misconceptions. *The Science Teacher*, February 1991, p. 21-23.

Press, F. and Siever, R. 1994. *Understanding Earth*. W.H. Freeman and Company: New York.

Rennie, L. and McClafferty, T. 1996. Science Centres and Science Learning. *Studies in Science Education,* 27, p. 53-98.

Ripley, E. 1970. *The sacred grove. Essays on museums*. London.

Robinson, E.S. 1928. *The behavior of the museum visitor.* National Association of Museums Publication Series Number 5, Washington D.C.

Robinson, M. 1991. Raise your Enrolment: How to bring more students into your chemistry and physics classes. *The Science Teacher*, February, p. 24-27.

Rodrigues, S.G.A. 1993. *The Role and Effect of Context in Learning Form Six Oxidation and Reduction Concepts by Female Students.* Ph.D. Thesis, University of Waikato.

Rost, A. 1984. Schatzkammer der Genies. *GEO-Magazin* 3, p.40-62.

Roth, W.M. 1998. *Designing communities.* Kluwer Academic Publishers: London.

Rowan, K. 1990. Explaining difficult ideas. *What research says about learning in science museums,* Whashington D.C. Association of Science-Technology Centers, p. 35-39.

Sakofs, M.S. 1984. Optimizing the Educational Impact of a Museum Tour. *Curator*, 27/2, p. 135-140.

Schwartz, D.L. 1993. The construction and Analogical Transfer of Symbolic Visualizations. *Journal of Research in Science Teaching*, 30/10, p. 1309-1325.

Schwartz, S. 1996. The Science Centre and Manawatu Museum - Te Whare Pupuri Taonga O Manawatu. *New Zealand Science Teacher*, 80, p. 12-16.

Screven, C.G. 1969. The museum as a responsive learning environment. *Museum News*, June, p.7-10.

Screven, C.G. 1975. The effectiveness of guidance devices on visitor learning. *Curator*, 18/3, p. 219-243.

Shaw-Miller, L. and Mason, R. 1995. Learning Curve. *Museums Journal*, June, p. 15.

Shea, H. 1996. Constructivism in Science Education. *Journal of Geoscience Education*, 44/3, p. 242.

Shettel, H.H. 1973. Exhibits: Art form or educational medium? *Museum News*, 52/1, p. 32-41.

Shettel, H.H. 1968. An evaluation of existing criteria for judging the quality of science exhibits. *Curator*, 11/2, p. 137-153.

Shortland, M. 1987. No business like show business. *Nature*, 328, p. 213-214.

Smith M.L. 1987. Publishing qualitative research. *American Educational Research Journal*, 24/2, p. 173-183.

Snook, I. 1981. Ethics of educational research. *Delta*, 29, p. 9-15.

Snyder, J.L. 2000. An investigation of the knowledge structures of experts, intermediates and novices in physics. *International Journal of Science Education*, 22/9, p. 979-992.

Solomon, J. 1980. *Teaching children in the Laboratory*. Croom Helm: London.

Solomon, J. 1992. *Schools of thought. on children's notions, Getting to know about Energy - in Schools and Society*, Falmer Press, London.

Solomon, J. 1993. The social construction of children's scientific knowledge. In: Black, P.J. and A.M. Lucas (Eds.): *Children's informal ideas in science*, London, Routledge, p. 85-101.

Solomon, J. 1994. The Rise and Fall of Constructivism. *Studies in Science Education*, 23, p. 1-19.

Springer, D.A. 1997. Geology in the popular press: Paleontology's greatest hits. *Geotimes*, 44, p. 242.

Stevenson, J. 1991. The long -term impact of interactive exhibits. *International Journal of Science Education*, 13/5, p. 521-531.

Stewart, D.W. and Shamdasani, P.N. 1991, *Focus groups: theory and practice*. 3rd. Edition, Sage : London.

Strauss, A. and Corbin, J. 1990. *Basics of qualitative research: grounded theory, procedures and techniques.* Newsbury Park, California: Sage Publications.

Summers, M. and Mant, J. 1995. A survey of British primary school teachers' understanding of the Earth's place in the universe. *Educational Research*, 37/1, p. 3-19.

Tansey,P.J. 1971. A primer of simulation: its methods, models, and application in educational processes. In: *Educational aspects of simulation*, Mc Graw-Hill Publishing Company Ltd, Maidenhead, England, p. 1-25 .

Towne, D.M, De Jong, J. and Spada, H. 1993. *Simulation-Based Experiental Learning.* Springer Verlag Berlin Heidelberg.

Treagust, D.F.Lindauer, I. and Joslin, P. 1989. Teachers use of analogies in their regular teaching routines. *Research in Science Education*, 19, p. 291-299.

Trend, R. 1996. Fostering collaboration as a means of enhancing geoscience teaching in Devon, UK. In D.Stow and G.J.H. McCall (Eds.) *Geoscience Education and Training, in Schools and Universities, for Industry and public Awareness.* Rotterdam:AA Balkema, p. 367-378.

Trend, R. 1998. An investigation into understanding of geological time among 10 - and 11-year old children. *International Journal of Science Education*, 20/8, p. 973-988.

Trend, R. 2000. Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history, and science. *International Journal of Science Education*, 22/5, p. 539-555.

Tulip, D. O'Connell, D. and English, L. 1994. Children's interests in Geology and Biology. *Research in Science Education*, 24, p. 331-337.

Turner, R.H. Nigg, J.M.and Daz, D.H. 1986. *Waiting for Disaster: Earthquake Watch in California.* University of California, Berkley, CA.

Ward Moser, P. 1987. Freudenhaus der Wissenschaft. *GEO- Magazin*, 9, p. 30-42.

Wellington, J. 1989. Attitudes before understanding: The contribution of interactive science centres to science education. In M. Quin (Ed.), *Sharing science: Issues in the development of interactive science and technology centres,* p. 30-32.

Wellington, J. 1991. Newspaper science, school science: friends or enemies? *International Journal of Science Education*, 13/4, p. 363-372.

Weschenfelder K. und Zacharias, W. 1981. *Handbuch Museumspaedagogik. Orientierung und Methoden fuer die Praxis.* Duesseldorf: Paedagogischer Verlag Schwann.

Wittlin A.S. 1970. Museums: In search of a usable future. London. In: Geyer, G.(1995):*Der Besucher im Naturkunndemuseum. Eine empirische Untersuchung im Haus der Natur, Salzburg.* Dissertation, Naturwissenschaftliche Fakultaet an der Universitaet Salzburg.

Wizevich K. 1993. *Creation and Reception of exhibitions: comparison of provider intentions and visitor response.* Ph.D. Thesis, Victoria University of Wellington.

Wright, D.R. and Hodder, A.P.W. 1997. Following the leaders: the development of science-technology centres in New Zealand, *Paper presented at the annual NZARE conference, Auckland,* New Zealand.

Wright, E.L. 1980. Analysis of the effect of a museum experience on the biology achievement ofsixth graders. *Journal of Research in Science Teaching,* 17/2, p. 99-104.