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Positioned as Expert Scientists:

Learning science through

Mantle-of-the-Expert at years 7/8

A thesis

submitted in fulfilment

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Abstract

This study emerged from concern that students disengage from science at an early age. It investigated whether using the drama-based teaching approach Mantle-of-the-Expert would support students' interest in and learning of science. To do this a mixed method action research study was conducted. A science-based unit was co-taught with the classroom teacher over nine-weeks with a class of year 7/8 students in a semi-rural school.

A Mantle-of-the-Expert unit was devised to support learning about buoyancy and stability with the students positioned as expert scientists re-investigating the sinking of the Wahine in Wellington Harbour, New Zealand on April the 10th 1968. Student assessment data, audio transcription of classroom episodes, the researcher's reflective blog, and classroom artefacts were gathered, analysed and used to describe student learning. Student and teacher perceptions of Mantle-of-the-Expert as an approach to learning science were sought via interviews.

The findings show that the participant framework of Mantle-of-the-Expert produced a collegial inclusive learning environment. Working within an ethical 'expert' scientist position enhanced students' motivation to learn and produce high-quality work, as well as enlarging their conception of how science affects humanity. The students' expert status was supported through a hybridised instructional model incorporating both transmissive and investigative components and using artefacts to create a conceptual bridge between students' actual knowledge and fictional knowledge.

Students demonstrated marked improvement in their understanding of the science concepts taught in their written and oral work. Student perceptions of their self-efficacy in science remained relatively unchanged and their attitudes towards school science declined slightly. There was evidence they gained a greater appreciation of the kinds of work and careers scientists have and that they were more aware of the contribution of science to everyday life.

The findings have implications for curriculum policy and practice in science and drama education through evidence that a Mantle-of-the-Expert based unit can contribute to science and to drama education. Mantle-of-the-Expert is one way that effective practices from both fields can be melded together to generate relevant and effective science learning opportunities. It contributes the notion of ‘fictional others’ to the theorisation and design of the Mantle-of-the-Expert approach as a way of encouraging ethical thinking and academic excellence. It also speaks of the value of using Mantle-of-the-Expert to enhance conceptual change.

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Chapter 1: Introduction

1.1 Personal motivation for this study

My interest in this study grew from my love of drama and science and my concern about student learning. It aims to bring these three passions together by exploring the use of a creative dramatic pedagogy to teach science.

I spent almost twenty years working as a medical laboratory scientist. As a scientist I was concerned whether there were sufficient scientists to maintain New Zealand's standard of living and economic base through research and development. However, I realised it was equally important to ensure all citizens are scientifically literate. Gluckman (2011) echoed that sentiment in a report to the New Zealand Prime Minister. He asserted that science education should not only provide a career path for future scientists, but also ensure all students have sufficient practical knowledge about how things work to function in a modern democratic society.

When contemplating a career in education, I visited a secondary school and noticed the students seemed bored in science. I became interested in finding and using innovative pedagogical approaches to potentially engage students in science. I undertook a Masters level paper on the drama-based pedagogy known as Mantle-of-the-Expert (Heathcote & Bolton, 1995). I found the approach engaging and wondered whether it could be used to enhance engagement and student learning in science.

1.2 Wider purpose for this study

It has been widely noted in the literature that students are disengaging from science and the possibility of science-based careers (Bolstad & Hipkins, 2008; Tytler & Osborne, 2012). Latest results from large external international assessment studies – the Programme for International Student Assessment (PISA) (May, Cowles, & Lamy, 2013), the Progress in International Reading Literacy Study/ Trends in International Mathematics and Science Study (PIRLS/ TIMMS) (Chamberlain & Caygill, 2012) and the New Zealand based National Monitoring Study of Student Achievement (NMSSA) (Educational Assessment Research Unit

& New Zealand Council for Educational Research, 2013) have identified some of the same negative trends in New Zealand students' science achievement and attitudes towards science.

Reasons for student disengagement in science will be discussed in full in chapter two but one suggestion, pertinent to this study, is that students without a positive science identity or trajectory are less likely to engage in science and/or contemplate science careers (Archer et al., 2010; Brickhouse, Lowery, & Schultz, 2000; Carlone, 2004). Possible causes for student disengagement include transmissive teaching approaches (Lyons, 2006) and the complexity of science (Aschbacher, Li, & Roth, 2010; J. Osborne & Collins, 2001; Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008). Other reasons identified as disengaging are that science is perceived as irrelevant to students' lives (J. Osborne & Collins, 2001; Tytler et al., 2008) and poor teacher/student relationships (Bennett & Hogarth, 2009; Darby, 2005; Tytler et al., 2008). Approaches identified as enhancing student engagement include: framing the learning in relevant contexts, using an investigative approach with practical hands-on activities and ensuring students have ownership over their learning (Bolstad & Hipkins, 2008; Marginson, Tytler, Freeman, & Roberts, 2013; J. Osborne & Collins, 2001; Tytler et al., 2008). Incorporating the arts into STEM (Science, Technology, Engineering and Technology) has also been recognised in South Korea and parts of the USA as useful in enhancing student "creativity and design" (Marginson et al., 2013, p. 15). Approaches that incorporate the arts are often known as STEAM (Science, Technology, Engineering, Art, and Mathematics) approaches (Marginson et al., 2013, Land, 2013).

While drama has been used to teach science (Dorion, 2009; Ødegaard, 2003), the use of the dramatic pedagogical approach Mantle-of-the-Expert to teach science has not been well described in literature. In this thesis, I explore the potential of Mantle-of-the-Expert for teaching science to a Year 7/8 class. A brief description of Mantle-of-the-Expert shall be given here to situate the reader but it shall be discussed in full in section 3.2.

Mantle-of-the-Expert was devised and developed by the late Professor Dorothy Heathcote (1926-2011) (Heathcote & Bolton, 1995) as a means of countering student disengagement and disenfranchisement in education. It is an active, collaborative, drama-based pedagogical approach for teaching across the curriculum. In Mantle-of-the-Expert, students are invited to participate in curricular learning framed within a sustained dramatical inquiry. They are positioned as expert members of an ethical team/enterprise or company and agree to take on the responsibilities associated with that position (Heathcote & Bolton, 1995). Students and teachers work collegially within the doubled reality of the classroom and the fictional world they are exploring (Edmiston, 2003; Heathcote, 2010b) with the teacher having responsibility for sustaining the integrity of the drama and student learning (Heathcote, 2008a). The company (as it is known in this study) is specifically chosen to support the curricular learning. In their professional roles, students take on a commission from a fictional client, which sets the parameters of the curricular learning. Working for a client, rather than the teacher, provides an external audience for student work (Heathcote & Bolton, 1995), giving the students both a purpose for learning and an incentive to produce high quality work (Fraser, Aitken, Price, & White, 2012; Heathcote & Bolton, 1995).

1.3 The context of this study

The participants in this study were the teacher and 29 Year 7/8 students (aged between 11 and 13) from one classroom in a moderately affluent semi-rural New Zealand school. I selected the school on the basis it already used Mantle-of-the-Expert. I chose to research with year 7/8 students, as it is a critical age for maintaining student interest in science. The study took place between July and October 2011 for two afternoons a week for nine weeks. As co-teaching is an established practice at the school, and is in keeping with the collaborative ethos of Mantle-of-the-Expert, I chose to co-teach the unit with the classroom teacher.

In New Zealand, teachers are required to design their own science units using the *New Zealand Curriculum* (NZC) (Ministry of Education, 2007b) framework document. The science-based unit on buoyancy in this study was framed around the sinking of the T.E.V. (Turbine Electric Vessel) Wahine in Wellington Harbour, New Zealand in 1968. The unit was designed to adhere to Heathcote's (Heathcote & Bolton, 1995) classical structure, and to ensure that the science concepts of buoyancy, stability, cyclones and isobar map prediction were taught. It was bounded by the requirements of the NZC. It looks closely at how curricular knowledge (both science content knowledge and the Nature of Science (NOS)) is taught through Mantle-of-the-Expert and whether learning in this manner enhances conceptual change.

The following research questions were designed to contain, define, and guide my study.

1. How did Mantle-of-the-Expert support or constrain the learning of science concepts and the Nature of Science by a class of year 7/8 students?
2. What shifts in students' written and verbal use of science concepts, Nature of Science, and science language, occurred over the course of a nine-week Mantle-of-the-Expert unit?
3. How did Year 7/8 students in this study come to perceive science now and in their future?

The research was situated within an interpretive worldview. My main strategy of inquiry was an action research approach within a co-teaching model. Mixed methods were used to collect, analyse, integrate and interpret the data. For the qualitative arm of the study, data was generated from audio recordings of the classroom episodes, interviews with a third of the students and the classroom teacher, and the collection of student work. Quantitative data on conceptual understandings and attitudes was collected through identical pre-and-post unit assessments using a combination of short and long answer questions for the conceptual questions, and a Likert scale for attitudinal data. Data was analysed both thematically and statistically. The findings were interpreted through the identity lenses of figured worlds (Holland, Lachicotte Jr, Skinner, & Cain, 1998) and positioning theory (Harré & van Langenhove, 1999c).

1.4 Structure of the thesis

Chapter one introduces the research and provides a justification for undertaking the study.

Chapter two describes relevant science education literature. It starts by giving the definition for curriculum used in this study. It highlights the tension between science for scientists and science for citizenship. It outlines learning science at school, looking at the literature on conceptual understanding and the NOS. It explores the literature on student attitudes towards science, scientists and science careers. The situation in New Zealand is described. Then, the focus shifts to examining two major factors that influence student engagement in science – identity and pedagogy. The construct of identity is described. The two identity lenses used in this study, figured worlds and positioning theory, are defined. Literature where these lenses have been used is outlined. The other major influence on engagement, the type of pedagogical approaches used in science education is explored looking both at the types of approaches that disengage and those that provide optimal conditions for students to engage into science and science careers.

Chapter three examines the literature on using drama to teach science. It starts by giving a historical overview of drama in education in New Zealand. It initially focuses on process drama, then specifically on Mantle-of-the-Expert. A fuller working definition of Mantle-of-the-Expert is given and its use in literature detailed. Then, the focus shifts to drama used to teach science and instances of the types of drama used are given, along with their advantages and disadvantages. It additionally outlines the use of positioning theory and figured worlds in the drama literature. Finally, the sparse literature combining science and Mantle-of-the-Expert is delineated.

Chapter four details the methodology and methods used in this study. My worldview is given. I describe why I use action research and co-teach. The use of mixed methods to collect, analyse, integrate and interpret my data is outlined. The research context and unit of teaching are detailed. Methods used to collect data are given. My data integration strategies and interpretation are described. Finally, the ethical considerations and trustworthiness measures pertinent to this project are detailed.

In chapters five, six, and seven, the findings from the study are presented. In chapter five the findings in relation to how students learn science through Mantle-of-the-Expert are examined. The importance of being positioned as experts, as ethical scientists, and being engaged in learning is detailed. The constraints of learning science in this way are also outlined.

In chapter six, the findings related to the learning of the science concepts taught are examined. The major science concepts - buoyancy and stability - are investigated through oral data from four representative classroom episodes, student assessments, student interviews and written reports. I briefly touch on cyclones and weather isobar-map interpretation because they are important factors in the sinking of the Wahine. I also examine whether the students' science understanding improved overall and whether or not student attitudes to science changed over the duration of the unit.

In chapter seven, student learning of NOS is explored, looking in particular at NZC (Ministry of Education, 2007b) categories of: understanding about science, investigating in science, and communicating in science (achievement objectives fold-out charts following p. 44). Student future career aspirations are detailed, as is student knowledge about science careers.

Chapter eight discusses the findings in terms of the research questions and links them to pertinent literature. The first question, which looks at whether the Mantle-of-the-Expert approach supports or constrains the learning of science, is discussed through breaking down the approach into its structural and procedural components. The second question, which looks at shifts in student learning of science concepts, the nature of science, student attitudes towards science and the third question, which examines whether students see themselves studying science or having a science career now or in the future and knowledge of science careers, are discussed under the heading of student science learning.

In chapter nine, the conclusion of the study is given, with the findings summarised. The limitations are described, the implications of the work set out and future directions for research outlined.

Chapter 2: Literature Review on science, identity - figured worlds and positioning theory, and pedagogy

2.1 Introduction

This chapter reviews literature on science learning. It begins by describing the conflicting aims of science education teaching science for citizenship and science for scientists. Next, a brief explanation about the New Zealand curriculum document specifically pertaining to science is given. Literature relating to enhancing conceptual understandings in science and learning about the NOS is briefly discussed. Student attitudes towards science and scientists and science-based careers highlighted in the literature is explored. The situation in New Zealand regarding student achievement and attitudes towards science is succinctly described. Following this, factors that influence student engagement with science and science careers are detailed, focusing on identity and pedagogy. The construct of identity is defined. The two analytical lenses used in the study – figured worlds and positioning theory are described and literature about their use in education given, focussing on science education. Literature on the importance of having a science identity is outlined. Finally, the influence of pedagogy on student engagement with science is surveyed. Comment is given on deleterious practice and contrasted with practices that may positively influence students to remain involved with science and consider science-based careers.

2.2 Learning science at school

Science is experienced at school through the curriculum. I take the working definition of curriculum from the National Research Council (2012), as “the knowledge and practices in subject matter areas that teachers teach and that students are supposed to learn” (p. 246). The tension between curriculum that support science for scientists and science for citizenship will be detailed in section 2.2.1.

Curriculum documents worldwide have expanded to include not only science concepts and NOS but also how science informs society (Department for Education, 2014; Duschl, 2008; National Research Council, 2007). This trend is also seen in the *New Zealand Curriculum* (NZC) (Ministry of Education, 2007b).

The national curriculum (Ministry of Education, 2007b) for mainstream schools in New Zealand is a framework curriculum and is not prescriptive. While schools are expected to ensure that students meet the intent and learning criteria of the curriculum, there is considerable freedom in how learning is structured and the resources used to teach and assess (p. 37).

There are eight curricular learning areas – "English, the arts, health and physical education, learning languages, mathematics and statistics, science, social sciences, and technology" (p. 16). There are eight curriculum levels for schooling years 1 - 13. Levels 1 – 5 relate to the first ten years of schooling with students ideally progressing through a level every two years. The later three levels equate to years 11, 12 and 13. Specific achievement objectives have been written for each area and level of the curriculum (p. 38) but they are not prescriptive.

The science learning area in the NZC includes a unifying Nature of Science (NOS) strand and four contextual strands (the Living World, the Planet Earth and Beyond, the Physical World and the Material World) through which scientific knowledge is taught (pp. 29, 30). As already mentioned the curricular document is succinct. For example, the achievement objective for the physical world strand at Level 3 and Level 4 in science, which is the appropriate level and main context strand in my study states:

> Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, identify and describe the effect of forces (contact and non-contact) on the motion of objects; identify and describe everyday examples (Ministry of Education, 2007b, foldout pages following p. 44).

Conceptual understanding in science will be looked at in section 2.2.2, while learning the NOS will be addressed in section 2.2.3.

2.2.1 The tension between science for scientists and science for citizenship

My review of literature related to the science curriculum found an obvious philosophical tension between scholars and policy makers for whom learning in science is about becoming a scientist and those who conceptualise learning in science as part of becoming a good citizen (Millar, 2006; J. Osborne, 2007). On one hand, governments and people involved in industry are concerned that insufficient students are being trained in science, technology, engineering and mathematics (STEM) careers to fulfil industry and research requirements (Economic and Social Research Council, 2006; Kjærnsli & Lie, 2011; Organisation for Economic Co-operation and Development, 2008; Tytler et al., 2008). This scenario is disturbing due to the perception in literature that the number of students considering STEM careers is declining (Bøe, Henriksen, Lyon, & Schreiner, 2011; Bull, Gilbert, Barwick, Hipkins, & Baker, 2010; European Union, 2004; Hackling, Goodrum, & Rennie, 2001; Hassan & Treagust, 2003; Hipkins & Bolstad, 2005; Lyons, 2006; Schreiner & Sjøberg, 2007; Tytler et al., 2008). On the other hand, governments are concerned about the requirement to have scientifically literate citizens (J. Osborne, 2007) who view science as part of everyday life and are actively and critically involved in science-related/based issues (Lindsay, 2011; Loughran, 2011). Scientifically literate citizens not only recognise key scientific concepts and the NOS (M. Braun & Reiss, 2006, p. 214), but also, according to Preczewski, Mittler, and Tillotson (2009), "recognize and engage in the practice of science" (p. 255).

This strong citizenship focus is underscored in the NZC (Ministry of Education, 2007b) essence statement.

> In **science**, students explore how both the natural physical world and science itself work so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role (Ministry of Education, 2007b, p. 17).

The New Zealand government has indicated it desires all students leave formal education with enough science to contribute to society. This emphasis on citizenship is signposted in other governmental reports such as the *Looking ahead: Science education for the twenty first century* report by Gluckman (2011).

The New Zealand government has further emphasised the importance of science to New Zealand in recent policy. The vision statement in *The national statement of science investment 2015-2025* (Ministry of Business Innovation & Employment Hīkina Whakatutuki (2015a) is "A highly dynamic science system that enriches New Zealand, making a more visible, measurable contribution to our productivity and wellbeing through excellent science" (p. 10), again emphasing the importance of science to the New Zealand economy. The government has initiated 12 National Science Challenges (Ministry of Business Innovation & Employment Hīkina Whakatutuki (2015b) to raise the profile of science and encourage science research. In the broader overarching science and society challenge, which has an education focus, the aim is to "produce more science and technology-competent learners, and more choosing STEM-related career pathways" (Ministry of Business Innovation & Employment Hīkina Whakatutuki, Ministry of Education, & Office of the Prime Minister's chief science advisor, 2014, p. 7). Action area 1 of this challenge sets out three area of future initiatives, which are pertinent to this study:

> **Action Area 1:** Enhancing the role of education
>
> › Improve initial teacher education through increased science and technology teaching competencies, leading to increased confidence
>
> › Better in-service professional learning and development for science and technology teachers
>
> › Build stronger links between science and technology educators, learners, technologists and scientists, in the classroom and in the community (p. 7).

In this study I explore the potential of Heathcote's (Heathcote & Bolton, 1995) drama-based pedagogy - Mantle-of-the-Expert - to develop students as ethical, responsible citizens who are able to make real decisions about science-related matters in their lives.

2.2.2 Conceptual understanding in science

A survey of the literature reveals that defining science concepts and conceptual understanding is complex. Concepts are sense making mechanisms (Nersessian, 2008), which are formed socially and "constitute the realm of ‘‘what is known’’"

(Wells, 2008, p. 330). According to Sainsbury and Walker (2011), they are used to both communicate, mediate meaning and to “facilitate[e] collaborative activity” (p. 265). Put another way, concepts are used to explain what we know about phenomenon and as a way of understanding behaviour. According to Duit and Treagust (2012) conceptions are the “internal representations” that learners mentally construct from the words, gestures, symbols, texts and models used by people and/or texts explaining about concepts/ideas (p. 107, 108). Examples of common science concepts would be forces, evolution and entropy. In my research I explore and seek to deepen students’ conceptual understandings about buoyancy, stability, cyclones and isobar map weather prediction. I will be looking to see whether the conceptions formed by the students about these concepts have changed over the study period through assessment data, their dialogue and written artefacts.

It is well recognised that children possess explanations about everyday phenomenon before they receive a formal science education, which Vosniadou (2012) terms preconceptions. These pre-instructional explanations for science phenomena are not necessarily the same as those recognised by scientists (Driver, 1989; Duit & Treagust, 2012; R. Osborne & Freyberg, 1985; Schwartz, Shapiro, & Gregory, 2013; Treagust & Duit, 2008; Vosniadou, 2012).

The dilemma of how to move students’ pre-instructional understandings closer to the scientific norm has been subject to extensive research and debate, with this process widely known as conceptual change (Rusanen, 2014; Schwartz, Shapiro, & Gregory, 2013; Taber, 2009). The difficulty, according to Vosniadou (2012) is that conceptual change in science not only requires students to gain an understanding of the science concepts, which may be counterintuitive to everyday explanations for phenomena, but also the process of science, and genre specific aspects like hypothesis formation and testing. In addition, the students also have to modify their pre-instructional or current conceptions, reformat how they categorises phenomenon and acquire or create new knowledge (Rusanen, 2014; Vosniadou, 2012). Due to the complexity of the process, and the fact that can be impeded by students’ identity aspirations, attitudes towards science and the pedagogical approaches used (Duit and Treagust, 2012), it is not surprising that the process may take considerable time (Vosniadou, 2012).

Posner et al. (1982) proposed that for alternate concepts to be ‘accommodated’ by the student, four conditions must occur. Firstly, the students must recognise the inadequacy of their current framework. Then proposed alternate concept/s must be understandable. The proposed concepts must also be consistent with their prior knowledge, and able to meet constraints of the phenomena being explored. Finally, they should be useful for answering further questions (p. 214). While useful, according to Duit and Treagust (2012), this approach may be limited if students do not recognise the inadequacy of their conceptions. Chi and Roscoe (2002) suggested that providing students with the missing knowledge, ensuring that they are aware of gaps in their reasoning and offering an alternate category to reassign the phenomenon into may make it easier for students to repair and realign their misconceptions to a more appropriate ontological category.

In Vosniadou’s Framework theory (Vosniadou, 2013a; Vosniadou, Vamvakoussi, & Skopeliti, 2008) when students are introduced to new explanations for phenomena several things may occur. They may reject the conception as not fitting their prior knowledge. They may accept them and rapidly change their conceptions (but this is rare). Or they may add the new ideas onto their pre-conceptions and distort it, leading to “misconceptions” or “synthetic conception and models” as the concepts have not been outlined in enough detail to the students for complete understanding to occur (Vosniadou, 2012, p. 123, 124; 2013b). According to Vosniadou (2013b), synthetic conceptions function as a “bridge between the initial concept and the scientific perspective” and allow the students to manage the dissonance between their preconception and the scientific conception until the knowledge is stabilised (p. 18). While incorrect, these synthetic conceptions have “some internal consistency and explanatory value” (Vosniadou & Skopeliti, 2014, p. 1430). Vosniadou (2013a) considers that the formation of synthesised conceptions is an intermediate stage of knowledge acquisition and notes that the synthetic conceptions are fluid and change according to context and need (pp. 21, 22).

Many researchers have highlighted that fostering conceptual change is challenging (Chi & Roscoe, 2002; Treagust & Duit, 2008, 2012). Researchers have emphasised that conceptual change is fostered when learning occurs in a socially relevant context with support given by the teacher in connecting prior knowledge to the concept being explored (for example, Duit & Treagust, 2012; Schauble, Glaser, Duschl, Schulze, & John, 1995; Vosniadou, 2012).

Brock (2015) and Vosniadou (2012) also highlight that the beliefs teachers (and students) hold about knowledge (such as a constructivist point of view rather than a traditional view) and the best way to impart knowledge can imped or enhance conceptual change. For example, Vosniadou (2012) asserts that students are more likely to “develop critical thinking, engage in hypothesis testing or look for alternative explanations” if they view science as changeable rather than “stable and consist[ing] of pieces of information” (p. 127). Brock (2015) concurs, arguing that students and teachers who view science this way tend to be more intuitive in their learning, which aids their conceptual learning.

The importance of dialogue in fostering conceptual change is well documented. Mercer (2008), for example, claims dialogue is pivotal to conceptual change (p. 353). Duit and Treagust (2012) and Vosniadou (2012) consider that student discussion in both small and large groups is useful as it provides a space for the students to construct knowledge but also for the teachers to assess the progression of their conceptual understanding. One advantage of working in small groups, according to Vosniadou (2012), is that students can work together to discover the “correct solution and supporting it with the best argument” (p. 128). Greeno and van de Sande (2007) consider conceptual understanding is demonstrated through students’ contributions to discourse and other activities and by how closely their discourse aligns to the “constraints that constitute that conception’s meaning” (p. 14). Roth, Lee, and Hwang (2008) concur, suggesting conceptual understanding is “articulated in and through the process of talk rather than driving the talk” (p. 249). Important to this study, Sainsbury and Walker (2011) suggest that conceptual change is whether the individual can communicate meaningfully in the (science) community, is recognised as belonging and can work collaboratively with others in the field (p. 266). Within the study I will not only explore student test results and other data sets to look for changes in conceptual understanding, but also dialogue to see whether students can communicate meaningfully about the science using language and processes that belong to the community of science.

The types of pedagogical practices, resources and artifacts used in teaching impact upon student learning of science concepts (Duit & Treagust, 2012; Vosniadou, 2012). Therefore, it is critical that relevant activities to enhance conceptual change (set at cognitively appropriate levels) be carefully developed (Duit & Treagust, 2012; Vosniadou, 2012, 2013a). Zhou (2010) recommends using an authentic inquiry model based on students' research problems; where experimentation and argumentation are used to test and defend science concepts, can through dissatisfaction and evidence from their scientific inquiry, help students change their pre-instruction science concepts. He suggests this method works on two levels: epistemologically – as argumentation highlights problems with student preconceptions and pedagogically – in terms of motivation and the mirroring of science communities (p. 109). In line with this, the use of inquiry and argumentation was also advocated by Vosniadou (2003, 2012). Rather than a superficial coverage of many topics Vosniadou (2012) promoted a prolonged investigation into a few key concepts aids conceptual development.

In my study I will be looking at whether the students' conceptual understanding shifts as a consequence of them learning within a socially relevant scenario through a process that also supports interaction and dialogue. These aspects are characteristic of my chosen pedagogical approach – the Mantle-of-the-Expert – as is explained later.

2.2.3 Nature of science

This section outlines what has been described alternatively, as science processes (Millar & Driver, 1987), scientific epistemologies (Sandoval, 2005) and the nature of science (NOS) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). In the science processes approach; students work in the manner of scientists and use scientific methods and science process skills like classifying, observing and inferring (Millar & Driver, 1987). In the scientific epistemological approach, students are concerned with scientific knowledge, in particular its derivation, truth and scientific merit (Sandoval, 2005, p. 635). While, according to Corrigan and Gunstone (2007), NOS incorporates both, "epistemological and sociological" components (p. 139). In this study I focus on/ base my discussion on NOS because this is the construct/approach used in the *New Zealand Curriculum*

(NZC) (Ministry of Education, 2007b).

Researchers worldwide have highlighted the importance of students understanding the NOS for almost 100 years (Lederman et al., 2002). However, defining the NOS is problematic with a wide variety of categories specified by different researchers (Lederman et al., 2002; McComas & Olson, 1998; J. Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Sandoval, 2005; Wong, Hodson, Kwan, & Yung, 2008). A commonly quoted classification is that of Lederman et al. (2002) who assert that the NOS is to do with the principles and expectations that underpin scientific processes. Under that definition science is: empirical, based on scientific theories, uses multiple methods of analysis, involves creativity and imagination, is situated within a socio-cultural context and is tentative. The NOS strand in the NZC (Ministry of Education, 2007b) states that students will understand, investigate, communicate, and participate and contribute in science. It further specifies that the aim of this is to support students to "learn what science is and how scientists work" (p. 28). The aspects of NOS that are supported in the NOS strand in the NZC (Ministry of Education, 2007b) are that science is tentative; empirical; imaginative and creative; subjective and theory laden; and socially and culturally embedded (Science Learning Hub, 2011). These are generally congruent with the way NOS is described in the science literature. I will be framing my study around NOS as it is defined in the NZC.

Despite the importance accorded to NOS, numerous studies have reported that teachers and students do not have a comprehensive understanding of NOS (Abd-El-Khalick & Lederman, 2000). Hipkins (2012) notes that teachers find it difficult to teach (see also Vannier, 2012; Bartos & Lederman, 2014), commenting the scenario is likely to continue unless teachers are supported to develop their understanding and are provided with the resources and strategies for teaching. Many researchers have recommended the explicit teaching of NOS as a solution (Abd-El-Khalick & Lederman, 2000; Christensen, 2011; Wong et al., 2008; Wong, Wan, & Cheng, 2011). Strategies to enhance student and teacher knowledge of the NOS include: situating NOS in contemporary real-life contexts (Wong et al., 2008), using argumentation (McDonald, 2010), using materials and other strategies to enhance teacher pedagogical content knowledge (Hanuscin, Lee, & Akerson, 2010) and reflection (Abd-El-Khalick & Lederman, 2000). This study explores strategies that may support student learning about NOS, in particular what scientists are and do, via the medium of Mantle-of-the-Expert.

2.3 Pertinent issues in science education

This section examines research on student attitudes towards science, scientists and careers in science. Then, the focus narrows to outline the situation in New Zealand regarding student proficiency in science and their attitudes towards science.

2.3.1 Student attitudes towards science

Concern has been raised in literature for over forty years about students having negative attitudes towards school science and science careers (Barmby, Kind, & Jones, 2008; Bolstad & Hipkins, 2008; Bybee & McCrae, 2011; Gardner, 1975; Hendriksen, 2015; J. Osborne, Simon, & Collins, 2003; Schibeci, 1984; Tytler & Osborne, 2012; Tytler et al., 2008). Research commentary indicates that while students start school enthusiastic towards science, their positivity declines throughout their schooling (Archer et al., 2012b; DeWitt & Archer, 2015; Kerr & Murphy, 2012; Colette Murphy & Beggs, 2003; Pell & Jarvis, 2001; Turner & Ireson, 2010). Alexander, Johnson, and Kelley (2012) report that even children under five years old are deciding not to engage with science.

A point of interest raised by Colette Murphy, Beggs, Carlisle, and Greenwood (2004), and reiterated by Kerr and Murphy (2012) is that this attitudinal drop in primary students is less apparent when students “are involved in practical, investigative science activities” (p. 628). Although disengagement towards science at secondary levels tends to coincide with a general disengagement from schooling, the level of negativity regarding science appears pronounced (Bolstad & Hipkins, 2008). As a counterpoint, Sjøberg and Schreiner (2010) assert that the *Relevance of Science Education* (ROSE) data indicates most young people are relatively positive towards science in general. This was also found in the *ASPIRE* data (see for example, DeWitt & Archer, 2015). The issue of declining attitudes towards science is central to my own study. I am interested to see what my eleven and twelve year participants reveal about their engagement or disengagement with science.

The effect of gender on student attitudes towards science has been well researched; with most studies suggesting boys are more positive towards science than girls (Bennett & Hogarth, 2009; Bybee & McCrae, 2011; George, 2006; Lindahl, 2003; J. Osborne & Collins, 2001; Schibeci, 1984; Sikora & Pokropek, 2012; Spall & Stanisstreet, 2004). Generally the literature suggests that while most students prefer biology, boys tend to like the physical sciences more than girls (Gardner, 1975; J. Osborne & Collins, 2001; Schibeci, 1984). Schreiner (2006) found boys more interested in topics like explosives and technology/machines, while girls liked human biology, health related topics, or unexplained phenomena. This gender based interest in the types of science was also identified in 2006 PISA results by Bybee and McCrae (2011) who stressed girls were more interested in health issues while boys were more technologically focussed. Sikora and Pokropek (2012) who also looked at the PISA data, found girls chose science careers in biology, agriculture and health, while boys were more interested in computing, engineering and mathematics (p. 255). Barmby et al. (2008) found the gender divide less obvious in the early years but increased as students moved into the higher grades. My study focuses on students aged 11-13. While gender will be addressed to an extent, it is not a major focus of this study.

2.3.2 Student attitudes towards scientists

A dominant factor identified in the literature as a deterrent to student engagement in science and science careers relates to the negative discourses surrounding the construct of ‘scientist’. Many researchers have explored student impressions of scientists. In their seminal work, M. Mead and Metraux (1957) drew on essay data from 35000 high school students about their impressions of scientists, to create a composite description of a scientist as an elderly, unkempt male with glasses, who wears a lab coat and experiments in a laboratory (p. 386-387). Finson (2002) noted that a “classical stereotypical image of a scientist” is still held by many students (p. 355). A common way of eliciting students’ impressions of scientist is through drawing a scientist (Chambers, 1983; Finson, 2002; Narayan, Park, Peker, & Suh, 2013). A number of studies have shown that students draw stereotypical pictures of scientists with the images common across different age groups and cultures; and hard to change (Cakmakci et al., 2011; Finson, 2002; Narayan et al., 2013; Schibeci, 2006). However, Finson (2002) asserts that these images can be positively changed through the use of "role models, activities and targeted career exploration" (p. 342). Miele (2014) concurs and advocates that promoting a more inclusive impression of scientists may challenge stereotypes. I am interested in finding out what understandings the students in my study have about scientists and the nature of their work. I will also use drawings of scientists to gauge students' preconceptions of scientists.

The ramifications of students possessing stereotypical impressions of scientists was highlighted by Bennett and Hogarth (2009), who found that students don't want a job in science because scientists are "weird," "uncaring" and do "boring" jobs (p. 1990). The year 6 students in the *ASPIRE Looking at Science Aspirations and Career Choice: Age 10-14* study, however, largely viewed scientists positively (DeWitt, Archer, & Osborne, 2013). In contrast, the perception that children who like science are "geeky" was perpetuated by almost half of the 78 parents in the ASPIRE study (DeWitt, et al., 2013, p. 1462). Interestingly, the students in the study described science kids as being "brainy" or "clever" (p. 1465). To offset this discourse, DeWitt et al. (2013) recommends teachers promote scientists as "normal" people and extend students perceptions of "scientists and their understandings of the breadth of careers available from science" to mitigate students dissociating themselves from the possibility of being a scientist by being positioned as the undesirable "other" (p. 1473). Hendriksen, Dillon, and Giuseppe (2015) also suggest that promoting a diverse range of possible STEM identities may shift science careers from 'unthinkable' to possible. In my study, I am interested to see whether the students consider being a scientist desirable and whether positioning scientists as being a high status enhances the desirability of that career choice.

2.3.3 Student attitudes towards science careers

Another well-recognised concern is that capable students are ruling out the possibility of science careers, from between 10 to 14 years of age (Cleaves, 2005; Kjærnsli & Lie, 2011; Korpershoek, Kuyper, Bosker, & van der Werf, 2013; Pike & Dunne, 2011; Tan, Calabrese Barton, Kang, & O'Neill, 2013). For instance, Bennett and Hogarth's (2009) longitudinal study highlighted that although 41% of students thought a science career possible at 11, by age 16 this had dropped to

14% (p. 1990). Findings from the *ASPIRE* survey of 9000 10 and 11 year old students showed a similar picture. Despite 40% of the students surveyed indicating that they would like to study science in the future, less than 17% would contemplate becoming a scientist (Archer et al., 2012b, p. 10; DeWitt et al., 2011).

It seems that while many students are positive towards science, they do not aspire to be scientists (Boe, Henriksen, Lyon & Schreiner, 2011; DeWitt, Archer & Osborne, 2014; DeWitt et al., 2013). In fact for many students in the *ASPIRE* study having a career in science was an “unthinkable” option (De Witt et al, 2013, p. 1052, 1055). This findings aligns with Jenkins and Nelson’s (2005) findings that science is ‘important’ but ‘not for me’. It appears that the ‘unthinkable’ aspect relates especially to scientists and not to other science related careers like becoming a doctor (DeWitt & Archer, 2015; DeWitt et al., 2014). It is the notion of having an identity as a scientist that creates the barrier to students picturing themselves in science careers (DeWitt & Archer, 2015; Lyons & Quinn, 2010, 2015). What is clearly shown is that although there may be interest in science itself, becoming a scientist is not always seen as desirable.

Another reason why science careers are not perceived as possible career choices may be due to students not having adequate information about them (Archer et al., 2012; Aschbacher, Ing, & Tsai, 2014; Hendriksen et al., 2015). It is recommended that science career information be made available to students (and their families) throughout their schooling (Archer et al., 2012b; DeWitt & Archer, 2015; Hendriksen et al., 2015; Lindahl, 2003; J. Osborne, Simon, & Tytler, 2009). This information should include realistic information about the wide range of science and applied science careers available (Hendriksen et al., 2015) and that studying science at non-compulsory levels can keep career choices open (DeWitt & Archer, 2015). What is important, according to DeWitt et al. (2014) is that offering a “wider image of science” gives students more options to find a possible identity for themselves in science (p. 1624). However, giving students more information about science careers, or even providing programmes where students have opportunities to engage in activities like scientists may not be enough to enhance their motivation to study science or become a scientist. This scenario was found in in Schütte and Köller’s (2015) study, where students visited science companies, and designed experiments around the subject matter, which they taught to young children. No more students in this study were motivated to study science after the programme, however, the authors put forward that these students were highly academic and well disposed towards science at the start of the unit.

It is also plain that some students have strong aspirations towards science and science careers (DeWitt et al., 2013). Findings from the ASPIRE study have identified that students who have a strong science capital (or family attitudes towards science and/or family members in science professions) and positive attitudes to school science are more likely to aspire to science careers (Archer et al., 2012b; Archer et al., 2013; DeWitt & Archer, 2015). In fact many scientists indicated that they made up their mind to pursue science by 12 or 13 years old (Lindahl, 2003; Maltese & Tai, 2010; Tai, Liu, Maltese, & Fan, 2006).

Sjøberg and Schreiner (2010) found that students from developing countries perceive science as a high status career, while paradoxically, "the higher level of development in a country, the lower interest the students express in learning about [Science and Technology] S&T-related topics" (p. 13). A possible reason given by Sjøberg and Schreiner (2010) is that students from more developed countries consider education as a "duty" and expect it to be "entertaining" and have more curricular choices; whereas students from less developed countries are more aware of the "privilege" of education, and grateful for the opportunity (p. 16). Schreiner and Sjøberg (2007) also proposed that western students do not perceive science as being vital for their country's development, whereas in developing countries being a scientist may be viewed as "heroic" or "attractive" contributing to the growth of the country (p. 242). Tytler et al. (2008) suggests that for youth from western countries such as Australia, the vision of science offered at school is not meaningful. Tytler considers students need to become aware of the "value of science and … why science matters" and that working in science can be the solution to "humanities problems" (p. 94).

In this study I am interested in finding out whether the 11-13 year-old students in my study have chosen a possible career and whether it is science related. I am also interested in their knowledge about science careers and whether my intervention influences this knowledge or alters their inclination towards science.

2.3.4 The situation in New Zealand primary and secondary schools

This section details the literature relating to student proficiency in science and attitudes towards school science in New Zealand. The types of activities students do in science and the time spent learning science are also outlined.

The literature shows that student achievement in both primary and secondary school science (when compared to an international cohort) is dropping. Results from the 2010/11 PIRLS/TIMSS (Progress in International Reading Literacy Study/Trends in International Mathematics and Science Study) (Chamberlain & Caygill, 2012) showed there was a "significant decrease in the average achievement of Year 5 students from 2006/07 to 2010/11" (p. 21, 22). Similarly, data from *Wānangatia te putanga tauira: National monitoring study of student achievement, Science 2012* (NMSSA) (Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013) showed that while year four students were achieving at the expected curricular level for their age, year eight students did not reach the expected curriculum levels (p. 27). This situation was echoed in the 2012 PISA (May et al., 2013) results, which revealed that while New Zealand students remain above the OECD average in science, student achievement in science at age fifteen has declined since the last round, with New Zealand dropping from seventh to eighteenth in country ranking, with the student average score dropping from 532 points in 2009 to 516 in 2012 (p. 20). This change was attributed to a small increase in the number of students at the lower end of proficiency and a slight decrease in the students at the upper levels (p. 22).

In common with the international data, the EARU & NZCER study found that year eight students are less enthusiastic about science than year four students (Bolstad & Hipkins, 2008; Caygill, Lang, & Cowles, 2010; Crooks, Smith, & Flockton, 2008; Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013) and year eight girls less positive than the boys (Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013). Poor achievement in science was recognised as adversely affecting student attitudes towards science (Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013). Of concern to Chamberlain and Caygill (2012) in the 2010/11 PRILS/ TIMMS results was that

New Zealand year five students were ambivalent towards science, lacked confidence and were not enthusiastic about doing science when contrasted with other nations (p. 21). This pattern of students lacking enthusiasm and confidence in doing science held true for the year nine students (one year above the students in this study) but in contrast to the year five students they were engaged in their lessons (Chamberlain & Caygill, 2012, p. 26).

When the 2006 National Education Monitoring Programme (NEMP) (Crooks et al., 2008) results were compared to the 2003 NEMP (Crooks & Flockton, 2004) data by Crooks et al. (2008), it was noted that students were less likely to be doing experimental work (p. 63). This finding was echoed in 2010/11 PRILS/ TIMMS (Chamberlain & Caygill, 2012) report, which showed compared to other countries, less time was spent in investigations and inquiry based learning in New Zealand (p. 32). This is commensurate with the NMSSA (Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013) data, for the most common approaches used for learning science were listening to the teacher and self-research instead of "investigating their own questions or applying science to issues of concern to them" (p. 45). A possible reason highlighted in the PIRLS/TIMMS (Chamberlain & Caygill, 2012) data for this, is that New Zealand Year five teachers have poor self-efficacy in teaching science, when compared to their international peers (p. 32).

Another factor identified in the New Zealand literature (Chamberlain & Caygill, 2012), is the wide range of proficiency among New Zealand students. Māori and Pasifka students' achievement and attitudes towards science are on average, lower than NZ European and Asian students (p. 21, 25), with girls less proficient than boys (p. 23, 25, 26), In addition, students from lower socio-economic schools are generally less likely to attain high levels than those in higher socio-economic areas (p. 31). These issues are obviously important but not the focus of my study.

This snapshot of where New Zealand students are placed in terms of their science proficiency and attitudes towards science and science careers is cause for concern with implications for students, science education and the economy.

The final two sections in this chapter explore influences that can affect whether or not students engage with science, or contemplate possible science-based careers.

Section 2.5 will look at identity-based factors, while section 2.6 will explore pedagogical factors.

2.4 Identity-based influences affecting student engagement with science

One factor identified in the literature as affecting student engagement into science is the mismatch between students' personal identities and the identities they need to work within in school science (Archer et al., 2010; Archer, DeWitt, et al., 2013; Barton et al., 2013; Brickhouse et al., 2000; Carlone, Johnson, & Scott, 2015; Carlone, Webb, Archer, & Taylor, 2015). In this section I first provide a brief description of the construct of identity as used in my study. Then I look at the specific identity lenses I used, which are: figured worlds (Holland et al., 1998) and positioning theory (Harré & van Langenhove, 1999c). I define these theories and explore how they have been used in educational settings, focusing on science education. Finally, I outline why science identities are important and discuss the literature detailing why some students either do not want a science identity or find it difficult to be recognised as having one. I do this as part of establishing a context for why I chose Mantle-of-the-Expert as the approach in the intervention I investigated.

Constructing a personal identity

A number of scholars use the notion of identity to explore student engagement (Archer et al., 2010; Gee, 2000; Penuel, 2011; Sfard & Prusak, 2005; Wortham, 2003). The notion that identity is improvised socially in contextualised settings is widely recognised (Davies & Harré, 1999; Goffman, 1956/1971; Holland et al., 1998; Roth, 2007; Varelas et al., 2007). Some scholars consider identity is performed (Archer et al., 2010; Carlone, Webb, et al., 2015). Still others propose it is communicated through dialogue and how one positions oneself and is positioned by and with others (Bucholtz & Hall, 2005; Harré & van Langenhove, 1999b). In this study I take identity to be our personal understandings about who we are, our place in the world, and how we wish to be known and to become (Holland et al., 1998; Schachter & Rich, 2011; Urrieta, 2007b).

Key writers on identity suggest that while a person's identity is fixed in terms of being physically embodied (Archer et al., 2010; Carlone, Webb, et al., 2015; Roth & Tobin, 2007), it is fluid in a social sense (Holland et al., 1998; Scantlebury, 2007; Urrieta, 2007b). They note that identity is shaped and reshaped through discourse within the constraints and affordances of the social settings or storylines one operates within (Davies & Harré, 1999). These in turn impact upon the range of identities that a person has access to and may embody (Brickhouse, 2012; Cahill, 2012; Shanahan, 2009).

The writers contend that while identity formation may be a reflection of the society in which we live; it is also agentic in that it is shaped by the choices that an individual takes to establish their place within the worlds they inhabit (Holland et al., 1998; Varelas, 2012). Some writers argue that just positioning oneself, as having a certain type of identity is insufficient; an identity has to also be acknowledged or identified by others in a social setting (Carlone, Webb, et al., 2015; Gee, 2000; Harré & van Langenhove, 1999a; Tonso, 2007).

Identity has been identified as pertinent to educational research (Penuel, 2011; Roth & Tobin, 2007; Schachter & Rich, 2011) because of the "connection between students' identity construction and learning" (Kane, 2012b, p. 460). It has been used to illuminate learning issues across a range of learning areas (see also Archer et al., 2010; Gee, 2000; Schachter & Rich, 2011; Sfard & Prusak, 2005; Wortham, 2006). Roth and Tobin (2007, p. 1) contend identity is especially useful in theorising science learning because it addresses both "knowing and learning" (Archer et al., 2010).

For the purpose of this thesis, understandings of identity will draw on Holland et al.'s (1998) notion of figured worlds and on positioning theory as elaborated by Harré and van Langenhove (1999c). These two theories enable a broad view and a close view of identity and the data respectively. They have been used in science and drama education. They are described in sections 2.4.1 and 2.4.2 respectively along with relevant examples of their general use and use in science education, and in section 3.2.2 in regards to drama education.

2.4.1 Identity explored through the analytical lens of figured worlds

In this section, I provide my definition of figured worlds. Then I look at how figured worlds is used in education.

A definition of figured worlds

I am using Holland et al.'s (1998) notion of figured worlds as a conceptual analytical lens in this study because it has synergies with the imagined and improvised worlds of drama where identities are shaped through dramatic play by drawing upon the past and "anticipating the future" (Edmiston, 2007; 2010, p. 200). Holland et al. (1998) describe figured worlds as "socially and culturally constructed realms of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (p. 52). Figured worlds are simplified worlds that occur in imagined "as if" domains (p. 49). Holland et al. (1998) suggest that the value of operating in "as if" imagined figured worlds is that through interaction, discourse and playing within the "as if" contextual frame, meaning can be explored, identities formed and agency enhanced (p. 49). This notion of playing in imagined "as if" figured worlds is similar to drama where one operates in both imagined and real worlds (see Andersen, 2004; Edmiston, 2003). People are inducted into figured worlds as novices and gradually learn to take on the characteristics and practices of the figured world they are operating within (p. 60). Holland et al. (1998) give the example of alcoholics joining Alcoholics Anonymous (AA) as novices, telling their stories and gradually locating themselves "within the figured world of AA" to explain this process (p. 70, 72). "Figured worlds are evoked, collectively developed, individually learned, and made socially and personally powerful" by artefacts (Holland et al., 1998, p. 61). The artefacts used in AA include, for example, the tokens, which are made powerful by the "meaning attributed to them" by the group (p. 51).

Fayez (2010) asserts that it is our experiences, in both past and present figured worlds that have an impact on our agency (p. 769). Barton et al. (2013) consider that working in figured works is useful as it illuminates the "dynamic and oftentimes intentional nature of identity work" (p. 43). Thus, figured worlds can be used both as a pedagogical tool to enhance learning and also as an analytical tool to illuminate identity formation in classroom learning. Figured worlds allows for the examination of how people place themselves in day-to-day activities as they craft their identities and also for researchers to come to conclusions about which types of figured worlds enhance agency in learning.

Figured worlds used in education

According to Urrieta (2007a), figured worlds have been used in education in a variety of ways. The first way is in illuminating how people shape their personal identities in education (p. 112). Two examples, given by him, one from a high school setting (Leander, 2002), and the other from participants from a post-secondary educational background (Urrieta, 2007b) relate to how individuals negotiate and perform their cultural identities through the discourse used, people associated with and the artefacts used. Jackson and Seiler (2013) used figured worlds to explore the identity trajectories of latecomers to science at a tertiary level introductory science-bridging programme. The authors noted that the students were constrained by the "cultural models in the figured world of the science program" (p. 851) and their prior experiences in science, and that they needed considerable support to author science identities for themselves.

Other studies show how working with experts in the field helped some students become acculturated into the figured world of the desired community. For instance the girls in Kangas, Seitamaa-Hakkarainen and Hakkarainen's (2013) study transitioned from being novice designers in the figured world of the classroom into the figured world of design by working with a designer on a technology design project. Working within "multiple worlds, combining values, practices, language, and tools from all of them" (p. 434), helped the girls make a table lamp and gain an insider's knowledge of the design process. Similarly, the students in Rahm's (2007) study worked in the figured world of the eight-week gardening programme and interacted with scientists in their figured science world. Doing this enhanced the visibility of science and offered opportunities for the students "to see themselves as potential insiders to that world" (p. 543). Some students in Rahm's (2007) study were identified as "integrating new discourses and genres about science and scientists and ... making new positions within that world possible for them" after visiting scientists in their workplaces and interviewing them about their jobs and pathways into science (p. 541). This exposure to other figured worlds (that of science and scientists) provided opportunities for the students to see if positioning themselves in that world could be a possibility in their future. These two studies offered the students a chance to work as novice architects and scientists respectively and certainly in the first study to become more ‘expert’ at their tasks in the figured worlds they were operating within. The notion of figured worlds is pertinent to my study, because students will work in the figured world of the drama, in role as ‘expert’ scientists with the support of their teachers.

Another way figured worlds is used, according to Urrieta (2007a), is to probe students’ identity development as active and engaged learners in “local educational contexts” (p. 112). Horn (2008) looked at how seven students from two high schools over five years working in the figured worlds of the “organization and enactment of the mathematics curricula” developed their mathematical identities (p. 204). She noted the different philosophical understandings of the teachers and schools provided different support for the students’ development of a mathematically competent identity. This picture was also seen in Boaler and Greeno’s (2000) study exploring mathematics teaching within six advanced placement (AP) Calculus classes. They found that students taught within a figured world that stressed didactic teaching, individual learning and received knowledge from the teacher were more restricted in the “application of selves” (p. 189), and had a narrow view of mathematics and lacked agency. Students whose mathematical figured world emphasised discussion-based collaborative learning and had to “contribute more of their selves” (p. 189) had a wider view of mathematics and were agentic both in their learning and in producing their mathematical identities. In every case the different figured worlds used by the teachers offered different opportunities for agency and authoring.

Figured worlds have been used to theorise what is happening in science classrooms. Tan et al. (2013) explain that science classrooms can contain different figured worlds, such as whole-class or small groups. Each figured world provides students with different affordances and constraints and offers different roles for the students to take up and different opportunities for authoring science identities (p. 1145). Tan and Calabrese Barton (2008) found that working in different figured worlds, such as whole-class, small group, individual and role-play contexts, afforded the girl focussed on in this article with different opportunities to re-craft her identity from a marginalised science student to a fully engaged student with a strong science identity. Building on this, Tan and Calabrese Barton (2010) described a study in a sixth grade science classroom, where the teacher used three figured worlds to teach science. They were: through storytelling, by reflecting the real world (as in being youth-based and linked to out of school experiences) and offering students a diverse range of positions such as pet caretaker and student leader (pp. 45-48). Using these different figured worlds gave the students in their study more “space” to engage with science and to become “ an “expert” rather than a “novice” and “experience validation for their contributions” through “more equitable learning opportunities” (p. 52). In another study, Calabrese Barton and Tan (2010) used figured worlds to explore student agency in an out of school programme with urban youth aged 10-14. They noted that using resources from multiple figured worlds allowed the students to enlarge their sphere of influence and expand the scope of their project. I will be looking to see how the figured worlds of my study impact on both their science learning and science aspirations.

The final way of looking at figured worlds mentioned by Urrieta (2007a) is as “worlds of possibility” (p. 114). In this case student perspectives or possibilities about learning are broadened through working in a figured world. Ma and Singer-Gabella (2001) and Robinson (2007) used figured worlds like this to expose pre-service teachers to different perspectives on learning and teaching. Barton et al. (2013) used identity and figured world to explore girls’ science identity trajectories in middle school. They noted “when their identity work is recognized, supported, and leveraged toward expanded opportunities for engagement in science” girls are more likely to see themselves in science (p. 37). It will be interesting to see if working through the dramatic approach Mantle-of-the-Expert makes any discernable differences in students seeing themselves in science; that is students expanding their worlds of possibility.

2.4.2 Identity explored through the analytical lens of Positioning Theory

My other analytical lens for conceptualising identity is positioning theory (Harré & van Langenhove, 1999c). I am using this lens because, according to Yamakawa, Forman, and Ansell (2009), it is a useful methodological tool to explore identity in classrooms as it enables one to see the identities that are "constructed through discourse" (p. 183). It is congruent with Holland et al.'s (1998) view of identity, one facet of which is positionality (p. 271). In this section, I define positioning theory and outline the meaning and nature of 'participant structures'. I also examine the use of positioning theory to understand the positions taken by participants in small discursive episodes and over longer time-periods.

A definition of positioning theory

Positioning theory emerged from the study of psychology and according to Yamakawa et al. (2009) is a useful means of highlighting the interconnections between "psychological phenomena and discourse" (p.180). It is defined by Harré and van Langenhove (1999a) as a "study of local moral order as ever-shifting patterns of mutual and contestable rights and obligations of speaking and acting" (p. 1). It consists of three major components: the "storyline", "social force" and "position" (p. 18). These are used to help the person analysing the conversation/discourse interpret what is occurring. Discourse, storylines and social force will be briefly defined, with position explained in more detail.

I take discourse to be both "language and language-like sign systems" (Davies & Harré, 1999, p. 34), constructed out of "previous encounters with people and texts" (Edmiston, 2000, p. 72). Storyline refers to both the history of the conversation and the flow of dialogue in a given episode. It is impacted by previous conversations with the participants (van Langenhove & Harré, 1999). Social force refers to the specific speech acts – both verbal and non-verbal (Slocum-Bradley, 2009) – and the intention of the speaker and how they shape the conversation (van Langenhove & Harré, 1999).

According to Harré and Slocum (2003), a position is a "cluster of rights and duties … with rights … being demands or requests for action by someone else [and] duties … demands for action by oneself" (p. 125). Taking up a subject position is known as first order positioning (van Langenhove & Harré, 1999). For example you might be introduced as a mother. The person thus positioned can choose to acquiesce to the positioning or can challenge or change the positioning to better fit their personal storyline or desire for power such as responding with, "actually I am a business woman with children". This challenge is called second order positioning (van Langenhove & Harré, 1999).

Positions taken up by people are fluid and may change depending on the context, persons present and the story one operates within (Davies & Harré, 1999; Ritchie & Rigano, 2001; van Langenhove & Harré, 1999). One reason for people taking up different positions in different settings is to do with power. To put this another way, "positioning determines whose power and whose authority dominates, is silenced, or gets shared in a group" (Edmiston, 2003, p. 226). In a given situation there may only be limited positions available for students to operate within (O'Doherty & Davidson, 2010). In fact, Penuel (2011) asserts, just being positioned and even agreeing to work in a positioning may not be enough to "shape" someone's identity; it also requires "recognition" by people who are in "authority" and have the capacity to both recognise and foster that identity and positioning into actualisation (p. 15). This means that accepting the position of a scientist is insufficient to change ones' trajectory. It involves both being recognised as possessing that identity and being supported to fully occupy the identity. In my own study, the aim is to use drama to offer opportunities for students to try out being a scientist with little risk (Edmiston, 2000; Heathcote & Bolton, 1995). I examine whether being positioned as an expert scientist helps shape students' science identities.

Positioning theory in Education

Educational researchers have engaged with positioning theory in a variety of ways. One way is through looking at the participant structures used (Cornelius & Herrenkohl, 2004; Gresalfi, 2009; Langer-Osuna & Engle, 2010; Philips, 1972; Tabak & Baumgartner, 2004; Wortham, 2004). Another way of looking at participant structures is by examining small portions of dialogue to see whether the positioning is first or second order and/or the types of pronouns used

(Crumpler, Handsfield, & Dean, 2011; Gresalfi, 2009; Herbel-Eisenmann & Wagner, 2010; Jakob, 2013; Linehan & McCarthy, 2000; Rahm, 2008; Reeves, 2009; Wortham, 2004). Other studies use positioning theory to look at the bigger picture by examining discourse collected over longer time periods (Gresalfi, 2009; Olitsky, 2007; Tan & Calabrese Barton, 2008; Varelas et al., 2007; Wortham, 2004). Literature relating these aspects is relevant to this study because positioning theory will be used to analyse what is occurring in both short and focused classroom episodes and over the period of the intervention.

Participant structures within positioning theory

According to Cornelius and Herrenkohl (2004) participant structures include how students are positioned with rights and responsibilities to learn, and how they are positioned linguistically and socially in relation to each other and the curriculum. As such, the notion of participant structures is a good fit with positioning theory (see also Slocum-Bradley, 2009). Commonplace participant structures include: learning as part of the whole class and a small group. Within a small group, students may also be positioned into various roles such as monitor, mentor and partner (Tabak & Baumgartner, 2004) or intellectual and audience roles (Cornelius & Herrenkohl, 2004; Herrenkohl & Guerra, 1998). These different types of structures affect student engagement and how the curriculum is taught. They also affect how power is configured in the classroom, whose voice is heard and how agentic students can be in their learning (Cornelius & Herrenkohl, 2004; Herrenkohl & Guerra, 1998; Langer-Osuna & Engle, 2010; Philips, 1972; Tabak & Baumgartner, 2004).

For instance, Cornelius and Herrenkohl (2004) identified that adding audience questioning roles to whole class discussion re-positioned students from being passive listeners to active creators of meaning through being supported to ask for clarification and challenging the science findings presented to the class by other students (p. 474). Gresalfi and Williams (2009) built on this idea, asserting that being positioned as “active meaning makers” rather than “receivers” (p. 314), opened up learning. Herrenkohl and Guerra (1998) consider that when teachers give up some of their rights and responsibilities for student learning to the students, then students can engage with each other and curricular content from a position of affordance rather than constraint. Langer-Osuna and Engle (2010) found that distributing expertise through positioning students as experts in a mathematics-based study enhanced students' ownership over their learning and opened up space for them to explore, discuss and defend their mathematics ideas. These three studies found that the participant structures chosen by teachers affected how students interacted with each other and also appeared to give students a sense of ownership over the knowledge.

In this study, I consider Mantle-of-the-Expert to be a participant structure similar to that described by Cornelius and Herrenkohl (2004) for Mantle-of-the-Expert attends to the underlying social features of the class and how participants are positioned linguistically in relation to each other and the curriculum. I am interested to see if using the participant structure of Mantle-of-the-Expert opens up space for students to engage productively with the curriculum.

Positioning theory to analyse small portions of dialogue

The second of the three ways the studies reviewed applied positioning theory was to look closely at small portions of dialogue or what Gresalfi and Williams (2009) term "moment-by-moment" analysis (p. 313). Examining interpersonal interactions to see whether first or second order positioning (van Langenhove & Harré, 1999) took place was a facet of some studies (Herbel-Eisenmann & Wagner, 2010; Linehan & McCarthy, 2000; Rahm, 2008).

Other researchers have used pronoun use to determine who was positioning whom and to observe the effects of self-positioning choices on the storyline. For example, Reeves (2009) explored pronoun usage to ascertain whether the teacher - Neal - positioned himself as an individual or as part of a group. Wortham (2004) suggested the exclusion of a student – Maurice - was shown by the teachers and students changing pronoun usage as they were "referring to [the student] as he, whereas before they had referred to him as "you" (p. 740). While Maurice was positioned as an outcast in terms of both academic and social identity, he challenged that positioning and tried to maintain his own identity both as someone whose "contributions in class and as an adolescent male respected by his peers" (p. 741). Analysing whether inclusive pronouns were used in the discourse identified whether the teacher was acting as a mentor-participant in small groups or a partner-participant in Tabak and Baumgartner’s (2004) study. The authors found that when the teacher disrupted the usual power structures in the classroom by co-inquiring with the students; the students were able to learn from how she interacted with the data and investigated the problem with them. Jakob (2013) used pronoun usage to explore what the students in her study knew about the relationship between atoms and molecules in a teaching interview, looking to see if the students were secure in their assertions or hedging their answers. Within this study, I am interested to see if the students accept their positioning as expert scientists through examining pronoun usage. As Mantle-of-the-Expert is an approach that also emphases inquiring ‘with’ students, it will be also interesting to see if the students consider learning science in this way as beneficial.

Positioning theory to analyse interactions over longer time periods

A third group of studies using positioning theory examined data over longer time periods looking for changes in the way students interacted with the curricular subject of science and in terms of personal science identities. Gresalfi and Williams (2009) consider positioning over a longer time frame advantageous because it assesses whether the use of a particular framework changes “the ways that students are expected, obligated, and entitled to participate with content [disciplinary positioning] and with others in the classroom [interpersonal positioning]” (p.313).

Tan and Calabrese Barton (2008) spoke about the effect that teacher positioning can have on students’ formation of science identities. They stated that positioning students in high status roles such as ““group leader” or “reporter” accords them power that can transform their learning experiences and affect identity formation in science class” (p. 570). Similarly, Olitsky (2007) noted that positioning students and their responses as legitimate in the participant structure of discussion enhanced student agency in talking science. This was seen in the eight grade students in Olitsky’s (2007) study using more science language and references to science content as the discussion about a science demonstration progressed and their responses were affirmed and legitimised. Varelas et al. (2007) described how positioning a task with options for decision making allowed third grade students the space to wrestle with ideas, draw on their prior knowledge and collaborate with each other to decide how to group objects as solids, liquids or gases. The degree to which individual suggestions were accepted in Varelas et al.'s (2007) study depended upon student identities and personal positioning. I examine whether positioning students as experts and repositioning how the curriculum is taught to maintain that positioning, enhances student learning when the learning is framed dramatically.

In summary, this section has defined positioning theory and given examples of its use in educational literature. The notion that the participant structures used in the classroom can impact students' learning was established. In this study Mantle-of-the-Expert will be investigated as a participant structure to see how using this structure affects student learning. Positioning theory allows for small portions of discourse to be examined to see what order positioning is used and whether the students' pronoun usage shows an acceptance of that positioning. In addition, larger portions of discourse will be explored to see if student identities are impacted favourably for science.

Both the previous section on figured worlds and this section on positioning theory, have explored literature relating to students' identity work in relation to learning in educational contexts. The next section will look specifically at the formation of science identities.

2.4.3 Establishing and being recognised as having a Science Identity

A number of authors consider that developing a positive science identity or trajectory can be a significant factor in maintaining student interest in school science and science futures (Archer et al., 2010; Archer et al., 2012a; Brickhouse et al., 2000; Calabrese Barton & Tan, 2010; Farland-Smith, 2009; Kozoll & Osborne, 2004; Olitsky, 2007; Roth, 2007; Schreiner, 2006; Varelas, 2012). Brickhouse et al. (2000), for instance, suggests that to learn science, students must "develop identities compatible with science identities" (p. 443). According to Carlone (2004) a person who has a science identity is meaningfully engaged with science and science knowledge, demonstrating practical and theoretical knowledge and has a view of himself or herself as a science person, which is acknowledged by others. Building on this, Carlone, Scott, and Lowder (2014) assert that "becoming scientific" or actuating a science identity involves a student self-positioning and being positioned as "good" at science and showing that they "fit" into the productive science identity positions available in school science (p. 839). The benefit of having a science-based identity and a willingness to operate within the normative behaviours of the school science community, according to Calabrese Barton and Tan (2010), is that it enhances student participation and success in science. However, Archer et al. (2010) highlight that constructing a productive science identity is not easy, as it needs to be compatible with the other facets of one's identity and also to be perceived as valuable by one's peers (p. 628).

Finding a 'good fit' in school science is not always easy, even for students who profess to like science. As was set out in section 2.3.2 and 2.3.3, some students may view scientists or science careers negatively and do not have comprehensive understanding of the tasks they do. In addition, other personal factors may impede the formation of a science identity, such as: gender, sexuality, social class, ethnicity and students' science capital (Archer et al., 2010; Archer, Osborne, et al., 2013; Brickhouse et al., 2000; Carlone et al., 2014, DeWitt & Archer, 2015). Taking all these factors into consideration, forming a science identity is not easy. Unless being a scientist meshes with their personal identity, their notion of idealised gender identity and impressions of their abilities as a learners, both in the present and in the future, students will be unlikely to consider science in their futures (Archer et al., 2010; Archer et al., 2012a; Archer, DeWitt, et al., 2013, 2015; Farland-Smith, 2009; Kozoll & Osborne, 2004).

Establishing and being recognised as having a science identity is identified in the literature as challenging to do. The perception of a person with a science identity and likely to have a career in science in the *ASPIRE* study was that they were clever, middle-class males from either a white or south Asian background with family members working in science (Archer, DeWitt, & Willis, 2014; Archer, Osborne, et al., 2013, p. 3). This means that even if boys like science, are academically proficient, and position themselves as science boys; if they do not fit the middle-class masculinity norms and lack social skills (Carlone, Webb, et al., 2015) or are identified as laddish (Archer, Osborne, et al., 2013), they are less likely to be recognised as having a science identity. This can be even more difficult if students are female or of a different ethnicity to the dominant culture

(Archer & Dewitt, 2015; Brickhouse et al., 2000; Carlone et al., 2014).

Kane (2012a) reminds us that science identities are not just constructed in school but are shaped within and between the different worlds students operate within. These can include the home and places like museums, science clubs (Barton et al., 2013) and out of school clubs (Calabrese Barton & Tan, 2010; Gonsalves, Rahm, & Carvalho, 2013). According to Barton et al. (2013) science experiences outside the classroom can have a pivotal role in supporting students' science trajectories as they provide students with more resources to author science identities for themselves (p. 72). Roth (2007) argues that few students will develop science-related identities unless classroom science has "emotional-volitional and ethico-moral dimensions" that they view as contributing to "common good" and that has real-life "consequences" (p. 182). By this he means that unless students come to see having a science identity as being relevant to their life-worlds and as contributing to the greater good of humanity they are unlikely to develop science identities (see also Tytler et al. (2008) and Schreiner (2006)).

This section on science identity has outlined literature suggesting that developing a science identity is an important factor in engaging students into science learning and contemplating science based careers. It has also identified that there are challenges to be overcome before students are recognised as having a science identity, such as overcoming negative discourses about science and scientists and the perception of what a person with a science identity is like. Factors that appear to enhance science identity development include: using structures in the classroom that enhance science-based identities, drawing on experiences outside the classroom, making sure that science is appealing to both genders; is relevant, connected to 'real life' and positioned as useful to humanity.

To sum up, section 2.4 has built on literature linking student engagement into science with student identity. A focus on identity and positioning is appropriate here because my study uses an approach to drama (Mantle-of-the-Expert) that shifts students' positioning and hence their identity. I have argued that figured worlds and positioning theory are both appropriate analytical lenses to examine student identity development. Both of these approaches have been used in science classrooms as well as in drama-based studies. In this study figured worlds is used to see if working in the figured worlds of the drama and the classroom enhances the space for students to explore both science and the possibility of being a scientist. Using positioning theory allows me to see the effect the different components of Mantle-of-the-Expert have on student learning. In addition, exploring pronoun use can illuminate who is positioning whom and whether the positioning is accepted or challenged. It also allows me see whether the identities the students were working in fictionally were viewed as possibilities for the students' career choices.

2.5 Pedagogically-based factors affecting student engagement in science

Literature clearly states that the pedagogical approaches used by teachers can have a critical influence on student learning and on whether students continue studying science (Tytler et al., 2008; Regan & DeWitt, 2015). The pedagogical factors highlighted by Tytler et al. (2008) as contributing to students' declining interest in science, and reiterated by Bolstad and Hipkins (2008) in the report *Seeing yourself in science: The importance of the middle school years*, are summarised below.

- A transmissive teaching approach
- Increasing complexity of science learning
- Science perceived as irrelevant to student lives
- The quality of student/teacher relationships

The pedagogical practices identified above as contributing to students' decreasing interest in science are discussed and practices deemed advantageous outlined.

2.5.1 A transmissive versus an investigative approach

This section details the perceived disadvantages of teacher dominated transmissive teaching approaches in science. It examines literature pertaining to the use of practical work in science and looks at the value of teaching through investigation. It offers comment on the type of teaching that occurs in the primary science classroom in New Zealand.

Teacher dominated transmissive teaching has been identified as a significant reason why students lose interest in science (Bolstad & Hipkins, 2008; Tytler et al., 2008). For example, the students in Lyon's (2006) study considered that using a transmissive teaching approach impeded their learning of science concepts. Teacher-dominated pedagogies affect student engagement with science because they lessen students' power in the classroom. Both J. Osborne and Collins (2001) and Tytler et al. (2008) considered that students become disengaged when they lack autonomy and control of their own learning. Sorenson (2007) warned that students who do not have space to voice their opinions, lead groups and control their learning, may disengage from science. She suggested that creating a democratic, collaborative classroom where students have control over their learning and evaluation, where participation of all is encouraged, and everyone discusses their learning and shares their perspectives could help students engage with science. Pike and Dunne (2011) take the positive perspective and assert that, "science would be more appealing if it was weakly framed with less teacher authority, more discussion-based learning and greater relevance to the everyday" (p. 498). An issue related to the transmissive approach, mentioned by J. Osborne and Collins (2001) and Lyons (2006), is the perception that you cannot be imaginative or creative in science. Science is thus perceived as being rigid with no scope for self-expression and this can deter some students from continuing in the discipline. However, Land (2013) counters this viewpoint, stating that adding the Arts to STEM could enhance the appeal of science, allow for innovation, "self-expression and personal connection" (p.548).

Teaching in a manner that involves student action and is activity-focused, rather transmissive, is recognised by many commentators as advantageous. Practical work is a commonplace science activity. Practical work can be defined as "any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the objects and materials they are studying" (Millar, 2010, p. 109). Reasons given for using practicals in science teaching are that they are: engaging; make science fun; and deepen students' understanding of science concepts, the NOS, scientific process skills and scientific ways of thinking (Chetcuti & Kioko, 2012; Maltese & Tai, 2010; J. Osborne & Collins, 2001; Swarat, Ortony, & Revelle, 2012; Tytler et al., 2008).

Practical work has also been found to enhance students’ problem-solving skills, offer opportunities for both collaborative learning and solo work, and provide a framework to anchor theoretical concepts (Chetcuti & Kioko, 2012; Hofstein & Lunetta, 2004; Kidman, 2012; Maltese & Tai, 2010; J. Osborne & Collins, 2001, p. 458; Swarat et al., 2012; Tytler et al., 2008).

Some concern has been raised in literature as to whether practical work always achieves its intended outcomes (Bell, 2005; France & Haigh, 2009; Roth, 2008b; Toplis, 2012). For instance, Berry, Mulhall, Gunstone, and Loughran (1999) found most students did not understand why they did practicals. Haigh, France, and Gounder (2012) provide evidence that practical work might actually hinder students’ understanding of scientific concepts. Reasons given for practical work not achieving its desired outcomes include: the use of teacher controlled pedagogies, teaching to assessment, and practical activities that do not encourage deep thinking such as cookbook experiments (Hofstein & Kind, 2012; Hofstein & Lunetta, 2004).

In order for practical work to enhance student learning, students need to engage their minds as well as their hands (Abrahams & Reiss, 2012; Berry et al., 1999; Hofstein & Kind, 2012). C. Hart, Mulhall, Berry, Loughran, and Gunstone (2000) consider that students are more likely to understand the science and purposefully engage with it, if the practical occurs after students are taught relevant content with the purpose of the experiment explicitly explained (p. 672, 673). More specifically, the type of practical work identified in the literature as beneficial for enhancing student scientific literacy and learning in science is investigation (Hackling et al., 2001; J. Osborne & Collins, 2001). In fact, the National Research Council (2012) considers it crucial that students carry out “investigations and other key elements of scientific practice” (p. 286). Barab and Hay (2000) assert that science learning is enhanced when learning contexts mirror, as much as possible, the working environments and practices of scientists (p. 95). They identify these as carrying out investigations, discussing evidence, constructing knowledge, and presenting and communicating findings (p. 96). Duschl and Osborne (2002) also endorse the importance of classroom science emulating the practices of the scientists, especially in terms of scientific argumentation. One way of doing this, they consider, is through making these practices transparent and scaffolding the learners by providing resources to promote "dialogic discourse and higher order intellectual reasoning" (p. 58). An example of this would be Herrenkohl and Guerra's (1998) intellectual roles used during the investigation and the audience roles and corresponding questions used during the discussion to support student engagement and development of scientific knowledge. Similarly in mathematics, Baldwin, Dees, Foulser, and Tartakoff (1995) found that giving each student a "clue" to share with the other students in a collaborative problem-solving exercise encouraged students to question and discuss the evidence together, which led to better outcomes than learning alone.

This section outlines the New Zealand context. An investigative approach is recommended in the 'investigating in science' strand of the online NZC (Ministry of Education, 2007c). Bull, Joyce, Spiller, and Hipkins (2010) describe this as students asking questions, gathering evidence and developing explanations to test their science ideas. However, while there is little debate that practical 'hands-on' investigative work enhances students' enjoyment of science and science learning, several constraints must be recognised. One major constraint is that primary teachers may not have much experience with the use of hands-on activities (Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013; Kidman, 2012; Cliona Murphy, Varley, & Veale, 2012); teacher demonstrations are the most common approach used (Educational Assessment Research Unit & New Zealand Council for Educational Research, 2013; Kidman, 2012). When practical activities are carried out by students, they tend to be recipe work or fair testing based (Haigh, France, & Forret, 2005) rather than actual investigations. This is despite investigative/inquiry hands-on pedagogies being recommended as best practice in policy and curricular documents (Education Review Office, 2010; Gluckman, 2011). Even if investigations are carried out in a classroom, assessment constraints and time might limit the investigation to a fair-testing scenario rather than an open-ended problem, which may not give students a realistic experience of working as a scientist (Hume & Coll, 2010). It would appear that while the pedagogical practices optimal for science learning are known, not every teacher or school is teaching science according to best practice. This would be commensurate with the findings of the *Science in the New Zealand Curriculum Year 5-8* (Education Review Office, 2012) study, which was concerned with the “overall quality of science teaching and learning” as they found that only 27 % of the schools investigated had a science programme that was generally effective or highly effective (p. 8).

To conclude, it would appear that students find transmissive teaching approaches unappealing and that they are not conducive to enhancing student science learning and/or interest. Alternatively, the use of a hands-on investigative approach where students are able to have some autonomy in their learning would appear to be advantageous for student learning. In this study I explore how and if Mantle-of-the-Expert might meet these criteria.

2.5.2 The complexity of science learning

The complexity of student learning challenges, which increase as students advance throughout their schooling, was raised by Tytler et al. (2008) and Bolstad and Hipkins (2008) as a reason for increasing student disengagement from science. For instance, issues around the mismatch between the language used in science and the language used in everyday life, the disconnected fragmented way science is taught and the potential mismatch between culture of science and students’ cultural backgrounds are widely recognised.

Science has “its own ways of organizing and presenting information and meaning, and its own patterns of meaning to present” (Lemke, 1990, p. 21). Learning science involves “learning to communicate in the language of science and act[ing] as a member of the community” (Lemke, 1990, p. 1). As language is not only used to communicate about science but also to construct meaning, Yore (2004) suggests it is critical that students gain fluency in “talking science” (pp. 71, 72). Related to this, students also need knowledge of mathematics as part of the language of science (Duschl, 2008). J. Osborne and Collins (2001) note that many students who find science difficult are not strong in mathematics. If students are not fluent in using science symbols and text, they may not be able to build a deep understanding in science, which can be a cause of disengagement.

The difficulty of learning science is also complicated by the fact that the everyday meanings of words may not be the same as that used in science classrooms (Lemke, 1990). The difficulty of learning science is described by Szybek (2002), who proposes that when learning science students need to act as if they are upon two different stages– an everyday one and a science one, where each stage has different ways of "act[ing], explain[ing] and mak[ing] meaning" (Lundin, 2007, p. 266). Lundin (2007) notes, that translating between the everyday stage and scientific stage while not easy, is crucially important for making science meaningful and relevant (pp. 266, 267). He asserts that until students know and are comfortable using the language of science they are likely to communicate in everyday language or a combination of the two. The 15 high-school baseball students in Brown and Kloser's (2009) two-year study were able to draw upon a variety of scientific and non-scientific discourses, including everyday, baseball and hybridized/blended language, to help them make context specific meaning about the science concepts. Conversely, Brown and Kloser (2009) and Yeo (2009) argue that the use of everyday terms may impede students' understanding of science concepts. Yeo (2009) makes the case that it is critical to "introduce the correct terminologies to the students when learning science since the same words can have different meanings in different contexts" (p. 919). Nonetheless, Lemke (1990) asserts, and Yeo (2009) agrees, that just because students do not describe a phenomenon using scientific language, it does not mean they lack scientific understanding (p. 916). Nonetheless, to be fluent in the language of science some congruence with the "thematic patterns" of science must occur (Lemke, 1990, pp. 12, 13). Being able to communicate science concepts in a manner that is typical of the discipline is one way of demonstrating conceptual understanding. Therefore, in this study I explore the impact of providing multiple opportunities for students to learn and use science vocabulary and to communicate their science ideas in a manner typical of the discipline.

The abstract disconnected way science content is delivered has been identified as another reason why students lose interest in science (Bennett & Hogarth, 2009; Chetcuti & Kioko, 2012; J. Osborne & Collins, 2001). The students in Lyon's (2006) meta-study commented that they could not see how they would use any of the science they were learning in their everyday lives as few teachers linked the science concepts to everyday life. Another related difficulty is that when science is taught in discrete units or subject areas, students may not recognise the cohesive whole and find learning fragmented (Aikenhead, 2006; J. Osborne &

Collins, 2001). This is exacerbated by rapid coverage between topics not allowing students enough time to fully understand the science concepts (National Research Council, 2007; J. Osborne & Collins, 2001).

One reason some students find science complex is the dissonance between the culture of science and their own cultural backgrounds. According to Meyer and Crawford (2011), science has its own "cultural understandings, interpretations, and … language" (p. 531). Students from a minority, religious or non-western science background may find it difficult to negotiate the culture of school science as they may lack insider knowledge or have different ways of knowing (Aikenhead, 2006; Cajete, 2000; Meyer & Crawford, 2011; Roth, 2008a). They may also be learning English as a second language, adding to the complexity of them distinguishing between the everyday and science meaning of some common words. Aspects of these cultural matters have been investigated in New Zealand (Cowie, Otrel-Cass, Glynn, & Kara, 2011), but they are not the focus of this study.

This section has highlighted that the language used in science and the culture of science is different to that used in general society. This can create difficulties for students in negotiating boundaries between everyday life and science. In addition, the abstract fragmented way science content is structured and how these aspects are taught, may deter students.

2.5.3 Science is perceived as irrelevant or relevant to students' lives

Many researchers cite perceived irrelevancy as a disengagement factor for students in school science (Cleaves, 2005; J. Osborne & Collins, 2001; Tytler et al., 2008). In fact, Reiss (2004) found that science occupied only a minor role in most students' lives (p. 108).

One reason that students may think science is irrelevant is that they perceive it as disconnected from 'real life'. Thinking about science as if it was "emotionally neutral" (Ratcliffe, 2007, p. 120), or totally objective was common throughout the 20th Century (Gunstone, Corrigan, & Dillon, 2007, p. 2). Various analysts have cautioned that teaching science as if it was value free or disconnected from real life may dissuade some students (especially girls) from continuing in science

(Haste, 2004; Sorenson, 2007).

Meaningful Contexts

Situating the learning in contexts that appeal to students' interests can make science learning more meaningful (National Research Council, 2007; Szybek, 2002; Tytler et al., 2008). Varelas, Becker, Luster, and Wenzel (2002) used rap songs and plays to help students connect the language of science with the language they commonly used. While Kamberelis and Wehunt (2012) described how using a hybridised discourse allowed two students to take on scientist and assistant roles using a "pop culture/surgery discourse" to help them dissect owl pellets and construct knowledge (p. 518).

Socio-scientific Issues

Situating science learning in Socio-Scientific Issues (SSI) can enhance relevancy. SSI are complex, open-ended controversial authentic social problems informed by and linked conceptually with scientific principles, theories and data and social influences such as politics, economics and ethics (Christensen & Fenshaw, 2012; Ideland, Malmberg, & Winberg, 2011; Sadler, 2004; 2011, p. 4).

Zeidler (Wong, Zeidler, & Klosterman, 2011) argues that it is critical SSIs contain "ethical tension" to hook the students into the learning and challenge their assumptions and demand high level reasoning skills (p. 275). Role-play can be used to explore different perspectives in SSI. For example, role-play was used in a problem-based approach to teach genetics (Van der Zande, Akkerman, Brekelmans, Waarlo, & Vermunt, 2012). The students in Wong, Wan and Cheng's (2011) study took on the positions of the different stakeholders affected by the SSI issue they were exploring.

Learning through SSI has been found to be motivating and engaging (Sadler, 2009; Sadler & Dawson, 2012). Christensen (2011, p. 141) asserts that students are more likely to consider science concepts or the NOS "relevant" and valuable when contextualised in contemporary community settings. However, Wong, Wan, et al. (2011) emphasises that the issues explored must be 'timely' and 'relevant' to those taking part.

Learning through SSI has been found to enhance students' scientific literacy, understanding of NOS, and science content conceptualisation; as well as providing scope for practicing argumentation, critical thinking and working socially (Ideland et al., 2011; Sadler, 2004; Sadler & Dawson, 2012; Wong, Zeidler, et al., 2011). Lindahl et al. (2011) argues SSIs are useful for improving group work, student autonomy and building efficacy in presenting and arguing a viewpoint and linking it to the science. Using SSI in the classroom has been proposed as useful in enhancing student interest in science careers or non-compulsory science education among students who not strongly committed to science careers (Ametller & Ryder, 2015; Henriksen et al., 2015).

Possible concerns raised are that students would perceive SSI as just an extension of normal teaching (Sadler, 2009), and the tension between the time needed to develop student understanding of the issue and the constraints of the classroom and assessment. One potential issue is that most teachers using SSI do not use experimentation (Lindahl et al., 2011).

Using ethics and values in science

Several commentators have highlighted that using ethics and values in science is engaging and enhances learning (Reiss, 2010; Roth & Tobin, 2007; Ryan & Buntting, 2012; Wong, Zeidler, et al., 2011). To Reiss (1999, 2010), ethics is a way of knowing, which to do with examining the thinking behind our moral decisions (over what is right and wrong) in a given context, and the justifications given to our choices and stances taken. Reiss (2010) further suggests that using ethics in school science can be a valuable adjunct to the curriculum and is "desirable … motivating" and a way of situating science teaching in the "real world" (p. 16).

Ryan and Buntting (2012) found that using an ethical framework helped the primary students in their study engage into science and learn science concepts. Haste (2004) suggests that connecting science to real-life ethical humanitarian issues engages girls but boys prefer value free science. Both Gunstone et al. (2007) and Sorenson (2007) found students more engaged when the connections between the values and issues in their communities and those associated with science as a practice were made clear. While Bazzul's (2015) study looked at ethics in biology textbooks, rather than ethics in general, he made some pertinent points regarding students' analysis of ethical issues. Namely, students need to be "put into the position of an ethical actor" to not only consider the ethical issue, but also "recommend or defend right behaviour" or a "correct course of action" in a restricted setting to extend their thinking and engagement (p. 28, 29).

Positioning science as contributing to the greater good of humanity

It is well established that relevancy is enhanced when the science taught is important to the students. Positioning science as contributing to the greater good of humanity may enhance the relevancy of science and promote science careers as meaningful career choices (Schreiner & Sjøberg, 2007; Sjøberg & Schreiner, 2010; Tytler et al., 2008). For example, the engagement of the rural students in Chetcuti and Kioko's (2012) study was enhanced when farming-related science was taught. The English students interviewed for the *Wellcome Trust* study on *Exploring young people's views on science education* asserted they would be more engaged in science if it was relevant to modern life and situated in real-life contexts (National Foundation for Educational Research, 2011). The year 7 - 9 students in Barmby, Kind and Jones' (2008) study considered that they would be more engaged if the science taught was "practical… well-explained … in our language [and relevant to] everyday life" (pp. 1088, 1089). This way of teaching is congruent with a description of effective teaching given by New Zealand middle school students who wanted fun lessons which included hands-on practical work, was challenging, relevant and taught by someone who knew their 'stuff' (Durling, Ng, & Bishop, 2010, p. 5).

In summary, this section identified that many students find science irrelevant to their lives. It was proposed that situating the learning in relevant contexts, using socio-scientific issues and ethics and values to teach science, as well as positioning science as valuable to humanity, might engage students into science.

2.5.4 The quality of the student/teacher relationship

Several key factors have been identified in relation to the teacher/student relationship that influence student learning in science. These include the teacher having a passion for science; being able to explain science concepts clearly;

encouraging active participation, discussion and reflection on science concepts and learning; making science relevant; and set at the level of the students but still challenging and having a supportive classroom environment that values student ideas (Darby, 2005; J. Osborne & Collins, 2001). Most primary teachers in New Zealand and Australia are generalist teachers and, "lack confidence in teaching science" (Chamberlain & Caygill, 2012, p. 32). Rennie, Goodrum, and Hackling (2001) recommend that primary teachers be given professional development to improve their proficiency and self-efficacy in science. Conversely, they also identify that while secondary teachers may possess an understanding of science content knowledge; they may need help in "facilitating inquiry-oriented, student-centred learning activities and formative assessment" (p. 490).

The quality of the relationship between science teachers and students can influence whether or not students decide to take science at non-compulsory levels at secondary school, at university or a science career (Hipkins, Roberts, Bolstad, & Ferral, 2006; Lyons & Quinn, 2010; Maltese & Tai, 2010). For example, Maltese and Tai (2010) found that it was the students' relationship with the teacher, rather than the science content that enhanced their interest in science careers (p. 682). Aschbacher et al. (2010) concluded that capable science students who did not persist in science were those who were not encouraged into scientific pathways by their teachers or guidance counsellors.

It would seem then, that positive relationships, high levels of interaction, active encouragement, as well as a deep knowledge of the subject are all important aspects for teachers to consider when supporting students into science. It was also the reason why I chose to co-teach the unit as I have knowledge of both science and drama. In addition, these are all characteristics of working in Mantle-of-the-Expert (see chapter three), which is used in this study and described in the next chapter.

2.6 Summary

This chapter has provided a review of the literature related to science education and student engagement in school science. The view of science education in the NZC (Ministry of Education, 2007b) was outlined: that all students need enough science to function in a scientifically literate manner in a society in which science plays a key role. It also highlighted the tension of ensuring there are sufficient scientists to innovate and drive a knowledge economy.

Literature relating to two key components of the science curriculum - science concepts and NOS was reviewed. It was established that student pre-instructional understandings of science concepts are not necessarily the same as scientists and that realigning or broadening them is a complex lengthy process. The literature suggests that building upon students' prior knowledge and situating learning in socially relevant contexts and teaching through inquiry and discussion enhances conceptual understanding. While the literature identified that an understanding of the NOS is important, it also recognised that both teachers and students find NOS hard to teach and understand. Strategies for mitigating this include: explicitly teaching about the NOS in situated real-life contexts using inquiry, argumentation and reflection.

Literature surveyed indicated that student interest towards science and science careers declines as they progress throughout their schooling. It also suggested that boys are more positive towards science and generally more interested in the physical sciences than the girls who tend to prefer human biology and health sciences. The review identified that although students recognise the value of science, few are interested in pursuing a career as a scientist due to the negative discourse about scientists and the notion that having a science career is unthinkable. To mitigate these effects, studies indicated that students should be introduced to a range of possible science careers and the pathways to achieve them from primary school onwards. The critical period for engaging students into science and science careers was identified as being between 10-14 years. New Zealand student achievement in science dropped in the 2012 PISA results, and the pattern of older students becoming less interested in science is continuing.

Two major influences were identified in the literature as affecting whether students remain positive towards science and science careers: identity and pedagogy. Identity was defined as our personal understandings about who we are, our place in the world, and how we wish to be known and to become. Figured worlds and positioning theory were described as two complementary analytical lenses to be used to explore identity in this study. The notion of figured worlds has been used in education to illuminate how the different constraints and affordances available in different settings, classrooms or structures (such as small groups) affect student agency in learning or identity formation. Being enculturated into a figured world by someone already part of it was recognised as enhancing one's induction into the figured world. One advantage of working in a figured world is that it provides a place where identities can be tried out, such as working as an expert scientist. In this study positioning theory was identified as a way of highlighting what is occurring by analysing the discourse through a focus on the storyline, positioning of the participants and social force of the speech acts. Positioning theory has been used to explore who positions whom in conversations and to identify pronoun usage. It has also been used to look for trends over longer time periods to ascertain identity formation or different affordances to learning. In this study it is used to look for changes in pronoun use in small pieces of data. Narrowing the focus, the importance of operating within a science identity was also explored. It was noted that achieving a productive science identity could be challenging.

Several pedagogical factors that negatively influence students' attitudes to science have been described. These include: transmissive teaching; the complexity of science language, fragmented content, and the culture of science; contexts that are irrelevant to students' lives, and poor teacher/student relationships. In contrast, approaches that include investigation and hands-on activities with scope for discussion are better able to support students' science learning and engagement. Positioning science as useful for the greater good of humanity; framing learning ethically; and/or situating it in relatable contexts were also identified in the literature as valuable. Positive teacher/ student relationships where students not only learn science concepts actively but also are encouraged were recognised as vital in sustaining student interest in science.

The next chapter reviews teaching and learning literature, with an emphasis on the drama literature including science through drama and Mantle-of-the-Expert.

Chapter Three: Literature review on using drama to teach science

This chapter starts with an overview of drama in education, predominantly focused on New Zealand. Literature detailing the Mantle-of-the-Expert approach is examined and my working definition outlined. Studies investigating Mantle-of-the-Expert's contributions to curricular learning and other pertinent aspects are explicated. The focus then shifts to literature describing the dramatic approaches used to teach science. Next literature relating to the teaching and learning of science through Mantle-of-the-Expert is scoped as a prelude to posing the research questions.

3.1 Historical overview of drama in education

In this section I briefly describe the genesis of drama in education in an international sense, touching on key theorists. Then I look at drama in education in New Zealand in a historical chronological manner, indicating key players and literature to support drama in education, process drama and Mantle-of-the-Expert. This chapter and indeed this thesis situates Mantle-of-the-Expert as a derivative of the drama in education tradition and considers the intersection of its progenitor - Dorothy Heathcote - with educational drama as practised in New Zealand.

International genesis of Drama in Education

According to Bolton (1985), drama in education had its genesis in the child-centred education movement of the 1870's in the United Kingdom. He considered Harriet Finlay-Johnson (1871-1956), an eminent early twentieth century British teacher, who used drama "as a vehicle for the acquisition of knowledge" was one of the earliest practitioners of the drama in education approach (p. 152). Bolton explained that the focus between the 1920s and 1950s was on teaching drama skills (Bolton, 1985). He stated that Peter (Slade, 1954) bought "natural play" (p. 153) into the classroom with students learning by "experience" and "interaction" through drama (Henry, 2000, p. 49). Bolton (1985) then said that Brian Way (1967) developed Slade's approach, stressing life skills.

In the 1960s, the work of Dorothy Heathcote (1926-2011) revolutionised drama in education in the United Kingdom and the world by emphasising Drama for Learning (O'Toole, 2009b). According to Fleming (2003), Heathcote’s work swung the pendulum back to “content, the quality of the experience of the pupils and the role of the teacher in elevating the quality of the drama and defining the learning area” (p. 17). Heathcote’s work was further developed by practitioners such as Cecily O’Neill, Jonathon Neelands, Gavin Bolton, David Booth and others (O'Toole, 2009b), and came to be known as process drama. In time, Heathcote developed her practice from short or medium sized process dramas to sustained experiences based on dramatic inquiry in which deep learning happened across the whole curriculum (Heathcote, 2002).) This sustained dramatic inquiry approach of what came to be known as Mantle-of-the-Expert, was initially devised by Heathcote in the mid 1970s and was further defined over many years (O'Neill, 2014). Heathcote and her work did not escape criticism. David Hornbrook slated Heathcote for being “anti-theatre and its traditions and against performance of any kind” (Neelands, 2010b, p. xvi). Abbs (1991) remarked that Hornbrook considered drama, as used by Heathcote (1984a) for curricular learning, had become “a method of teaching without a subject” (p. ix). Others defended Heathcote against these criticisms on the grounds that she was theatre trained and used theatre techniques to drive learning, even describing herself as a playwright. Hence, the vehemence of the criticisms appears to be misdirected (Heathcote & Bolton, 1995; O'Toole, 2009a).

Early drama education in New Zealand

In New Zealand the status of the arts and drama in education has fluctuated. This thesis will focus on an English model of drama – Mantle-of-the-Expert. However, it would be remise not to mention that the arts have had a prominent position both in pre-European Māori New Zealand (Derby & Grace-Smith, 2014; H. M. Mead, 1999) and present-day Māori culture (H. M. Mead, 1996) in both traditional and contemporary art forms (H. M. Mead, 1999) and as such, has a significant place in the dramatic terrain in New Zealand. However, a thorough examination of the literature is beyond the scope of this thesis.

Prior to the 1960s, drama in New Zealand schools focused on performances such as plays (Cook, 1984; Lomas, 1982). The shift to "non-performance or participatory drama" (Cook, 1984, p. 51) began in the 1960s (Cook, 1984, p. 51). Direction for this change was provided by Maisie Cobby who visited New Zealand in 1964, to educate teachers on the drama in education practices being used in the United Kingdom (Lomas, 1982). The enthusiasm for drama in education was such that John Osborn ran an in-service drama workshop in 1966 (Lomas, 1982). He wrote *Classroom drama for forms 1 to 4: Suggestions for teachers in primary and secondary schools* in 1969, to support drama in the classroom and it was revised and later re-published in 1973. It described drama as, "*a creative activity in its own right*, and it is *a way of teaching and learning in any subject*" (Department of Education, 1973, p. 3).

In 1974, Sunny Amey was appointed as New Zealand's first Curricular Officer for drama, as she had worked with "Peter Slade, Brian Way, Cecily O'Neill… and Maisie Cobby" (Battye, 2005, footnote December 8, 2011). During her time as Drama Curricular Officer she advanced the status of "drama as a learning medium" (Cook, 1984, p. 52). In 1975 Arnold Wilson was employed by the Department of Education to develop arts initiatives to improve outcomes for Māori students. "Students and teachers were taken onto the marae … to live with elders and artists of the community and develop art works from local histories" (Greenwood, 2009, p. 249). Greenwood (2009) described the 1980s as a time of renewal and growth of Māori theatre born out of protest.

Heathcote's visits - 1980s to 2000

Dorothy Heathcote came to New Zealand in 1978 and 1984 to teach and encourage the use of drama in education and presented workshops to primary, intermediate and secondary teachers (Battye, 2005; Lomas, 1982). She became patron of the Zealand Association for Drama in Education in 1985 (Battye, 2005) and was, until her death on October 8, 2011, strongly connected with and interested in drama in New Zealand. Amey, in her role as Curricular Officer for Drama, considered Heathcote's 1978 visit changed teachers' perceptions on drama by showing them that drama could be used "to bring topics alive in classroom drama [and be] directed not at performance but at facilitating learning"

(Cook, 1984, p. 52). Following Heathcote's visit in 1978 many teachers began experimenting with process drama and used early versions of Mantle-of-the-Expert[1] in their classrooms. A network of drama teachers was established and a drama newsletter was published that supported teachers using drama in the classroom (Lomas, 1982). Following the first visit some drama practitioners went to Great Britain to train under Heathcote and other prominent drama educators and upon their return contributed significantly to drama in New Zealand education (Battye, 2005).

Drama was acknowledged as a means of experiencing language and communicating in the 1983 *English: Forms 3-5 Statement of aims* (Ministry of Education, 1983) syllabus. Dramatic experiences mentioned included: "Watching and participating in plays, creative drama, mime, improvisations, movement, conversations, role-playing, interviews" (Ministry of Education, 1983, p. 19). The resource - *Drama and Learning* (Ministry of Education, 1990), was written to assist "'ordinary' classroom teacher[s] to use various drama approaches to learning" (Battye, 2005, "What contribution did", para. 1). Its impetus was on "learning through participation in a dramatic activity rather than with performance to an audience … a process in which teachers and students work together in role" (p. 1). Neither Dorothy Heathcote nor Mantle-of-the-Expert were mentioned in this document even though it was based around process drama. However, Mantle-of-the-Expert was mentioned as a dramatic convention by Peter O'Connor in a drama called Jacob's Secret (O'Connor, 1994) formed collaboratively by teachers doing a drama in education paper in 1993 (S. Bleaken, personal communication, Jan 25, 2015).

Drama in the New Zealand curriculum - 2000-2008

In 2000, drama was formally included in the *New Zealand Curriculum* as part of the arts curriculum along with visual arts, music and dance (Ministry of Education, 2000). This curriculum was developed by the Auckland College of Education, with input from primary, secondary and tertiary sectors and subject

[1] Heston (1994) has in the appendices to her thesis, three early documents from Heathcote about Mantle-of-the-Expert – appendix 10 from 1972 p. 216, appendix 11 from 1984, p. 217 and appendix 12 from 1992, p. 223.

associations (New Zealand Association of Drama in Education - henceforth known as NZADIE, 1998). It specified that all four disciplines were to be studied in years 1-8, at least two in years 9 and 10 and with opportunity for specialist education in years 11-13 (Ministry of Education, 2000, p. 7). Process drama was mentioned explicitly in the preamble to *The Arts in the New Zealand Curriculum* (Ministry of Education, 2000). This states, "In process drama, which is not intended for an audience, participants build belief in roles and situations and explore them together, negotiating, interpreting, and reflecting on role and meaning" (p. 36). It is further defined in the glossary as, "a form of drama in which the purpose is to participate in learning, inquiry or discovery rather than to present drama to an audience" (p. 49). Significantly, Mantle-of-the-Expert is only mentioned in this document as a convention of process drama, which has lead to some confusion about the difference between this and the full-form planning approach used in this study (V. Aitken, personal communication, March 20, 2014).

The teaching of process drama in primary and early secondary school as required by the implementation of *The Arts in the New Zealand Curriculum* (Ministry of Education, 2000) was supported through two Ministry written resources. The resources - *Telling our stories: Classroom drama in years 7-10* (Ministry of Education, 2004) and *Playing our Stories: Classroom drama in years 1-6* (Ministry of Education, 2006), were written to "increase teacher confidence and competence in delivering the Arts" (Mallard, 2004, May 31, para. 4). Elizabeth Anderson and Kate Dreaver who wrote the accompanying book to *Telling our stories: Classroom drama in years 7-10* video (Ministry of Education, 2004) suggested that process drama enables students "to create and visit fictional worlds in order to better understand their roles in the real world and the roles they might take in the future" (p. 4). The notion of process drama is further elaborated in this document, with the authors mentioning drama theorists such as Cecily O'Neill (1995a) and Pamela Bowell and Brian Heap (2001). Mantle-of-the-Expert was not mentioned by name, although a version of it was used in the 'Tangiwai' process drama (p. 59). In this example students were in role as researchers, commissioned to make a documentary about heroes of the Tangiwai rail disaster[2]. Another Mantle-of-the-Expert type drama - Taonga – was included in *Playing our Stories: Classroom drama in years 1-6* (Ministry of Education, 2006). Dedicated Ministry of Education advisers supported drama education from 2000 to 2004 but were withdrawn in 2005 (G. Price, personal communication, 2011). Since then, support for drama in education has been more ad hoc. Drama New Zealand, an association of teachers of educational drama in New Zealand, endeavours to support drama in New Zealand schools at all levels. It is a voluntary organisation sustained by the efforts of teachers.

Drama was retained in the 2007 *New Zealand Curriculum* (Ministry of Education, 2007b) and since that time has become well established. For instance, in 2011, 4412 (7%) of students took drama at NCEA Level 1, out of a total of 62 527 students (Ministry of Education, 2012).

While process drama is explicitly mentioned in *The Arts in the New Zealand Curriculum* (Ministry of Education, 2000), in the much-conflated latest curriculum document (Ministry of Education, 2007b) it receives no specific reference. Drama is evoked in the document simply as an expression of “human experience through a focus on role, action, and tension, played out in time and space” with the stated aim of using "dramatic conventions, techniques and technologies to create “imagined worlds” (p. 20).

Mantle-of-the-Expert in New Zealand 2009 - 2015

In 2009, University of Waikato became the first University in New Zealand to offer papers on Dorothy Heathcote’s (1995) Mantle-of-the-Expert at third year initial teachers education and at Masters level. This specialism was consolidated with the August 2009 International Conference *Weaving our Stories* in Hamilton, New Zealand. Presenters at the conference included practitioners from the UK and Dorothy Heathcote addressed delegates via videoconferencing. After this conference regional cluster groups were organised and the pedagogy has grown in

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[2] At 10:21 pm on December the 24th in 1953, 151 lives were lost when the Wellington to Auckland Express train crashed into the Whangaehu River, due to the bridge being washed out by a Lahar from a crater lake at Mt Ruapehu.

popularity, with several schools now using the approach as a regular part of the programme (V. Aitken, personal communication, June 25, 2014).

In 2013, Drama New Zealand conference presentations included several with a Mantle-of-the-Expert focus. The book *Connecting curriculum, linking learning* (Fraser, Aitken, & Whyte, 2013), based on the *Connecting curriculum; connecting learning; negotiation and the arts* Teaching & Learning Research Initiative (Fraser et al, 2012), which outlines the approach and gives examples of classroom usage was launched. Other research involving Mantle-of-the-Expert is also in progress in Wellington (McGregor, Anderson, Baskerville, & Gain, 2014).

As of January 2015, there are three primary cluster groups around New Zealand to support practitioners of the approach. A New Zealand Mantle-of-the-Expert website http://mantleoftheexpert.co.nz/ was commissioned by Dr Vivienne Aitken in May 2010, with the notation – "This website is for teachers in Aotearoa New Zealand interested in Dorothy Heathcote's dramatic inquiry approach to teaching and learning (Aitken, 2010). This website offers support for New Zealand teachers using Mantle-of-the-Expert. It has blogs of teacher journeys and lists resources and literature pertaining to Mantle-of-the-Expert. It is separate from the UK based Mantle-of-the-Expert website http://www.mantleoftheexpert.com but has a close philosophical association.

This section has outlined the historical inclusion of drama in education with a focus on New Zealand and looking in particular at process drama and Mantle-of-the-Expert. The next section sets out a working definition of Mantle-of-the-Expert, which is the pedagogical approach under investigation in this study.

3.2 Mantle-of-the-Expert

This section is divided into two parts. Section 3.2.1 explores the literature to give a working definition of the major components of the Mantle-of-the-Expert approach. Section 3.2.2 details literature on the use of Mantle-of-the-Expert in education.

3.2.1 The major components Mantle-of-the-Expert

In this section, I situate Mantle-of-the-Expert within the drama literature. I detail the key characteristics of Mantle-of-the-Expert. Next, I outline the philosophical framework supporting the Mantle-of-the-Expert approach. I describe how one enters into a Mantle-of-the-Expert unit. Then, I elaborate on the core components of the Mantle-of-the-Expert approach. The different pedagogical approaches used to support the Mantle-of-the-Expert approach are then given. Finally, the working definition of Mantle-of-the-Expert, as it is used in my study, is given.

Situating Mantle-of-the-Expert within the dramatic field

In this thesis I take Mantle-of-the-Expert to be a specific type of process drama. Dorothy Heathcote, who was one of the main progenitors of process drama, developed Mantle-of-the-Expert (Heathcote, 2002).), and hence it has many similarities with process drama.

Process drama according to O'Toole (1992) began in the UK in the 1950’s and was originally known as drama in education (Heathcote, 1984c). It grew out of the “work of Dorothy Heathcote, Gavin Bolton, Cecily O’Neill, and others” who wanted to explore curricular content in diverse settings by engaging students imaginatively through drama (Schneider, Crumpler, & Rogers, 2006, p. xiii). The term process drama was used by Australian and North American theorists in the 1980s according to O'Neill (1995a), to differentiate a pedagogical approach that whilst informed by theatre, was different from less structured improvisational classroom drama in the tradition of Slade (1954) and Way (1967). O'Toole (1992) defined process drama as “the form of dramatic activity centred on fictional role-taking and improvisation” (pp. 4, 5). While O'Neill (1995a) asserted the critical components of process drama were “active association with and exploration of fictional roles and situations” (P. Taylor & Warner, 2006, p. 36).

Outlining the key characteristics of Mantle-of-the-Expert

As Mantle-of-the-Expert has developed as a teaching approach, definitions of the key characteristics have been given in literature. These characteristics have changed over time (see Aitken, 2013; Heathcote, 2007, 2009, n.d.; Heathcote & Bolton, 1995). Appendix A traces the core elements in this development. From the analysis, four common aspects were identified: the fictional world/context, the enterprise, the client and the curricular tasks. These four components are similar to those mentioned by Luke Abbott, who described Mantle-of-the-Expert as, "a client, a responsible team, there is a job to be done and there is all sorts of ways of making that happen and representing it" (Boschi, 2011, p. 60). However, Heathcote claims that there is both an "elegant simplicity to the approach (Heathcote, 2009, p. 3) and a complexity that enables exploration of curriculum and "what it is to be human" (p. 2, 20). In terms of simplicity, her most succinct rendering of the approach is that it is "created around the context of serving a client" (p. 10). When distilled down, I suggest that the literature identifies four core components that distinguish a Mantle-of-the-Expert drama from process drama, which are:

- Positioned as an expert
- The company/enterprise/responsible team
- The client
- The commission

However, as shown in the table in Appendix A, in terms of complexity there are many other facets to the dramatic approach. For instance, Aitken (2013) identifies ten critical components in Mantle-of-the-Expert. These characteristics are: fictional context, 'company''enterprise' /'responsible team', frame, commission, client, curriculum framed as professional tasks, powerful repositioning, reflection, tension and drama for learning / conventions (Table 3.1, pp. 40-41).

Philosophical Underpinnings of Mantle-of-the-Expert and entry into the approach

Underlying the Mantle-of-the-Expert approach is a strong emphasis on 'being human'. In fact, O'Neill (2014) claims that Heathcote created Mantle-of-the-Expert to be a model of "authentically holistic teaching" (p. 4). As Heathcote (2009) herself says, her aim was to "transform the power-less structure of most classrooms" (p. 2). She was concerned about "learners who are rarely provided with opportunities to develop a sense of active citizenship in a world where many young people are increasingly disenfranchized and alienated from society" (O'Neill, 2014, p. 4). Working in a way that promotes an active citizenship would be compatible with the citizenship focus of science education.

Mantle-of-the-Expert, according to Heathcote (2009), is a child centred "<u>dramatic</u>

convention used for teaching the school curriculum in a humanised yet fictitious context" (appendix, 17a). It provides a framework by which knowledge (both academic and those pertaining to being a human being) can be situated and experienced (Heathcote & Bolton, 1995, p. 32). The knowledge to be learned is contextualised in "real life situations" (Heathcote, 2009, appendix 17b) with the teaching "meshed within broad curriculum knowledge and skills" (Heathcote & Bolton, 1995, p. 16).

Heathcote maintains that working on authentic, short, curricular-based professional tasks, episodically, over a sustained period of time, situated within authentic dramatic contexts from which learning emerges, provides students with meaningful dramatic experiences and enhances curricular learning (Heathcote, 2008a, 2009; Heathcote & Bolton, 1995). The tasks "carry" the learning (Heathcote, 2009, Appendix 4d), and as they increase in complexity, deepen the level of student commitment or engagement into the Mantle-of-the-Expert drama and the curricular learning (Heathcote, 2010a). Heathcote describes an engagement continuum of ten levels (Heathcote, 2009, Appendix 4d), where students are first "attract[ed] ... then move through interest, engagement, involvement to productive obsession" (Heathcote, 2010a, p. 25). In the engagement phase (level 4) the drama is moving – students have agreed to be involved. At level 6 – students are "invested in our enterprise and the existence of our client and our workplace". At level 8, they are committed to the work and at level 9 are productively obsessed and demonstrate this by talking to their parents about the work (Heathcote, 2009, Appendix 4d). Heathcote (Heathcote & Bolton, 1995) considers that "productive *obsession*" takes time to develop and occurs when students are deeply involved with their learning (p. 19). While the tasks used in Mantle-of-the-Expert are critical to developing students' engagement into learning, Edmiston (n.d.-b) claims that the Mantle-of-the-Expert approach intrinsically motivates students to learn because it "breeds engagement". The reason, he suggests, is that it "harnesses children's enthusiasm and ability for imagining that they are other people in a community" (p. 4).

The reason for teaching in a humanised context is that Heathcote wants children to glimpse the possible, and to experience the accomplishment of creating a fictional world that is hardworking, collaborative, responsible and community minded (Heathcote & Bolton, 1995, p. 170). Therefore, Heathcote (2010a) stresses it is vital to work in a way that supports the development of the child - academically, socially, ethically and morally. One way that this learning occurs in Mantle-of-the-Expert is through "operat[ing] from a community point of view" with both teacher and students interacting and creating work (Heathcote, 2009, p. 1) to high levels of ethicality (Edmiston, n.d.-b, p. 7). The reason why the community point of view is used in process drama (and Mantle-of-the-Expert) according to O'Neill (1995b) is that, "learning occurs most efficiently within a supportive and collaborative community" (p. viii).

Students can enter into a Mantle-of-Expert drama in three ways – through Drama for Learning, inquiry learning or through what Aitken (2013) terms "Expert framing" (Abbott, n.d.; Aitken, 2013, p. 36). In Drama for Learning – students enter the learning through drama; this may be through using process drama and/or theatre or a variety of drama techniques and conventions. It "works by creating micro-worlds which allow human events and motivations and outcomes to be explored … It may but need not, involve performance for and to audiences" (Heathcote, 2010b, p. 9). There is the notion of working both in real-and-imagined worlds in a holistic learning community. Inquiry is another method used to hook and sustain the students into learning in a Mantle-of-the-Expert unit. In line with Edmiston and McKibben (2011), I take inquiry to mean, "longer-term and more sustained inquiries focused by questions that are explored from competing viewpoints" (p. 94), not just a short term curiosity. In terms of entering the drama through expert framing, I take this to be when the tripartite factors of company, client and commission are in play and the students and teachers are working in expert role to sustain both the imagined reality and classroom reality.

Mantle-of-the-Expert operates within a fictional context, (similar to that of a figured world (Holland et al., 1998)), with learning occurring in the doubled realities of the classroom and the fictional domain. Heathcote (1991b) explains that in process drama and by extension - Mantle-of-the-Expert, students work in the classroom where they "seem to 'really exist' and the 'as if' world where [they] can exist at will" (p. 104) and also between the two, as required by the demands of the fictional act. The ramification of operating in a "doubled reality" according to Edmiston (2003) is that what occurs in one world and the meanings formed in social interaction there, can potentially affect other worlds. That is why careful framing is vital, for not only does framing provide distance for protection (Heathcote & Bolton, 1995); it also "limits and opens possibilities for learning" (Heston, 1994, p. 167) and communicating their learning (L. Johnson & O'Neill, 1991). Just like in process drama, in Mantle-of-the-Expert students use improvisation to explore and create possibilities by working in an unscripted yet purposeful manner in imagined roles and situations (O'Neill, 1995a) within the framing of the drama (or the perspective by which people enter the drama) (Heathcote, 1991d). The value of using improvisation, according to Heathcote (1991c) is that students' thinking is extended by the discoveries made by "walking in someone else's shoes" (p. 44). This is another way in which students can explore what it is to be human. This is an area that can be further explored in my thesis in terms of the students working as expert scientists and also thinking beyond themselves to see how the science explored in this study can impact other peoples' lives.

Core components of the Approach

The notion of being positioned as an expert or what Aitken (2013, pp. 41, 47) terms "powerful repositioning" is important within Mantle-of-the-Expert. In Mantle-of-the-Expert students are positioned and agree to take on the role of "someone who is an expert at running something" and committed to meeting the responsibilities associated with this role (Heathcote & Bolton, 1995, pp. 18, 23, 28). However, Heathcote (2008b) stresses the importance of students and teachers agreeing to operate in a fictional domain without coercion and freely accepting the 'big lie' of being gifted with "social and moral responsibilities their age and immaturity does not normally permit" (p. 10). This means that students are aware they are 'playing' and agree to take on 'expert' roles. Students do not take on the persona of another but "stay in their own mind but inhabit unfamiliar places and contexts for action" and being a critical "spectator" to their contributions in the drama (Heathcote, 2007, p. 9), within the "doubled reality" of the world of the classroom and the dramatic world which they are exploring (Edmiston, 2003, p. 223). However, Heathcote (2007) cautions that the label of expert is not a gift; it is earned by working in the manner of a particular expert, being recognised as one and in actuality gaining some/many of the skills of an expert through learning.

The uniqueness of this specialised role is acknowledged by O'Neill (1995b) who reports, “the students inhabit their roles as experts … with increasing conviction, complexity and truth” (p. viii). She further articulates that the students grow into the fullness of the expert identity as they carry out the curricular tasks for the client and are challenged by the teacher within the framing of the drama to elevate their ‘capabilities’ both in the role and in the learning connected to it (p. viii, ix).

Another core component of Mantle-of-the-Expert is the fictional enterprise that students work in (Aitken, 2013; Heathcote, n.d.). Alternate names for the enterprise are the “company” and “responsible team” (Aitken, 2013, p. 40). Heathcote and Bolton (1995) state that in Mantle-of-the-Expert students are “framed as servers committed to an enterprise” (p. 32), which is ethical in derivation (Edmiston, n.d.-b). There are at least eleven possible enterprises (Heathcote, 2009; Heathcote & Bolton, 1995) ranging from servicing enterprises such as transport and haulage to arts establishments. The enterprise forms the bounded parameters from which curriculum content can be taught and provides the context in which work can occur with the exact frame chosen being dependent upon the “curricular areas desired by the teacher as being essential to be learned, practised and understood” (Heathcote, 2007, p. 8). Once the enterprise is chosen, students are invited to become part of the collective enterprise, not as novices but as fully functioning, experienced adult expert members who have had the responsibility of running the company for some time (Heathcote, 2008a). According to Heathcote (2007), the shift into the enterprise is driven by two factors; language - specific to the context both in inclusivity and in professional tone; and sign - indicating locus and a sense of time and space, or dramatic encounters using embodied, oral and written language. Heathcote and Bolton (1995) also point out that although students are positioned as responsible members of a team or company, the status takes time to actualise requiring practice and a supportive teacher. In this study the signs used to establish the company are detailed, along with any shifts in language to support the students’ positioning as experts.

The role of the client is recognised in literature as a crucial component of Mantle-of-the-Expert (Aitken, 2013; Heathcote, 2007, 2009; Heathcote & Bolton, 1995). Heathcote explains that in Mantle-of-the-Expert, students in role as expert members of the enterprise, agree and are commissioned (Heathcote & Bolton, 1995, p. 17) to work for a client (p. 170). The client, who is evoked by the teacher through sign and role conventions, is “generated in our heads and mutually agreed upon to make demands upon us” (Heathcote, 2007, p. 10). According to Heston (1994), Bolton considers that the client is “distinctly separate” from the company but there is a notion of being “interdependent” (p. 155). The client is generally positioned as having a higher status than the students or the teacher (Aitken, 2013). Student work is prepared for the client rather than the teacher (Heathcote, 2007). Heathcote and Bolton (1995) argue that it is the climate of care between the company and their clients that creates both the requirement and desire to provide service that is of a high standard and by extension high quality class work.

The client (and any ‘other’ deemed important to the running of the enterprise) also provide the crucial sense of an outside audience to the drama (Heathcote & Bolton, 1995). Although not as fundamental to process drama as traditional theatre forms, many commentators still suggest audience is vital. For instance, Neelands (2010a) asserts while there is no requirement to have “spectators” to the work, there will always be at least “the sense of an audience” (p. 103). In fact O'Neill (1995a) states the participants “are an audience to their own acts and observers of the consequences of their acts” (p. 80) and the very act of negotiating meaning between each other means they are acting as an audience and the feedback received will affect the direction of the drama and by extension the learning. It is working to an audience that Heathcote and Bolton (1995) suggest is vital for enhancing excellence. The importance of audience was also identified as a key finding in the *Connecting curriculum, connecting learning; negotiation and the arts* Teaching and Learning Research Initiative (TRLI) project (Fraser et al., 2012) where it was noted that the sense of audience appeared to make the learning purposeful and enhance students’ motivation to produce quality work (p. 5). According to Heathcote, the interactions between the students and client are generally “channelled” by the teacher-in-role or through other role conventions such as letters, thus providing a conduit through which work is presented (Heathcote & Bolton, 1995, pp. 172, 173). Thus, in my study, I will examine the impact that working for a fictional audience(s), such as the client, has on student learning in science.

The commission was highlighted by Aitken (2013) as an essential component of Mantle-of-the-Expert. Heathcote (2010a) and Heathcote and Bolton (1995) suggest the commission letter from the client is crucial in designating the parameters of the Mantle-of-the-Expert engagement, the curricular areas to be covered, skills to be developed and the momentum for the project. It provides precise goals to work towards and a necessity to "publish" or produce work for the client that is specific and fit for their required aims (Heathcote, 2010a, pp. 24, 25). The commission is often not completed in the real world, as this would demonstrate the obvious "*in*expertness" of the student who is acting in the role of an expert (Heathcote & Bolton, 1995, p. 18). Additionally she argues, it is the performing a task for a client that is important rather than doing work for a master/teacher, as the later bestows upon the students low status, and the former high status, in which everyone (teacher and students) can participate (Heathcote, 2002).).

Pedagogical approaches for Mantle-of-the-Expert

Literature has described several pedagogical structures used by the teacher to support the Mantle-of the-Expert approach. These include: sign (Heathcote & Bolton, 1995, p. 178), dramatic role conventions (Heathcote & Bolton, 1995, pp. 18, 185) and dramatic tension (Heathcote, 2010a, p. 10). Other components relate to building an inclusive classroom, how power is used and the importance of reflecting upon learning.

The use of sign is a facet of process drama and Mantle-of-the-Expert (Heathcote & Bolton, 1995, p. 178). Sign encompasses both aural and written word, the gestures we use to communicate with and the meaning they embody when rendered contextually (Neelands & Dobson, 2008). According to Heathcote (1991d), sign is used both in theatre and real life with "human beings signalling across space, in immediate time, to and with others" (p. 160). She also states that in Mantle-of-the-Expert sign is used to evoke "authenticity", "history" and "place" (Heathcote & Bolton, 1995, p. 177). Careful signing is important, with meaning evoked by the placement of people and the use of representative objects to draw the participants into the drama and make the fictitious real through praxis

(Heathcote & Bolton, 1995, p. 173) and recording what one has discovered or learned (Heathcote & Bolton, 1995, p. 57). Sign in this study encompassed both aural and written words, and the placement of people. For example, the company was signed through a company notice board. I also signed that I was in role as Ms Swan by wearing a scarf. I would also sign the students by mentioning the word ‘scientists’ or ‘company’. As mentioned, time is also an important facet of Heathcote’s work (Heap, 2014) and Mantle-of-the-Expert in which everyone works in “now immediate time of social engagement” (Heathcote, 2009, p. 3).

Role taking, according to Edmiston (2003), is pivotal to process drama and by extension to Mantle-of-the-Expert and can occur in the social worlds one inhabits as well as the imagined worlds being created. The types of role one inhabits in process drama vary considerably and can be collective or singular (O'Neill, 1995a). In my study, students will work in one main collective role – expert scientists with other roles used to support the learning at different times. Role use, according to L. Johnson and O'Neill (1991) is advantageous because it can hook students into learning, show a different way of living, be an inquiry focus, someone to play against, an emotional or attitudinal challenge or a pressure to evoke a planned response (p. 205). O'Sullivan (2011) additionally suggests that the benefit of role taking, is that students can explore different “perspectives”, “possibilities”, or in the case of education not just learn information, but to build their own understanding of knowledge through lived experiences (pp. 512, 513). Eriksson (2011) considers that role taking in Heathcotian drama is attitudinal rather than character based (p. 119), which is certainly the case in Mantle-of-the-Expert for students take on an expert role rather than a different character to work within.

Teacher-in-Role (TIR) is a specific type of dramatic role convention attributed to Heathcote by O'Toole (2009b) where teachers take on a dramatic role within the drama. According to Morgan and Saxton (1989), TIR usage is common in process drama. However, Ackroyd (2004) found that how TIR is used and played by the teacher varies widely. The value of working in TIR according to O'Toole and Stinson (2009) is that it “suspends and alters” the normal status and power relationships within the student/ teacher relationship (p.66). Another advantage of TIR highlighted by O'Toole (2009b) is that the learning and the drama can be managed from within the drama. What Heathcote and Bolton (1995) consider critical is that the teacher chooses a role in Mantle-of-the-Expert where students in role as experts can offer the teacher "advice and guidance about the immediate tasks" (p. 24). The different roles registers (see Morgan & Saxton (1989) for more information) used change according to the aim of the drama. The teacher can, for example, be figured as 'tell me more' or 'I'll get you what you want' (Aitken, 2014d) with the register used changing teacher/student interaction. Using different roles or role registers allows the teacher to change the authority of the role (or role itself) in order to shift power or change status, so that students' learning is enhanced (Heathcote, 1984c, pp. 68, 69). Therefore, TIR will be an important component of my study.

Use of dramatic conventions and dramatic tension has been highlighted in literature as significant, because they can engage, deepen and facilitate learning (Heathcote, 1991d, 2010a; O'Toole, 1992; Poston-Anderson, 2008). According to the glossary provided on the New Zealand teachers' website *Arts Online* (Ministry of Education, 2007a), conventions are "established ways of working in drama (for example, hot seating, role on the wall, freeze-frame images) that explore meaning or deepen understanding; or established practices in theatre (for example, the soliloquy, aside)" (no page number). However, Heathcote described 33 different role conventions that can be used by the teacher or students to support learning (Heathcote, 1991d, pp. 166, 167), which can be iconic, symbolic or enacted (A. Taylor, 2006b). Examples of role conventions include: "No. 29 – a reported conversation with two people reading the respective 'parts'" and No. 5 – "the role as a portrait of a person. Not three dimensional, but in all other ways the same as an effigy" (Heathcote, 1991d, pp. 166, 167; A. Taylor, 2006b). The value of role conventions is that they both permit and support students' work in drama because they "*slow down time* and enable classes to get a grip on decisions and their own thinking about matters" (Heathcote, 1991d, p. 166). In addition, they "bring in "others" from outside the enterprise; [and] … protect students from feeling they are being stared at" by moving the focus from the students onto the convention (Heathcote & Bolton, 1995, p. 185).

Dramatic tension can be used to drive and intensify action in dramatic episodes, being the fulcrum between "the presentation and the realisation of self" (P.

Taylor, 2000, p. 34) and the dissonance between what is or what people have and what people want to attain or accomplish (Poston-Anderson, 2008). Heathcote (2010a) agrees and further asserts that productive tension occurs by “leaving something in the situation to chance, which cannot be controlled entirely” (p. 10). According to O'Toole (1992), tension occurs both inside the fictional context (in the tension of the task, through relationships, surprise and secrecy) and in the space between real and imagined contexts through metaxis and importantly provides an emotional impetus to action. Metaxis can be explained as being aware of your own identity while playing a role and using that awareness to reflect upon what is occurring within that role and the interactions between the real and fictional worlds you inhabit (O’Connor & Anderson, 2015). Heathcote (2010b) describes at least 24 levels of tension, which can be used in isolation or combined. She notes that the tension can be assisted through the use of iconic, symbolic and embodied sign (action). The tension must be appropriate for the situation and attractive to draw the students into the task/episode. In my study I will see if the use of ethical tensions, such as “Level 6. Threats because of stupidity” and “Level 12. Loss of faith in some companions” (Heathcote, 2010b, p.11), will draw the students into learning.

The importance of creating an inclusive classroom culture in Mantle-of-the-Expert was highlighted by Heathcote (2007). Heathcote claims that developing a collegial context, wherein students and teachers can be part of a company or enterprise together is crucial in changing power in the classroom (Heathcote, 2009, Appendix 17b). Edmiston and Bigler-McCarthy (2006) agree, suggesting that working in a collegial manner creates opportunities for all voices to be heard and knowledge and identities affirmed. Heathcote and Bolton (1995) argue that power is changed in the classroom when students “direct, decide and function” (p. 18) and the teacher is no longer seen as the fount of all knowledge, but an “enabler of learning” (Heathcote, 2009, p. 5). One way of creating this collegial culture according to Heathcote (2007) is through language choices. Heathcote (2009) indicates that this collegial culture can be identified linguistically; instead of students using singular personal pronouns such as you and me, plural personal pronouns are used, implying “inclusivity” thus drawing the students into a collaborative team (p. 5). Linguistic changes are also a facet of positioning theory (see chapter 2.5.2). I will examine pronoun usage in my study to see whether the students accepted being positioned into their roles as a company of expert scientists.

Another aspect identified by Heathcote (Heathcote, 2009; Heathcote & Bolton, 1995) as important in Mantle-of-the-Expert is power. Looking at Heathcote's writing from a number of sources, it can be seen that she characterises power in three ways: (i) in relation to the classroom structure; (ii) as it affects students' control of their learning; and (iii) in how power is shared between student and teacher in the classroom. Heathcote considers that many students are disenfranchised by the school system (Bolton, 2003, p. 126). She claimed that Mantle-of-the-Expert could "transform the power-less structure of most classrooms, to the power-full exploration of being human in controllable domains selected for learning purposes" through play (Heathcote, 2009, p. 2). Heathcote (Heathcote & Bolton, 1995) further argued that the advantage of working in dramatic play in Mantle-of-the-Expert, was that students have "the power ... to direct, decide and function" within that world and "grow in expertise" (p. 18). This, Bolton considers is "empowering", because as the students grow into their expertise, they become responsible for "their own work" (Heathcote & Bolton, 1995, p. 189). However, in order to maximise students' self-efficacy, Heathcote warns that teachers must support students to "operate in the enterprise to their fullest ability" (Heathcote, 2008a).

A teacher always has more 'power' or 'authority' than a student (Edmiston, 2003, pp. 226, 227). The teacher can choose to have "power over" the students in a subjective manner or "power with" the students (Edmiston & Bigler-McCarthy, 2006, "Using power over", para.1., "Using power with", para. 1"). Drama can disrupt the normal power 'over 'positions, such as those used in transmissive teaching, when the teacher works in lower authority positions (Edmiston, 2003). The "power with" approach is implicit in the Mantle-of-the-Expert approach, for power is shared by positioning students as "knowledgeable and competent colleagues" (Heathcote, n.d, para. 5; Heathcote & Bolton, 1995) within the company where the teacher also is positioned as a member of the company. However, handing over power and authority to work in a collegial manner with students is not without risks. According to Aitken, Fraser, and Price (2007) to do it successfully, the teacher needs to be secure in his or her own abilities, be proficient and comfortable teaching using dramatic pedagogies and know that their students can cope with the ambiguities present when working in drama (p. 11).

Reflection is seen as an essential component of both process drama and Mantle-of-the-Expert (Heathcote, 1975, 1991; O'Neill, 1995b). By reflecting, Heathcote (1975, 1991) asserts, trust is formed; there is time to listen, challenge and discuss what is occurring; shared understandings are built; and curricular learning and metacognition are deepened (p. 92). Reflecting on life within the protection of ‘as if’ imagined worlds can enable participants to safely view the interconnections with the ‘as is’ real world both explicitly and implicitly (Heathcote, 1991a, p. 149; O'Neill, 1995a, p. 4). Heathcote (1984a) considers it is “reflection that permits the storing of knowledge” (p. 97). Working in Mantle-of-the-Expert, in an extended role-play, allows the participants, according to Heathcote (2008a), to “open up reflection, debate and philosophical discourse about morality and about world and society responsibility” (“planning for mantle”, para. 5). Thus, it is important in my study to allow time for the participants to not only reflect on their learning, but also to reflect on wider issues and ponder how science affects ‘real people’.

Summary

The literature on Mantle-of-the-Expert is summarised in the following definition, which serves as my definition for the rest of this thesis. Mantle-of-the-Expert is a child-centred, collaborative, drama-based pedagogical approach for teaching the whole curriculum. It is exploratory, episodic and open-ended. The students and their teacher are invited to believe and frame their learning in a fictitious domain. They agree to become part of a company or enterprise of responsible experts carrying out a meaningful commission for a client, which is accomplished through incremental tasks. This repositioning of teacher and students changes the power relationship in that they function together as colleagues. The enterprise is carefully chosen to enable the students to work in the curricular areas that need to be studied whilst carrying out the commission and to provide scope for developing the students socially and personally as well as academically. The commission provides the purpose for learning. Student work is prepared for the client, who functions in the role of audience for the student. Learning is amplified through the use of dramatic conventions, sign and dramatic tension. It occurs both in the world of the classroom and the fictional world of the drama. Out of role reflections serve to embed the learning in a metacognitive manner.

3.2.2 Mantle-of-the-Expert in action in curriculum learning

The major focus of this section is literature that explores how Mantle-of-the-Expert has been used to teach the curriculum. Mantle-of-the-Expert has been used in junior classrooms (Finneghan, 2012; O'Brechain, 2006, 2012), primary classrooms (Bromley & Labrow, 2006/7; Rouse & Wilde, 2007), in intermediate/middle school classrooms (Edmiston & McKibben, 2011; M. Hall, 2014; Kidd & Millard, 2007; Sheldrake & Banham, 2007; Towler-Evans & Law, 2007), as well as in secondary classrooms (Kidd, 2011; Lomas, 1982; Stoate, 2013).

As science is the main focus of my study, literature relating to Mantle-of-the-Expert and science is explored in more depth later (section 3.4).

Many classroom researchers have found that Mantle-of-the-Expert enhances students' motivation to learn. For instance, both the junior students of O'Brechain (2006, 2012) who used both process drama (O'Neill, 1995a) (dramatic story) and Mantle-of-the-Expert (Heathcote & Bolton, 1995) (fictional enterprise), and Finneghan (2012) who used Mantle-of-the-Expert were more motivated to learn than in similar classes not using drama. Similarly Bromley and Labrow (2006/7) identified that student motivation and engagement improved during their Mantle-of-the-Expert unit. This was also seen in Kidd and Millard's (2007) integrated year 7 English and humanities teaching programme where the students were able "to write for a range of purposes and audiences with enthusiasm and focus" (p. 60). Furthermore, Kidd (2011) noticed that her GSCE English students were more engaged in learning Shakespeare when using Mantle-of-the-Expert to learn Shakespeare. Likewise, the students in the challenging male dominated Year 8 class described by Towler-Evans and Law (2007) were engaged into the learning and "didn't want to let go of it" (p. 29). This motivation was also identified by Lomas (1982), who investigated drama as a teaching and learning method in a

New Zealand context, where Mantle-of-the-Expert was one of the three dramas used within a third form (year 9) social studies class. She noted that the "students seemed to find the work in this phase [Mantle-of-the-Expert] motivating and demanding enough that they continued on their displays while the drama teacher was away" (p. 253), which was not demonstrated in the other drama sections. As engagement is a facet of Mantle-of-the-Expert, I shall be looking in my study to see if the students were engaged and motivated to learn.

Working in Mantle-of-the-Expert has been shown to enhance students' academic achievements. For instance the four and five year-old Irish students in Finneghan's (2012) study showed "significant improvements in … the use of acquired concepts" (poster presentation). This was also seen in Bromley & Labrow's (2006/7) study where the Wheatley Hill school's students' "SAT results in relation to literacy and science have been higher than expected" and the students at "St Godrics' achieved or exceeded end of year literacy targets by the end of spring term" (Bromley & Labrow, 2006/7, p. 13). Furthermore Kidd (2011) noted that scholastic achievement improved in two GSCE English classes with a high number of 'challenging' students. Stoate (2013) found that authentic frame of the Mantle-of-the-Expert drama allowed her 16-17 year-old students to collaborate dialogically as they constructed a devised piece of theatre to fulfil the demands of their New Zealand National Certificate in Educational Achievement (NCEA) Level Two assessment. I will be interested to see if the students in my study also show improvements in their understanding of the concepts taught.

Mantle-of-the-Expert has been shown to enhance students' command of English. The literature found that it appeared to enhance students' oral language (M. Hall, 2014; Kidd & Millard, 2007; O'Brechain, 2006, 2012; Rouse & Wilde, 2007; Towler-Evans & Law, 2007) and listening skills (Kidd & Millard, 2007; Towler-Evans & Law, 2007). In addition, the students' in Kidd and Millard's (2007) study not only showed "marked improvements in speaking and listening … [they also] heighten[ed] their language to suit the purpose" (p. 62). In a similar manner, the students of Edmiston and McKibben (2011), "engaged with themes, characters, and the plot of King Lear in ways that went far beyond usual expectations for this age group" (p. 98). The students in Rouse and Wilde's (2007) study had "higher writing and literacy test scores than expected" in national testing (p. 21). Although, literacy is not the main focus of this study, I am interested to see if the students in my study heighten their vocabulary and use more sophisticated science words in their oral and written discussions rather than colloquial language by the end of the unit.

Another aspect noted in the literature about Mantle-of-the-Expert is that it enhances students' agency in learning. For instance, Rouse and Wilde (2007) noted that their students were more willing to attempt complex work. Sheldrake and Banham (2007) reported that the students who used Mantle-of-the-Expert to learn history enjoyed "acting like adults," working in a "business company" and holding a responsible challenging position (p. 42). The students in Towler-Evans and Law's (2007) study became empowered and one said, "Often teachers don't think we can do things and this has proved that we can actually run something very big" (p. 29). Stoate (2013) considered that using Mantle-of-the-Expert gave most students the impetus to work professionally in an independent ethical manner and achieve the assessment goals. Furthermore Kidd (2011) noted there were fewer behaviour issues and the students were proud of the work they had done and appreciated working in role. It will be interesting to see if the students in my study find that working in Mantle-of-the-Expert enhances their willingness to do science.

Other positive changes noticed in the literature were that the approach provided opportunities for students to work collaboratively (Dawson, Cawthon, & Baker, 2011; Sayers, 2011; Stoate, 2013; A. Taylor, 2006a; Towler-Evans & Law, 2007). Rouse and Wilde (2007) claimed that in addition to academic improvement, students also developed a sense of cultural heritage, moral development and growth in creative learning and expertise in drama (pp. 21-23). While Barnes (2009), in an action research study that used aspects of Mantle-of-the-Expert and enactment of the Expert (Hughes & Arnold, 2008) found that when the 11-12 years old students in his study worked in role as "regional school professionals" commissioned to "discuss the important matters affecting students" (p. 4), they were able to discuss sensitive issues with more fluency and maturity than they usually displayed in the classroom. He also recognised that when he took a lower status role; dialogue was enhanced, became more critical and more students participated. It seems that Mantle-of-the-Expert also provides opportunities for students to grow socially.

Feedback from the students, their parents, and their teachers about learning through Mantle-of-the-Expert is mostly positive. The students interviewed by A. Taylor (2006a) considered the approach was fun, liked having choices and working in groups (p. 9, 10). The experienced practitioners she interviewed considered that Mantle-of-the-Expert supported key learning skills, curricular learning and used inquiry. Likewise Huxtable (2009) concluded that Mantle-of-the-Expert could be used to support the development of the key competencies in the NZC (Ministry of Education, 2007b). Sayers (2011) recognised that Mantle-of-the-Expert could be used in a cross-curricular collaborative manner in which the teacher and students could work together in an enterprise, creating opportunities for dialogue and writing-in-role in many different genres. While Bunting (n.d.) commented that parental feedback on using Mantle-of-the-Expert in the classroom was positive and that he personally had found a teaching approach that allowed him "a way to be [himself] in the classroom" (p. 21). Parkinson (2012) noted that Mantle-of-the-Expert provided a positive environment for boys to learn within. I will be asking both the students and their teacher their impressions of working in Mantle-of-the-Expert and whether they consider the approach supports the learning of science.

While there are acknowledged benefits to using Mantle-of-the-Expert in the classroom; there are several obstacles mentioned in the literature that may limit the implementation of approach. One obstacle to using Mantle-of-the-Expert (and drama) in the classroom is that generalist teachers or student teachers may lack knowledge of not only the approach, but also dramatic conventions (Aitken, 2014c), and to mitigate this Aitken recommends that teachers start with small aspects such as TIR to build up confidence first. Another barrier is that the literature pertaining to the approach is mainly written in English. However, it has been used by people who have trained in the approach in countries such as Brazil (Boschi, 2011), Palestine (Abbott, 2013) and Greece (Kolovou, 2011). The necessity of having institutional support when implementing the approach was also highlighted as important (Boschi, 2011; Bunting, n.d.; A. Taylor, 2006a). A. Taylor (2006a) suggested that for Mantle-of-the-Expert to succeed there must be trust between students and teachers and the teachers must be willing to give up power. Similarly, Huxtable (2009) also mentioned that teachers would need to change how they planned, taught and shared power to work within the Mantle-of-the-Expert model. Sayers (2012) warned that teachers may find it difficult to produce a high quality classical Mantle-of-the-Expert without knowledge of “sign systems or theatre forms” and being able to use dramatic “tension” in their dramatic “narrative” (p. 266, 267). Similarly, Bunting (n.d.) cautioned that this way of teaching may not suit everyone’s’ teaching style and teachers who lack confidence in drama may be reluctant to engage with the approach. He also signalled that managing how the curriculum content was covered and assessment using the new collaborative model was challenging.

As well as the studies above which explore Mantle-of-the-Expert and the curriculum, several researchers have examined Heathcote’s’ work and the structure of Mantle-of-the-Expert. Brian Edmiston (n.d.-b), a prominent Mantle-of-the-Expert theorist, outlined the main points of the Mantle-of-the-Expert approach. He also used positioning theory to examine process drama (Edmiston, 2003, 2007), drama as ethical education (Edmiston, 2000, 2010), literacy teaching (Edmiston & Enciso, 2003) and figured worlds[3] to theorise dialogical dramatical inquiry (Edmiston, n.d.-a). Positioning theory was also used by Aitken (2014b) to theorise what occurred in the student discourse when she used researcher-in-role in a research study involving Mantle-of-the-Expert rather than a conventional researcher role.

Heston’s (1994) thesis detailed Heathcote’s drama in education approach from the literature in the Heathcote archive. B. F. Hart (2006) examined Mantle-of-the-Expert in terms of theoretical framing to evaluate how the approach contributed to ‘meaningful learning’. Hymers (2009) determined that the structure of Mantle-of-the-Expert and its core elements provided students with a rich environment to engage dialogically and collaboratively think and learn in her dissertation. Similarly, Stamp-Dod (2009) as part of her masters study claimed that Mantle-of-the-Expert helped students learn through collaborative exploration in and out of role, by the use of discourse and meta-cognitive reflection in a supportive

[3] Positioning theory and figured worlds are the main analytical lenses used in this study

environment that encouraged self-direction and mastery. In my study I will be looking at how the individual components of the approach contribute to student learning in science.

Other studies have focussed on exploring Mantle-of-the-Expert and leadership (Bunting, n.d.; Parkinson, 2012), using Mantle-of-the-Expert in non-English speaking countries such as Brazil (Boschi, 2011), gender identity (Terret, 2013) and looking at Mantle-of-the-Expert in terms of a community of practice (Sayers, 2011, 2012).

To sum up, this review of the curricular-based literature has shown that the approach is being used to support the learning of students at all levels of the curriculum. The main findings are that Mantle-of-the-Expert appears to engage students into learning, enhances their academic learning of the curricular subject being taught, improves their oral, written and listening skills and gives them more agency in their learning. The format of the teaching encourages collaborative learning and enhances their social skills and moral growth. Students tend to find the approach enjoyable, with teachers finding it useful for teaching the curriculum. Parents also look with favour upon the approach. However, the approach is not always easy to implement. Institutional support is recommended. Teachers have to be willing to share power with the students and become skilled in the use of drama.

3.3 Dramatic approaches used in science education

Learning curricular subjects through the arts has been widely acknowledged in the literature as enhancing student learning (Ewing, 2010). Drama has been used pedagogically in science since the 1980s (Dorion, 2009, p. 2248).

For instance, drama has been identified as useful in hooking students into science because it is engaging (Begoray & Stinner, 2005; Bencze & Upton, 2006; Carpineti, Cavinato, Gilberti, Ludwig, & Perini, 2011; Darlington, 2010; Dorion, 2009; Kuksa, Scriven, & Rumney, 2011; Ødegaard, 2001b; Smith, 2006; Tulloch, 2010; Warner, 2013; Warner & Andersen, 2004). It also has been shown to improve students' comprehension of science concepts (Arieli, 2007; Aubusson, Fogwill, Barr, & Perkovic, 1997; Çokadar & Yılmaz, 2010; Hendrix, Eick, &

Shannon, 2012; Karakas, 2012; Kuksa et al., 2011; Metcalfe, Abbott, Bray, Exley, & Wisnia, 1984; Peleg & Baram-Tsabari, 2011; Saricayir, 2010; Smith, 2006; Tulloch, 2010; Tveita, 1993; Wilhelm, 2006). It also enhances the learning of NOS (Boujaoude, Sowwan, & Abd-El-Khalick, 2005; Cakici & Bayir, 2012; Duveen & Solomon, 1994; McGregor et al., 2014; Pongsophon, 2010). The evidence relating to whether drama enhances students attitudes towards science is mixed with Çokadar and Yılmaz (2010) and Kolovou (2011) finding that drama improves students' attitudes towards science slightly and Hendrix et al. (2012) noting that in their study with grade four and five students that attitudes slightly decreased.

Another benefit stressed in the literature, is that drama enlarges the learning space for students to explore, discuss and reflect upon science knowledge and to look at differing perspectives on scientific issues as it contextualises and humanises science, thus giving students the opportunity to make connections with their own lives (Darlington, 2010; Ødegaard, 2001a; Yoon, 2006). Working in drama has been shown to assist students to connect with science learning not only intellectually and emotionally but also through physical embodiment (Braund, 2015; Ødegaard, 2001a; Varelas et al., 2010). Other advantages, raised by Dorion (2009), from his multi-case study of secondary drama, were that drama adds relevance, social interaction, humour and fun to science.

Studies have also highlighted potential disadvantages of learning science through drama. These include the time required to prepare and to build belief in the drama (Alrutz, 2004; Darlington, 2010; Dorion, 2009; Kolovou, 2011; Stevenson, n.d) and the necessity to have a suitable space to move (Dorion, 2009; Stevenson, n.d). Other research has identified that some teachers lack confidence in drama (Darlington, 2010; Ewing, 2010), while others cite behaviour management issues (Alrutz, 2004), and mention that there are assessment constraints working in drama (Darlington, 2010; Dorion, 2009; Kolovou, 2011; Stevenson, n.d). Nicholas and Ng (2008) and Smith (2006) raised the concern that the science used in drama may be lightweight or inaccurate. Braund, Moodley, Ekron and Ahmed (2015) caution that the role-play might "generate additional misconceptions for learners or might embed existing ones" (p. 114). Ødegaard (2001b) warned that the drama should not focus on NOS to the exclusion of science concepts.

Darlington (2010) advised that the drama should not be additional to the science but connected to the learning and that reflection about the process is vital to embed the learning.

I now look more closely at the types of dramatic approaches used in the science classroom. To frame my synthesis I draw on Ødegaard (2001b, 2003) who placed dramatic approaches along a continuum from structured drama (plays/theatre) to semi-structured drama (role-play) to explorative drama. I also use Dorion's (2009) work. He divided drama into two classes: physical simulations and social simulations. I examine the literature under four categories: theatre performances/plays, physical simulations, role-play, and teaching using a variety of dramatic approaches. My study falls within Ødegaard's (2001b) role-play and Dorion's (2009) social simulation categories.

Theatre performances and plays

Using plays and theatre performances to teach science sits at the more structured end of Ødegaard's (2001b) continuum. Student involvement in this category can range from watching science theatre with professional actors (Carpineti et al., 2011; Peleg & Baram-Tsabari, 2011; Wieringa et al., 2011) to active participation while visiting a theatre performance (Kuksa et al., 2011), acting in scripted science plays (Begoray & Stinner, 2005) and writing their own plays (Arwani, 2012; Boujaoude et al., 2005; Bruce, 2005; Nicholas & Ng, 2008; Pongsophon, 2010; Varelas et al., 2002). Overall these studies found that using structured forms of drama may help students to access science information in an engaging way (Begoray & Stinner, 2005; Carpineti et al., 2011; Kuksa et al., 2011; Smith, 2006). Watching or participating in the plays appears to deepen students' understandings of the science concepts (Kuksa et al., 2011; Peleg & Baram-Tsabari, 2011; Smith, 2006) or the NOS (Boujaoude et al., 2005; Pongsophon, 2010) taught. The benefits appear increased when students are actively involved in the theatre performance (Kuksa et al., 2011). Also recognised as important in this group of studies is the necessity to have space to explore and discuss the science in a critical reflective manner after the performance to embed the learning and help students make meaning about any science ideas (Begoray & Stinner, 2005; Boujaoude et al., 2005; Bruce, 2005; Kuksa et al., 2011; Pongsophon, 2010). The major caution raised about this approach was the necessity to ensure that the science presented is accurate (Nicholas & Ng, 2008; Smith, 2006).

Physical Simulation

Modelling science concepts through analogy is another use of drama in science (Dorion, 2009). This dramatic approach has been variously described in the literature as drama models (Tveita, 1993), role-play (Braund et al., 2015), simulation role-plays (Aubusson et al., 1997), analogy drama (Wilhelm & Edmiston, 1998), analogical role-play (McSharry & Jones, 2000) and physical simulation (Dorion, 2009). I have chosen to use the term physical simulation because Dorion (2009) who conducted a recent review of the literature used it.

Physical simulation, as described by Metcalfe et al. (1984), is where students "take on the role of … an inanimate other" to model abstract science concepts (p. 78). Examples in the literature where students physically model science concepts include: electrons in a circuit (Tveita, 1993), photosynthesis (Carlsson, 2003), molecular bonding (Coll, 2010), particle theory (Dorion, 2011a), density (Karakas, 2012), human fertilisation (Braund, 2015; Braund et al., 2015), and energy types and changes/sources, cell structure and sound/hearing (Braund et al., 2015). Other examples involve students representing natural phenomenon by becoming the circulatory system or the lungs (Aubusson et al., 1997; Mesure, 2005, p. 13). These examples are generally accompanied by theoretical explanations and used to help students explore, challenge and understand mental models about scientific concepts (Aubusson et al., 1997; Dorion, 2011a, 2011b; Karakas, 2012; Taber, de Trafford, & Quail, 2006; Wilhelm, 1998).

The advantage of using physical simulation is that it caters for different learning styles (Aubusson et al., 1997), is enjoyable (Aubusson et al., 1997; Dorion, 2011a) and can increase students' confidence and support them to take risks with their learning (Mesure, 2005). It also offers scope for both individual and collective participation (Dorion, 2011a). Many commentators also indicated that the physical simulation used contributed to students' conceptual understanding of abstract concepts (Aubusson et al., 1997; Karakas, 2012; Metcalfe et al., 1984; Saricayir, 2010; Tveita, 1993) with students appearing to be more able to discuss and explain the phenomenon taught both orally and in written formats (Aubusson et al., 1997; Dorion, 2011a; Mesure, 2005).

Braund et al. (2015) described a study, in which six fourth year BEd students majoring in science used simulation role-play to support the learning of science concepts with the aid of a drama specialist. Weaknesses in pre-service teachers conceptual knowledge were revealed in the execution of the drama and not all pre-service teachers were able to formulate useful analogues or extend students' understandings. The writers recommended that drama be a part of science teacher's methodology from year one with support given to becoming proficient in drama techniques and to make the science concept links in the drama explicit. Ewing (2010) and Aitken (2014c) also reiterated that teachers need support to become proficient in drama techniques that are used to enhance curricular learning.

Role-play

The other major mode of drama described by researchers is exploring science through role-play or by what Ødegaard (2001b) refers to as "enactment of the socio-cultural process" (p. 13) and is based on the process drama model, of which Mantle-of-the-Expert is a derivative. McSharry and Jones (2000) describe role-play very broadly as an "interactive/experiential" way of learning, in which the child (and in some situations the teacher) interact (p. 73). It has been used to support student learning of science concepts (Bailey & Watson, 1998; Braund et al., 2015; Tulloch, 2010; Wilhelm, 1998) and the NOS (Cakici & Bayir, 2012; Duveen & Solomon, 1994; Ødegaard, 2002).

The types of 'socio-cultural' process drama or role-plays used vary from small one session dramas to those carried out over one day, to longer periods. A variety of process drama-type role-play will be outlined but those specifically relating to Mantle-of-the-Expert will be discussed in section 3.4. Wilhelm (1998) used role-play to deepen and challenge student understandings of the science concepts of kinetic motion through them taking on roles such as physicists, police tracking the speed of cars and investigative reporters. He considered role-play made the concepts "real and concrete" (p. 146). Tulloch (2010) found that changing the context of her first year biology teaching to a 'crime scene investigation' meant that student engagement, interaction and discussion of science concepts was enhanced, with 80% of the students indicating that they found the format helpful in learning science. Similarly the seven to eleven year old students in Bailey and Watson's (1998) study, who explored ecological concepts by taking on a role of a living organism in the 'Ecogame', demonstrated a considerably higher understanding of the ecological concepts than those students who had the normal teaching. McNaugton (2007) also explored ecological issues such as waste recycling and rainforests through process drama to teach year six students. She concluded that working through drama was advantageous because it was enjoyable; contextualised learning; helped the students explore different viewpoints; fostered empathy; and "develop[ed the] skills and attitudes necessary for active citizenship" (p. 19).

Framed expertise was used by Warner and Andersen (2004) with second grade students on a one-day field trip to an unspecified university. Framed expertise, according to the authors, is similar to Mantle-of-the-Expert (Heathcote & Bolton, 1995) but differs in that inquiry is the main focus for learning and apart from the contextual frame, no other dramatic or role conventions are used (p. 72). The students were divided into two groups to study snails and their care. One group used an inquiry method, while the experimental group used inquiry and drama. In the experimental group, pre-service teachers were in role as zookeepers who did not know much and the children were positioned as expert zoologists. The pre-service teachers in the control group helped the students more traditionally. Warner and Andersen (2004) considered that the students who worked through drama were more involved and committed to their learning, and drew more accurate diagrams of snails and wrote more than the control group. In a later yearlong integrated study, involving 19 seventh graders, Warner (2013) used framed expertise to explore genetics (DNA) and ethics. The pretext was Lois Lowry's book, *The Giver*; the teacher was in role as an archeological site supervisor and the students as anthropologists, who were given a problem to solve, formed the basis for the science inquiry. The researcher found that structuring the learning in this way was engaging. It enabled the students to generate inquiry, lead their own learning and find appropriate resources to "make sense of the information … to answer scientific questions" (p. 274). The exact scientific concepts learned and whether the learning was significant were not included.

Bencze and Upton (2006) explored enhancing teacher efficacy in teaching science by using a Mantle-of-the-Expert-like approach (although not explicitly stated) in a piece of action research. (I have shown the Mantle-of-the-Expert components in brackets). The classroom teacher, who was uncomfortable with science, reconfigured the science learning in her class in the form of an integrated drama-based science and technology project. Due to the ozone of the world being depleted, students in role as explorer teams (company) were asked to find and design new habitats/communities for the earth’s populations to live within. As required they came out of role to learn more science to answer the questions and fulfil the brief (commission) of the Ministry of Public Safety (their client). Students had to demonstrate how energy was harnessed to help the community survive through written plans, role-play and models. The study indicated the students were engaged and positive towards science learning. They demonstrated formatively and summatively they had learned science. The students test results were not part of the study. Furthermore the teacher researcher gained more self-efficacy in teaching science. In a similar study, Jurow (2005) used figured worlds to explore the nature of student engagement with curricular understandings in a grade eight classroom where students were architects designing a research base in Antarctica. While this seven-week extended role-play study was in mathematics, as its design was similar to Mantle-of-the-Expert, it was pertinent to include.

Additionally, role-play has been used to support student learning about the NOS. For instance, Duveen and Solomon (1994) used role-play to discuss and explore the implications of science in the ‘Great evolution trial’ where students took on roles as people involved in a fictitious debate between Darwin, his supporters and his antagonists. Likewise Cakici and Bayir (2012) deepened students’ understandings of NOS about science and how scientists work with 18 ten to eleven-year-old children in ten three-hour sessions through structured role-play. In this study, critical aspects of the lives of Isaac Newton and Marie Curie were given in a Power-Point presentation. Students improvised role-plays about the lives of these scientists. Student commentary showed that the students linked their understanding to what had occurred in the role-play. Post-unit assessments confirmed that student understandings of the NOS and the theory behind science and scientific methods improved (p. 1075).

John Carroll's process drama, *The treatment of Dr Lister* was described by both O'Connor (2013) and Heathcote (1984b), to explore both science concepts and the NOS. Students in role as doctors preparing for an exam on the history of medicine, learned about the work of Dr Joseph Lister and his influence on modern medicine using a variety of dramatic conventions. Not only did the students explore historical pictures about medicine and research the time of Lister, but also interviewed the doctor (in role) about his work (Heathcote, 1984b, p. 136). Through this they learned how medicine changed over time (NOS). They also learnt about infection through their work with agar plates and moulds (Heathcote, 1984b, p. 136). This example of process drama is very similar to the Mantle-of-the-Expert approach I will use in this study, in that I will be looking at both the NOS and science concepts with the students in role as professionals.

Ødegaard (2001b) contends role-play is useful for exploring historical events and issues. In her doctoral research (2002) she describes how bio-ethical issues were interrogated through role-play with four classes of 18-19 year olds in a Norwegian secondary school. Students were given roles and information about their character and explored the scenario in an improvised manner, acting 'as if' they were the person but drawing upon their own knowledge of the situation. Ødegaard (2002) proposed that the students who thought critically about the issue of genetic testing displayed "ethical competence" (pp. 9-10) and showed a greater propensity to explore the issues. However, she also cautioned that the focus in socio-cultural plays might be on how scientists work, rather than learning specific science concepts (Ødegaard, 2001b). The use of role-play to explore the NOS and ethical issues is something I shall explore in my study.

This literature in this section has shown that role-play has been used in science to support the learning of science concepts and the NOS. Using role-play in science appears to be engaging and fun, enhancing students' motivation to learn. It has been shown to support and deepen students' understandings of the science concepts as well as helping the students defend the science and write in a scientific manner. In addition, the use of role-play provided a way for one teacher to gain confidence in teaching science. As the literature in this section has demonstrated that role-play can be a valuable way to teach science, further exploration of a specific type of role-play – namely Mantle-of-the-Expert, could provide valuable insights.

Teaching using a variety of dramatic approaches

Not every drama experience can be clearly categorised into one type of drama such as a theatre performance or a physical simulation. The examples in the following literature use more than one type of drama or dramatic conventions in their studies. The reason for this, according to Dorion (2009), is that depending on the purpose of the lesson and the needs of the students, different types of drama or dramatic conventions might be more appropriate to use at different times. For example, these commentators used multiple variants of drama in their studies, such as: dramatic monologue, readers' theatre, improvisation, mime, sound scapes, hot seating, small-group and whole-group role-play, acting out mini-historical plays and TIR (Fels & Meyer, 1997; McGregor, 2012; McNaugton, 2010). While I use one main dramatic approach – Mantle-of-the-Expert in my study, a variety of dramatic conventions such as Role-on-the-Wall, teacher-in-role and freeze-frames will also be used to support the students' learning.

A number of research-based studies have shown that student understandings of science concepts are enhanced through the use of drama that incorporates different aspects. For instance, Arieli (2007) asserted that the sixth grade students in her research study liked learning through creative drama such as "games and the use of props… where students move, jump, dance, rap, write scripts, improvise, act out skits, sing songs, perform pantomimes or play musical instruments" (p. 79) and demonstrated improved "understanding of the scientific content" to do with mixtures and solutions (pp. ii/v).

Similarly Çokadar and Yılmaz (2010) observed that seventh grade students who had received creative drama instruction such as acting out dramatic moments, playing games, using analogy and reflecting on the learning (p. 84, 87) in an ecology unit had significantly better acquisition of scientific conceptions and attitudes towards science than the students who had only teacher centred instruction as demonstrated by their post assessment scores. The authors suggested the effect of the drama-based science might be attributed to heightened affectual interest and active student participation and discussion. Hendrix, Eick, and Shannon’s (2012) comparative study, investigating whether creative drama enhanced students’ ability to learn difficult science concepts and develop positive attitudes towards science, with grade four and five students found that the students in the drama treatment group achieved significantly higher gains than the students who did not have the drama extension. However, in their study there was a small but significant decrease in student attitudes towards science, which the researchers conjectured might have been due to the already high positivity towards science and the time of the year the attitudinal assessments were taken (early in the year, which may have been artificially raised from previous experiences) or some outliers in the study (p. 837, 838). In the United Kingdom component of a comparative study investigating whether students understanding of the NOS can be enhanced through drama (McGregor et al., 2014), the researchers used a dramatic monologue to inform students about the lives of scientists before the students performed practicals based on the scientists’ work. Student comment was sought from 230 students on the value using drama to teach science and scientific literacy through a questionnaire. 80% of these students thought using drama to teach science was more fun, and 62% considered it helped them to learn science more (p. 28). The authors also indicated that the majority of the students felt that drama was helpful in enhancing their scientific literacy (p, 29, 30). Similar to these studies I will be looking for demonstrations of changes in understanding about science concepts, the nature of science and student attitudes towards science.

To conclude, this section has described the advantages of using drama in teaching science. The major benefits mentioned were that drama enhanced engagement and provided space to explore science physically, and to discuss the nature of science, science concepts and issues pertaining to science. Moreover, the use of drama contextualised and humanised science and created a fun working environment in the classroom. Drama also provided opportunities to work collaboratively.

Studies also highlighted several perceived disadvantages to learning science through drama. Time was raised as a negating factor in using drama; both in preparation and in having insufficient time to teach due to the pressures of assessment. Concerns were raised about a lack of physical space and possibly losing control by teaching in a more active power-sharing manner. The major anxiety was about ensuring the science was accurate and the need to ensure the dramatic process did not negate or trivialise the science. In order to fully utilise the value of the dramatic learning, it was advised that students reflect and discuss the science after the dramatic session or out of role.

3.4 Mantle-of-the-Expert used in science education

Somewhat surprisingly, given the way science is highlighted in Heathcote's view of education, I was not able to identify many studies using Mantle-of-the-Expert to teach science. According to Allern (2008) Mantle-of-the-Expert is Heathcote's attempt to "unite science and art" (p. 327), for it "combines theoretical and scientific investigation with performance" (p. 331). This assumption by Allern (2008) is supported by Bolton (2003) who identifies the science laboratory as the room in the school, which epitomises Heathcote's vision of education. Her vision was one where students were involved in doing "experiments, making observations, recording the results and communicating findings" (p. 125). Thus, it would appear that the Mantle-of-the-Expert approach is well suited for teaching science – the curricular area I am exploring.

Heathcote provides an example of teaching science in the seminal book *Drama for Learning* (Heathcote, Bolton, & Heathcote, 1995). In this example, students in role as monks were asked to produce an illuminated manuscript. To fulfil the commission they had to redevelop and enlarge the scriptorium. "For the sake of the work to be done in our monastery," students learned about light so the monks would have adequate light to create the commissioned manuscripts (p. 68). To learn about light, the students moved into "normal science practice", experimented with shadows, used magnifying glasses and "textbook explanations of light phenomena where appropriate" (p. 68). Student engagement and learning was not explored in this study.

Carr and Flynn (1993) described a single Mantle-of-the-Expert lesson involving grade two students in role as expert NASA employees planning a space mission to one of the planets. The study showed how framing the learning of science through working in role as members of a company might be engaging and help students to apply science facts. They considered the approach could be used to help teachers to assess how much information the students “already possess and how much they have learned” but did not assess the students in this example (p. 24).

Stevenson (2009, n.d), in an abstract for the International Drama in Education Research Institute (IDIERI) 2009 conference in Sydney and in her masters thesis, described her utilisation of Mantle-of-the-Expert in a year five classroom in an Australian school. Students were enrolled as ‘trainee’ scientists preparing for a ‘Scientist State of Origin Competition’ in a Mantle-of-the-Expert like scenario. I have termed this a Mantle-of-the-Expert like scenario because the students were enrolled as novices not as experts and they were preparing for a competition rather than a commission for a client. The students “were challenged to work scientifically in solving problems, conducting experiments, recording and analysing data, making generalizations and producing documents of recommendation to address the question “What is wrong with these water samples?” (Stevenson, 2009, abstract). Findings indicated students were engaged, empowered and had a sense of belonging when they studied science using this approach (abstract). Data obtained from in-role writing, a written assessment, oral presentations and student questionnaires demonstrated learning had taken place as students showed a “greater sense of confidence in their science learning, displayed deeper understandings in the science content, and exhibited an increased ability in using scientific language in context” (Stevenson, n.d, p. 105) by the end of the study. However, Stevenson also noted some disadvantages to the approach, including the difficulty of juggling multiple roles, the pressure of time and assessment and finding adequate space to work within (pp. 146 - 147).

Kolovou (2011), as part of her Masters research, conducted a mixed method practitioner research study in a Greek middle school with three classes of 15-16 year olds. All classes learned about genes and DNA. Traditional methods were used in one class (control) and the other two were taught through a combination of inquiry and Mantle-of-the-Expert. Students, in role as reporters, were commissioned to report on a conference about Watson and Crick. The students explored the life of Watson and Crick, conducted laboratory experiments with DNA and prepared a report to give at the conference. “The study confirmed that drama-based instruction, combined with inquiry based instruction, has a significant effect on student achievement, retention of science thinking levels, and attitudes to science” (O'Sullivan & Kolovou, 2012). The author commented however that preparation time was increased for the teacher. It also took time for the students to build belief in the drama and get used to working using dramatic inquiry. She also noted that as the lessons were taught by two different methods, using the same assessment tool was not optimal (Kolovou, 2011).

In another study, described by Aitken and Townsend (2013), students worked in role as documentary makers commissioned to investigate the issues behind the roundup and culling of feral Kaimanawa wild horses in New Zealand.[4] The major aim was for students to be able to “debate an [New Zealand] ethical issue related to animals and bio-ethics” (p. 79). Drama was used to build a strong ‘save the horses’ perspective. Productive tension was introduced by a request from a fictional Department of Conservation representative who explained that the area was a unique ecological habitat and challenged the “documentary team to include a scientific perspective on the horse issue” (p. 66). Students realised there were multiple viewpoints on a given issue. This ethical tension and challenge to include a scientific perspective provided opportunities for the students carry out “hands-on science activities” (p. 67). They explored “erosion … did observational drawings … looked at the different species of native plants unique to the area” (p. 67). Whilst working on the experiments, they also discussed “the wider issues of horses and their impacts on the land” (p. 67). Both written and oral data showed that the students developed a strong understanding of the ethical issues and science explored in this unit, producing work that was sophisticated, well presented and of a high standard (p. 79, 80). It was also reported that all students except one were engaged in and enjoyed the unit. The researchers identified that the disengaged student had been absent at the belief building stage and suggested that maintaining ‘continuity’ was critical in engaging students (p. 80). As well as

[4] Kaiamanawa wild horses are found on the Volcanic Plateau in the North Island of New Zealand. They are descended from horses released in the late 19th and early 20th centuries. They are strictly managed both for the health of the horses and to mitigate the effects on endangered plant species in a unique ecological area.

covering science - social studies, English, mathematics, health and physical education, drama and the key competencies were explored.

One recent article (McGregor et al., 2014) contrasted two dramatic approaches – one using dramatic monologues and insights into scientists' lives and the other using Mantle-of-the-Expert – to enhance the learning of the NOS with 7-11 years olds in the United Kingdom and New Zealand. As I have already looked at the non-Mantle-of-the-Expert dramatic study in section 3.3, only the Mantle-of-the-Expert portion will be detailed here. The Mantle-of-the-Expert component of the paper was a retrospective study carried out in one classroom in New Zealand, with an unspecified number of students aged 7-9 years who were positioned as marine scientists looking at marine biology, geology and oceanography in both in role work and out of role activities. In the course of the study, students "modelled the drilling and interpretation of core samples", completed a research poster on marine research and argued why marine research was important (p. 27). While the authors stated that "substantive understanding was developed about the living world", no empirical evidence was given (p. 30). In terms of NOS, the main area of growth identified was "explor[ing] the relationship between science and society" (p. 30) where the authors noted that while the students "used imagination and creativity to "be" scientists, they did not use them "as scientists" (p. 30). However, their understandings of "science and scientists were challenged" and they gained a greater awareness of scientists (p. 30) and the value of science in society (p. 31).

As highlighted in this section the literature relating to using Mantle-of-the-Expert in science is scant, with only four research-based studies identified. These studies indicated that science learning occurred both inside and outside the dramatic frame but was bounded and contextualised through the commission (or in the case of Stevenson (2009, n.d), preparing for a competition) and moderated through dramatic tension. Three authors suggested the approach was useful for engaging and empowering students in science. One author mentioned that the approach could be used to ascertain how much students knew about a topic. The studies provide evidence that the students were not only able to carry out experiments but were able to work critically, discussing science ideas and debating pertinent scientific issues. It also appears that working in this manner was advantageous for supporting learning about and experiencing the nature of science. In three of the studies, student data demonstrated that they had learned the science concepts being taught through written reports, in assessments, orally and through observations. Disadvantages noted relate to the time required for planning, building belief in the Mantle-of-the-Expert storyline and using dramatic techniques. The requirement to have sufficient space for students to work was only mentioned by one person. My study will draw on and extend these studies on the use of Mantle-of-the-Expert in science education with students working through an extended unit on buoyancy.

3.5 Chapter Summary

This chapter has explored the literature for examples of using drama as a pedagogical tool to teach science at school. In the first instance, the history of using drama in education in New Zealand was outlined and the interconnections with Professor Heathcote and Mantle-of-the-Expert detailed.

Secondarily, a working description of the Mantle-of-the-Expert approach was compiled from the literature.

The third area examined literature pertaining to how the Mantle-of-the-Expert was used to teach the curriculum. It showed that students were engaged and motivated to learn. In addition most students showed improvement in the curricular learning area being studied. Gains were identified in listening skills, and oral and written English. Findings also showed that the Mantle-of-the-Expert approach appeared to enhance students' agency to learn and willingness to attempt challenging work. Other aspects highlighted were that the students enjoyed the social nature of the approach and demonstrated growth socially. Parental and teaching feedback about learning through the approach was largely favourable. However, caveats identified were that this way of teaching does not suit everyone. For instance, teachers who are not willing to give up power, or who are not confident in teaching in drama may find it difficult. Also because the approach is more fluid, curricular coverage may be uneven. Assessing students under the old paradigm and not acknowledging their 'expert' status is problematic; therefore changes need to be made to assess learning in a way that reflects the actual learning.

The focus of the chapter then shifted to exploring the literature for examples of using drama to teach science. In the first instance, the advantages and disadvantages of using drama to teach science in a generic sense was outlined. Literature on teaching science through drama was examined under four categories: theatre performances/plays, physical simulations and role-play and teaching using a variety of dramatic approaches. Although each approach was slightly different in terms of structure and student interaction, there were similarities. Namely, students who learned science dramatically appeared to be more engaged. This literature strongly showed that drama could be used in science to support not only the learning of science concepts, but also the NOS. Also stressed in the literature was the importance of having both space to explore the science physically and dramatically and space to reflect upon the learning. In order to ensure optimal learning, the researchers considered that the science taught through drama must be accurate and students discuss and reflect upon their learning. Factors identified that negatively impact science learning through drama were: having insufficient time, restricted space and the teacher being unfamiliar with drama.

Literature studies where Mantle-of-the-Expert was used to teach science were also detailed and my study situated. The notion that working in science is a natural fit for learning through Mantle-of-the-Expert gives weight to the choice of the curricular area for examination. In the studies reviewed, students enjoyed the experience, were engaged and seemed focussed on the tasks set. Importantly, they were empowered in science; they examined relevant scientific issues and both spoke and wrote critically about them. Assessment data showed students had learned science concepts through this approach. The caveat of needing time and space to teach in this manner was mentioned, as was the difficulty of relevant assessment.

As already mentioned, there are very few studies available that investigated Mantle-of-the-Expert in science, thus providing a gap for my investigation. This study, therefore, is both pertinent and significant in that it is the first New Zealand doctoral study to combine a dual focus on Mantle-of-the-Expert and science education with a physics focus with intermediate aged students. The research questions that will be explored in this study are:

1. How did Mantle-of-the-Expert support or constrain the learning of science concepts and the Nature of Science by a class of year 7/8 students?
2. What shifts in students' written and verbal use of science concepts, Nature of Science, and science language, occurred over the course of a nine-week Mantle-of-the-Expert unit?
3. How did Year 7/8 students in this study come to perceive science now and in their future?

The next chapter details the methodologies that support this study and the methods used to collect and analyse the data.

Chapter 4: Method and Methodology

This chapter sets out the methodology or "strategies of inquiry" (Creswell, 2009, p. 11) used and the methods employed to collect and analyse data to answer my research questions. In section 4.1 I outline my ontological, epistemological and axiological beliefs and describe why I position myself in the interpretative worldview. In section 4.2 my chosen inquiry strategies are detailed. In section 4.3, the research setting is described and the research-teaching unit outlined. Section 4.4 details the main methods used to generate data and section 4.5 sets out how my data was analysed. Finally, section 4.6 outlines the ethical issues pertinent to my study and the criteria used to ensure my research is trustworthy.

4.1 The research worldview

This section outlines the underlying "beliefs and feelings about the world and how it should be understood and studied" (Denzin & Lincoln, 2013, p. 26) that I possess and their interconnection with my research. It is well recognised that the decisions and actions that one undertakes in a given situation are underpinned by how one understands the nature of existence -*what is* (ontology), perceives or builds knowledge – *what it means to know* (epistemology) and the values or ethical stances one holds (axiology) (Creswell, 2009; Gray, 2004; Hesse-Biber & Leavy, 2011; Lincoln & Guba, 2000; Somekh & Lewin, 2011a; J. Willis, 2007). The ontological, epistemological and value assumptions a person operates through can be encompassed within what is known alternatively as worldviews (Creswell, 2009; Guba, 1990), methodologies (Hesse-Biber, 2010a; Somekh & Lewin, 2011a) or paradigms/interpretive frameworks (Denzin & Lincoln, 2003). In this study I use Creswell's (2009) term worldview.

Both Creswell (2009) and Hesse-Biber (2010a) suggest the researcher should disclose the worldviews he or she holds, as this will moderate design and analysis choices. So this is where I will begin. Drawing from K. T. Anderson (2008) and Cunliffe (2011), I operate from an ontological standpoint, which sees reality as mediated through social interaction between people in specific contextual and situational settings. Gray (2004) states that, "epistemology provides a philosophical background for deciding what kinds of knowledge are legitimate and adequate” (p. 16). In terms of epistemology, I am adopting the view that meanings are created in dialogue between self and others yet are embodied (K. T. Anderson, 2008; Cunliffe, 2011). This way of thinking about reality and meaning resonates with Heathcote (1984a), who considers “drama is about filling the spaces between people with meaningful experiences” (p. 97). This ethical approach is congruent with Mantle-of-the-Expert, which Edmiston (2000) suggests is built upon ethicality and our actions as ethical people (p. 67).

A variety of worldviews are used in educational research. Creswell (2009) identifies four: postpositivism, constructivism, advocacy/participatory and pragmatism (p. 6). Teddlie and Tashakkori (2009) speak of five categories: positivism, postpositivism, pragmatism, transformative and constructivism (p.88). Recently, Denzin and Lincoln (2013) stated that the “major interpretative paradigms … are: positivist and post-positivist, constructivist-interpretive, critical (Marxist, emancipatory), and feminist-poststructural” (p. 26). This study lies within the interpretivist paradigm.

Blaike (2009) suggests that in interpretivism, meaning is understood as being “produced” and “reproduced” as part of social interaction between people (p. 99). It is concerned with the individual participant, and how they view and interpret reality with the researcher seeking to understand their experiences and actions from inside the context rather than at a remove (Cohen, Manion, & Morrison, 2011). Working in interpretivism is consistent with my axial or value assumptions, which include the importance of working in a way that is ethical, collaborative and uplifting.

4.2 Inquiry strategies

The ‘strategies of inquiry’ (Creswell, 2009; Denzin & Lincoln, 2013) are the conduits through which the research question is connected to the research method (Hesse-Biber, 2010a). Hence, the strategies of inquiry chosen depend on the questions being asked (Hesse-Biber, 2010a). The main strategy I used was action research, within which I co-taught in a unit of work. Mixed methods were used to generate, analyse, integrate and interpret my data. The main methods used for data generation were student assessments, student and teacher interviews and observations, my reflective blog and the collection of classroom artifacts. A description of data generation methods and my rationale for using them will be outlined in section 4.4.

Action Research

The strategy of inquiry chosen for this study was action research. It was chosen over a comparative study because a Mantle-of-the-Expert unit can take substantial time to implement and it was not feasible to repeat the same unit within the time available for data generation. Aside from this, it was not clear how I could identify a similar class to repeat the unit with. Another reason is that Mantle-of-the-Expert is by nature improvisational (Heathcote, 1991c; O'Neill, 1995a; O'Toole, 1992), which means direct comparison would be difficult.

Action research was chosen rather than case study because I wanted to involve myself fully in the classroom as well as the research – to be “useful” and to be part of the solution (Harrison & Callan, 2013, p. 1). Although the researcher can participate actively in case studies (Cohen et al., 2011; Harrison & Callan, 2013), according to Cohen et al. (2011), they are generally non-interventionist in derivation (p. 129).

Action research, according to Taber (2013), is a small-scale inquiry implemented to affect change in praxis in “personally experienced” social settings (p. 107). Typically, it involves “action” and “reflection” (McNiff, 2013, p. 24). According to Somekh (2008), in action research, collaboration occurs between the researchers who are outside the research and the “participants who are “insiders” to the situation under research” (p. 6).

There are many advantages to using action research. As a lot of action research projects in education occur in the researcher’s school, it can be easy to organise and find participants (Punch, 2009). It is also useful for generating new ideas (Cochran-Smith & Donnell, 2006) and is professionally relevant as it links theory to practice for both teachers and academics (Cochran-Smith & Donnell, 2006; Punch, 2009). Another advantage is that rich, detailed studies can be produced, allowing for easier comparison of context and settings (Stringer, 2008). A possible reason for this, suggested by Menter, Elliot, Hulme, Lewin, and Lowden

(2011) who drew upon Cochran-Smith and Lytle (2009), is that the dualistic roles of researcher and practitioner allow textured insights that would not be apparent if only one role was present (p. 55).

A common concern about action research is that the approach lacks rigor. Many theorists caution that action research findings are not easily generalised, as they are highly contextualised (Fenshaw, 2009; O'Toole & Beckett, 2010; Punch, 2009; Stringer, 2008; Taber, 2013). Punch (2009) suggests that the research may be weak academically and lack subjectivity because the researcher has a vested interest in the project (p. 44). Therefore, in order to enhance the rigor of the approach, Levin and Greenwood (2013) consider theory and praxis must be linked (pp. 59-61). So, it is essential that my research be strongly based in theory.

In addition, there are ethical considerations specific to action research. For instance, it is important to ensure that action research is conducted in a manner that is transparent, collaborative, transformative and justifiable in terms of outcomes for the community (Groundwater-Smith & Mockler, 2007, pp. 205, 206). McTaggart (2014) suggests it is important that action research is not undertaken just for intellectual curiosity but also to inform practice (p. 465).

Action research configurations range from participatory, critical, classroom, industrial, action learning, action science, to soft systems approaches (Kemmis & McTaggart, 2005, pp. 560-563). My action research is firmly situated in the culture of the classroom (Somekh, 2008, p. 6). However it was not initiated by the classroom teacher and hence is not classroom action research in the classical form (Kemmis & McTaggart, 2005, p. 579).

The form of action research closest to that used in my unit is Participatory Action Research (PAR). PAR is a social, participatory, practical and collaborative process, where both researcher and participants work together in a manner that is emancipatory yet critical and reflexive, with the goal of exploring their “shared social worlds” to change practice if desired (Kemmis & Wilkinson, 1998, pp. 23,24; Miskovic & Hoop, 2006). It has been widely used in educational research (Buck, Cook, Quigley, Prince, & Lucas, 2014; Miskovic & Hoop, 2006; Nolen & Vander Putten, 2007; Somekh, 2008), including science education research (Buck et al., 2014; Goodnough, 2011) and drama educational research (M. Anderson, 2012; Cahill, 2006). M. Anderson (2012) deems PAR optimal for drama research as it utilises "praxis: practice and action as research" (p. 145). Another drama theorist, Cahill (2006), considers that there are similarities between PAR and process drama, for both approaches use "dialogue, praxis, participatory exploration and transformation" to collect and analyse data multi-modally (p. 62). I am using a form of action research similar to PAR, to analyse a science-based Mantle-of-the-Expert unit, which is a derivative of process drama. Thus, according to Cahill's (2006) parameters, there is justification in using an action research or a PAR approach as my inquiry strategy when working in drama. I only consider it is close to PAR, because the students did not act 'as' researchers, even though we were critical and reflexive in analysing how using Mantle-of-the-Expert effected our science learning.

To sum up, using action research meant I was able to involve myself in praxis and to co-construct meaning with my participants – the class teacher and students - as I explored the use of a drama-based pedagogy within science. Just as importantly, it is compatible with the Mantle-of-the-Expert pedagogy, which stresses collaboration, growing together as experts and through reflection. The main way I collaborated with the classroom teacher was through co-teaching, which is explained in the next section.

Co-teaching

Co-teaching has been used in special education (Friend & Cook, 2003; Murawski & Lochner, 2011), in pre-service teacher education (Carambo & Stickney, 2009; Colette Murphy & Beggs, 2010; L.-D. Willis & Menzie, 2012) as well as science education (Colette Murphy & Beggs, 2010; Tobin & Roth, 2005). In co-teaching, two or more teachers work together to "meet the learning needs of students" (Colette Murphy & Scantlebury, 2010, p. 1). The teachers co-plan, co-instruct, co-evaluate the lessons and co-assess the students learning together (Murawski & Lochner, 2011, p. 15; Colette Murphy & Scantlebury, 2010, p. 1; Tobin & Roth, 2005, p. 314). Underpinning co-teaching according to L.-D. Willis and Menzie (2012) is a strong ethic of care and responsibility for the individual learner and the necessity to ensure that their views are "solicited, accommodated, accepted, incorporated and acted upon" (p. 16).

Benefits identified in co-teaching are that it “can expand the learning opportunities” (Colette Murphy & Beggs, 2010, p. 26; Tobin & Roth, 2005); enhance interpersonal relationships (Tobin & Roth, 2005); and the “emotional climate of the classroom” (L.-D. Willis & Menzie, 2012, p. 20). In Murphy and Beggs’ (2010) study in 100 primary schools in Northern Ireland, co-teaching also appeared to have a “positive effect on children’s interest and enjoyment of science” (p. 31). Co-teaching aligns itself well with Mantle-of-the-Expert, which emphasises power sharing, growing together as experts and reflection (Heathcote & Bolton, 1995).

However, several factors have been highlighted as problematic in coteaching. I will mention the ones pertinent to classroom teaching. Namely, that teaching with another person may be risky (Gallo-Fox, 2010), as pedagogical approaches differ. If poor relationships develop between the teachers, student learning may be compromised (Colette Murphy, Carlisle, & Beggs, 2009). Thus, Colette Murphy and Beggs (2010) recommend that only teachers who are aware of the challenges and aims of the approach should co-teach.

In the classroom co-teaching instruction can consist of six different configurations, which are “(1) one teaching, one observing, (2) one teaching, one drifting, (3) station teaching, (4) parallel teaching, (5) alternate teaching, and (6) team teaching” (Friend & Cook, 2003, p. 178). In terms of this study, team teaching was an established practice at the study school with the teacher used to collaborative planning and teaching. In my case, the major unit was planned with support from my supervisor. The classroom teacher and I co-taught the unit using the various configurations described by Friend and Cook (2003). When introducing a topic or section, I tended to take the lead teacher role with the classroom teacher Jayne (pseudonym, henceforth known as TJayne) assisting. When conducting the science experiment, we worked in stations. Often one would start and then the other would pick up the instructional thread. We[5] worked together collaboratively. I also assisted TJayne in assessment and report writing at the end of the term. This way of teaching and learning extended to the students,

[5] When I mention “we” in connection with teaching I mean the classroom teacher TJayne and myself. However, when I mention “we” in terms of the Mantle-of-the-Expert drama, “we” stands for the fictional company SEERS that “we” (teachers and students) are a part of.

with them co-teaching us what they knew as we worked in role together as expert scientists.

Mixed methods for data collection

While Creswell (2015) recognises that mixed methods can be positioned as a philosophical stance, a methodology, or within different approaches such as interpretivism, he argues that mixed methods research is a method. Creswell contends that to count as mixed methods, a study needs to include at least one quantitative method and one qualitative method. Data from both methods have to be analysed, merged together and interpretations based on the combined strength of both sets of data used to answer the research question (p. 2). This said, Creswell suggests that it is important to acknowledge one's philosophical viewpoint. As previously mentioned, I am working within interpretivism.

Mixed methods studies vary in their design configurations. The main types are: convergent, explanatory sequential, and exploratory sequential design (Creswell, 2015). My mixed methods design meets Creswell's (2015, p. 36) definition of convergent because the qualitative and quantitative data was generated and analysed separately, then merged and interpreted. This configuration was chosen because it suited the research questions and supported the structure of my unit. Figure 4.1 outlines the configuration of my mixed methods study.

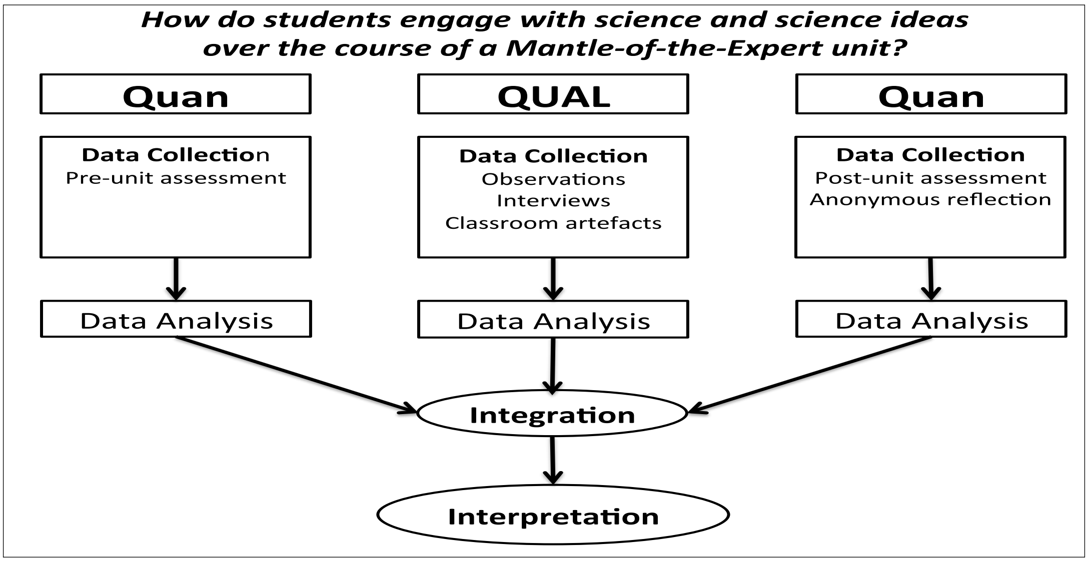

Figure 4.1 Graphic showing how the data was collected, integrated and interpreted in this convergent mixed methods design

Using different methods is advantageous because, in combination, they compensate for areas of weakness and consolidate the strengths of each method (Teddlie & Tashakkori, 2009). Mixed methods are useful for “increase[ing] the scope, depth and power of [the] research” (Punch, 2009, p. 295). They allow the researcher to triangulate data obtained by different methods and check for convergence and corroboration thus enhancing validity (Erzberger & Kelle, 2003; Greene, Caracelli, & Graham, 1989; Hesse-Biber, 2010b; Stringer, 2008).

The quantitative arms of my mixed methods research were taken from the pre and post unit assessments. In the first assessment A (Appendix D) students were surveyed about their attitudes towards science and Mantle-of-the-Expert using Likert scales and short answer questions The students were surveyed in assessment B (see appendix E) about their understandings of the science concepts of buoyancy, stability, tropical cyclones and isobar map prediction. The questions in assessment B were a mix of multi-choice and short answer questions. The assessments were marked on the same day. All answers were converted into numerical variables, a process known as quantitizing (Hesse-Biber, 2010a). The multi-choice answer were either correct = 1, or incorrect = 0. For the short answer questions, numbers were assigned based upon how complete the answers were. For example, totally incorrect = 0, partially correct = 1, fully correct = 2. The results were inputted onto an Excel spread sheet (see section 4.4.1 for more on assessments) and section 4.5.2 for statistical analysis.

For the qualitative arm of my study, data from the teaching episodes was collected from the classroom episodes. It included audio transcripts from the classroom episodes, samples of student work, my reflective blog, and student and teacher interviews. Qualitative methods are outlined in sections 4.4.2 and 4.4.2 with section 4.5.1 detailing how thematic analysis occurred.

4.3 Research Context

This section provides a description of the school, the teacher and the students. It summarises the derivation of the teaching unit. I present this information prior to detailing the data collection methods because it contextualises my study giving justification for my data collection methods.

Research situation My research was conducted in a decile 8[6] Year 1- 8 state school on the outskirts of a medium-sized city (OECD-EC definition, Dijkstra & Poelman, 2012) in New Zealand that draws its pupils from both urban and rural settings. Approximately 260 students attended this school at the time of the study. "The ethnic composition was [approximately] New Zealand/European 78%, New Zealand Māori 15%, Pacific 1% and Others 6%. A significant majority of students, including Māori and Pacifica, are achieving at and above national expectations in reading and mathematics" (Education Review Office, unspecified year)[7]. The school and teacher were chosen because they attended the Mantle-of-the-Expert cluster group and were known to my supervisor Viva.

The Principal encouraged the use of creative individualised learning methods and was supportive of learning through drama. Some teachers at the school used Mantle-of-the-Expert regularly. Co-teaching was a distinctive feature at this school, with teachers often planning, teaching and assessing together in different configurations to suit the learning needs of the students. Therefore, co-teaching rather than conducting solo research was planned.

TJayne was a second year teacher in her early 20s, who had a strong background in drama. She had used Mantle-of-the-Expert before but was not confident in science. While it is not normal to include primary data in the methodology chapter, it seems pertinent to have TJayne speak about her comfort levels with drama and science here.

> I've followed through with drama in every way that I could…I just wasn't confident in [science] to be honest ... I think I just wasn't at the right stage when I was younger. It was a little bit too beyond me and not enough motivation... I think maybe it could have been from primary school - from not being exposed to it enough and feeling like I was on the back foot once

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[6] "Deciles are a way in which the Ministry of Education allocates additional funding to schools to enable them to overcome the barriers to learning facing student from low socio-economic households…A school's decile rating indicates the extent to which it draws its students from low socio-economic communities. Decile 1 schools are the 10 percent of schools with the highest proportion of students from low socio-economic communities, whereas decile 10 schools are the 10 percent of schools with the lowest proportion of these students" (Ministry of Education, 2015)

[7] The year of the Education Review Office report is not given to hide the identity of the school.

> I got to high school. I did third form science and that's all. And possibly fourth form ... At Uni – just basic science (TI1, 25/07/11).

Twenty-nine students aged 11 to 13 were involved in this study. There were 13 boys (2 Māori, 10 NZ European and 1 other) and 16 girls (3 Māori, 12 NZ European, 1 East Asian and 1 Pasifika). Fifteen students were in year 7 and sixteen from year 8. I was not given specific data on the students' learning abilities, however I was advised by the teacher that two girls and three boys found learning difficult and one girl was on the aspergers spectrum. National data on individual student science knowledge is not collected in New Zealand.

Unit Design

New Zealand teachers plan their own teaching unit using the NZC as a reference point. The planning for this study was based on a model used by Heathcote (2010a). I drew upon resources from the Mantle-of-the-Expert UK website and followed a format developed by V Aitken (personal communication, August 26, 2015) for teachers in New Zealand. The unit was planned in collaboration with my supervisors. An outline of the unit is included in Appendix B, as is a page of the detailed planning (see Appendix C). I co-taught the unit with TJayne in a combined year 7/8 class, twice a week for ninety minutes, for nine-weeks.

The main aim for the unit was for students to explore the science concepts of buoyancy, stability, cyclones and using isobar maps for weather prediction. During the unit students were enrolled as expert scientists, commissioned to re-investigate the science behind the sinking of the Wahine. The Wahine sank in Wellington Harbour (Wellington is New Zealand's capital city) in 1968 with the loss of 51 lives. A range of dramatic conventions and teacher-in-role positionings were used during the unit, which are described in more detail in section 4.4.2 and Table 4.2.

4.4 Data generation

The main methods for data generation were: pre and post student assessments, interviews (student and teacher) and observations. I also wrote a reflective blog. Data was additionally generated through the use of dramatic participant conventions: such as teacher in role, writing in role, hot seating, freeze frames, and Role-on-the-Wall. Copies of student written work were collected. Photographs were taken of students during activities and of notations on the whiteboard. All classroom episodes and interviews were audiotaped.

Table 4.1 below details how each data source was labelled. When the data was collected on a certain day, the date was also recorded when quoting the data.

Table 4.1 Data abbreviations

Data Type	*Abbreviated Nomenclature*
Anonymous Assessment	AA
Episode Transcript	ET
Focus Group	FG
Pre-Assessment A Attitudes	PreAA
Pre-Assessment B Concepts	PreAB
Post-Assessment A Attitudes	PostAA
Post-Assessment B Concepts	PostAB
Reflective Blog	RB
Student interview	Child Initial & Child initial, Day/Month/Year Example JG&TW, 05/10/11
Teacher Interview	TI(1, 2 or 3, Day/Month/Year
Written Report	WR

4.4.1 Student assessments and reflections

In this section, I describe the pre and post-unit assessments undertaken in this study. I also detail an anonymous assessment that the students did at the end of the unit.

Pre and post unit assessments

The pre and post-unit assessments provided the quantitative aspect of my research design. The pre-test provided base-line data and the post-test showed how the students' knowledge changed. This data was used to provide "evidence of overall patterns of effectiveness" (Patton, 2002, p. 151). However, Patton also argues "quality has to do with nuance, with detail" (p. 150). It is the meaning and the human face behind the statistics that are important and this is taken into account in my presentation of the data in chapters five to seven.

Figure 4.2 shows the pathways taken to develop the assessments, how they were coded and first stage analysis.

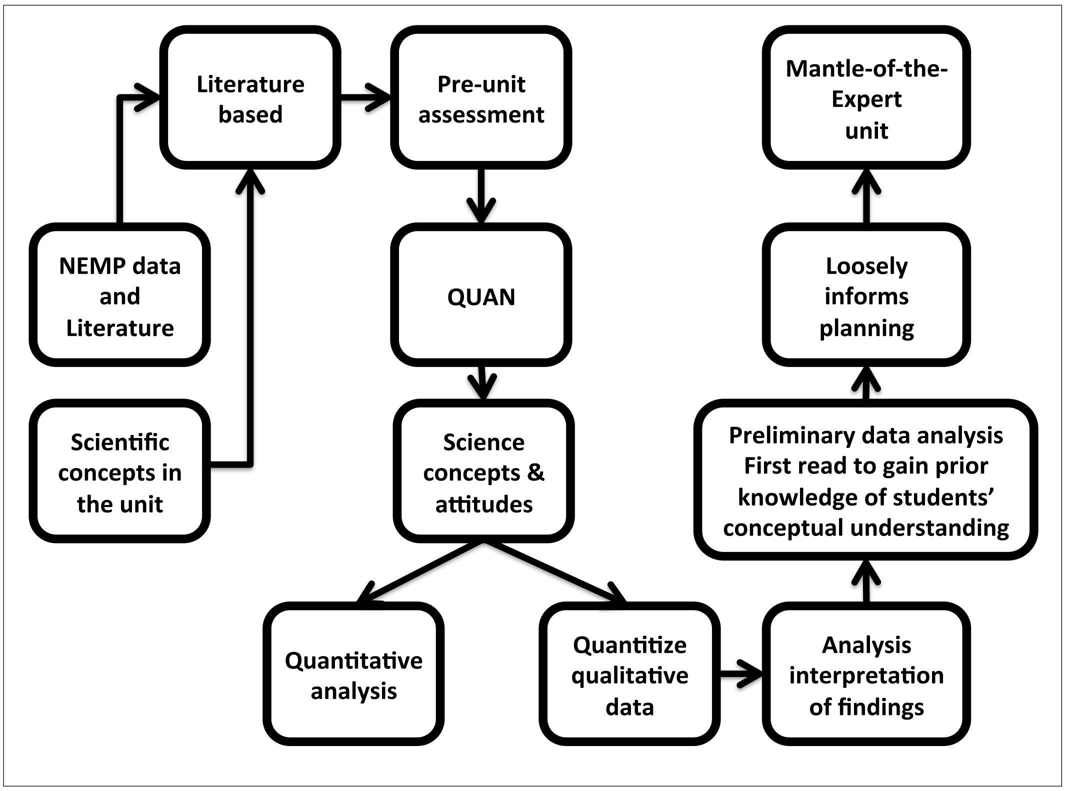

Figure 4.2 The derivation of assessment and first stage analysis

The assessment questions were modelled after the National Education Monitoring Project [NEMP] (Crooks et al., 2008) assessment design for science, which had both attitudinal and conceptual questions and was used with permission. Following NEMP, the concept to be tested was contextualised, visual images provided and several questions were asked for each concept to generate a deeper understanding of students' knowledge. Using a New Zealand based assessment as a model, meant I could compare the class I worked with to the students who took part in the NEMP assessment.

As already mentioned in section 4.2, students were assessed using the same test, pre and post the unit. In part A (see Appendix D), students were asked (via a Likert scale), about their attitudes towards science and science careers, and their attitudes towards learning through the Mantle-of-the-Expert approach. They were also asked some short answer questions. Twenty-five students completed this assessment. In Part B (see Appendix E) students were asked about buoyancy, cyclones and weather prediction through multi-choice questions and short answer questions. Twenty-seven data sets were collected here. The assessments were marked on same day, with short answer questions converted to numerical variables (see section 4.5.2 for more details).

Anonymous reflection

Data was also generated through an anonymous student reflection. The value of anonymous reflection is that it provides an opportunity for silent or marginalised voices to be heard and to generate negative data (Finley, 2008; Stringer, 2008). Class time was provided for students to comment anonymously on their learning once the unit was completed. Prompt questions were developed from my research questions (see Appendix F). Students' answers were written on identical pieces of paper and placed anonymously in a box.

4.4.2 Classroom data collection

In the classroom I was both a teacher, albeit a co-teacher, and a researcher. As a researcher I situated myself as a Participant-as-Observer. Gold (1956) in his seminal work, describes this orientation as someone who fully participates in the community being studied, with the participants fully aware research is taking place (see also Cohen et al., 2011, p. 465). This orientation therefore was consistent with my role as co-teacher. In my role as co-teacher, I functioned both as an insider (classroom teacher) and as an outsider (researcher) (Hellawell, 2006; Merton, 1972). This is considered advantageous by Hellawell (2006), because it allows the researcher to be aware of both perspectives. He argues that one must have empathy but yet "make strange" or have distance from the world one is researching in (p. 487). I was inside the research and experienced what the class was experiencing as a teacher but with an outsider's perspective because I was also researching what was happening.

According to Patton (2002), the time allowed for observational data generation should flow from the "purpose of the study and the questions being asked" (p. 275). In this study the decision was that I would participate in a full Mantle-of-the-Expert unit of work. These require considerable planning and time to build a sense of community and to develop 'productive obsession' (Heathcote & Bolton, 1995). Therefore, I carefully negotiated with the school and teacher to spend a term with them and at least two afternoons a week, in order to have sufficient time to build the drama.

Audio-recording

I functioned as a Participant-as-Observer who co-taught, which meant I could not take notes. Therefore, I digitally audiotaped all classroom episodes so I had a permanent record of what was said. Stringer (2008) considers this crucial because nothing substitutes for "actual things said by real people" (Patton, 2002, p. 380). This was also a useful portion of the audit trail. Three digital voice recorders were used for redundancy in the case of equipment failure. Both TJayne and I carried an audio-recorder and an additional recorder was placed on a desk. While Morrison (1993, p. 88) cautions that having an observer, or electronic device changes how the children react, using a recording device in this study did not appear to markedly affect the students' actions.

Dramatic participant conventions

Multiple dramatic conventions were used in this study (see Table 4.2) to deepen the drama and to teach the science concepts. When planning each lesson, different role conventions were chosen according to the needs of the drama. For example, when introducing the figure of the Captain, I wanted students to be able to get additional information about the sinking of the Wahine and so I selected role convention number 7: "the role as a portrait of a person" (Heathcote, 1991d, pp. 166). I used a portrait of the Captain, and spoke in role as the captain telling them about what had occurred on the vessel that day with information drawn from resources such as *The Wahine disaster* (Lambert & Hartley, 1969). In the session where students were learning about metereology and isobar maps, the goal was for students to consider and read out weather 'facts'. Here, the convention used was a variation on number 29, "A reported conversation with people reading respective 'parts' (Heathcote, 1991d, pp. 167). While there is not space to describe in detail how every convention was used, table 4.2 lists the dramatic conventions used in this study and matches them with the convention name and number from Heathcote's role convention list.

The role conventions also served as data collection tools, but in using them this way I was careful that data generation did not take precedence over learning, which O'Toole and Beckett (2010) warns is a risk. The major dramatic participant conventions used to generate data were: writing in role, speaking in role in the classroom discourses, through role-on-the-wall, and from photographs of students at work. These included the student CVs, the Role-on-the-Wall sheets and 25 reports to the client.

Table 4.2. Dramatic conventions used in this study

Teacher in role (TIR)	*Students in Role*	*Freeze Frames*	*Hot seating*	*Role-on-the-wall*	*Writing in Role*	*Other*
DH No. 1 TIR as Malcolm the Company CEO TIR as Ms Swan the PA to the CEO of SEERS **DH No. 1 & No. 16** TIR as Linda – the imagined wife of someone who was on the Wahine TIR as Albert the Expert meteorologist **DH No. 7** TIR as Captain of Wahine	**DH No. 1 & 29** Members of a company of 'expert' scientists Students in collective/ blanket role as Albert the meteorologist **DH. No. 7** One child in role as Captain of Wahine	**DH No. 8** Re-enacting when the Wahine sank newspaper photographs **DH. No 2** Walking through the final voyage of the Wahine in time sequenced freeze-frames Showing the sinking of the Wahine in time sequenced freeze-frames to the client	**DH No. 1 & No. 16** Linda – the imagined wife of someone who was on the Wahine Albert the meteorologist **DH No. 7** The Captain of the Wahine (picture)	**DH. No 10** Exploring who scientists are and what they do.	**DH No. 18** Writing in role the report to the client **DH. No. 21** Writing a tribute to share to those on the Wahine	**DH No. 25** Imagined telephone conversation with Malcolm **DH No. 23** Email from Malcolm & writing CVs **DH No. 29** Overheard conversations and emails about the fictional other Roger **DH No. 2** Interviewing the applicants for the position in SEERS Devised piece about job application

* Called DH as taken from Dorothy Heathcote's Role Conventions (Heathcote, 1991d, pp. 166, 167; A. Taylor, 2006b).

DH No. 1 – "The role actually present, naturalistic, yet significantly giving and accepting responses"
DH No. 2 – "The role actually present, except framed as a film. That is, people have permission to stare but not intrude. 'Film' can be stopped and re-started or re-run"
DH No. 7 – "The role as a portrait of a person. Activated to speak only but not capable of movement"
DH No. 8 – "The role depicted in picture: removed from actual life, as in a slide of a role, a painting, a photograph or drawing. This includes those made by the class, as well as prepared depictions"
DH No. 10 – "A stylised depiction of someone"
DH No. 16 – "An account of a person by another person in naturalistic fashion"
DH No. 18 – "An account written by a person who now reads it to others. The role is present in this case but in contact through their writing as an author might well be."
DH No. 21 – "The report of an event but formalised by authority or ritual"
DH No. 23 – "Letter read by another with no attempt to portray the person who wrote it, but still expressing feeling"
DH No. 25 – "The voice of a person overheard talking to another in informal language, that is using naturalistic tone"
DH No. 29 – "A reported conversation with two people reading the respective 'parts'"

Digital photographs

Digital photographs were taken of the activities that took place during lessons and of notations on the whiteboard. I also gained permission (from students and their parents) to take and use photographs of the students. The photographs were used in the class book and to stimulate recall during the reflective interviews with the teacher as recommended by Patton (2002).

Reflective blog

I recorded my impression of what happened during the classroom interactions in a research diary as soon as possible after the lesson. Somekh and Lewin (2011b) describe research diaries as ‘external memory’ to record what occurs during research. They can contain “both ‘data’ and reflection, interpretation and analysis” (p. 44). They can provide a ‘thick description’ of the events and establish an ‘audit trail’ which is useful for triangulation (Creswell & Miller, 2000; Stringer, 2008).

My research diary was in the form of a reflective blog posted in closed format to my supervisor who is an experienced practitioner in Mantle-of-the-Expert, who acted as an audience for my reflective writing on the classroom episodes. In it I described what had happened during the classroom episodes, reflected on possible reasons and linked what had occurred to literature. This process helped me view the action at a distance, “observ[ing] self as well as others, and the interactions of self with others” (Patton, 2002, p. 299). It also informed my teaching actions for the next day.

Class book

A class book was created from my reflective blog during the unit (see Appendix G for an example page). The book included representative photographs and described all of the classroom episodes. Students were invited to comment on it but apart from signatures, none did. My impression was that the children perceived it as *taonga* (a precious treasure) and were reluctant to comment.

4.4.3 Interviews

An in-depth interview is a purposeful conversation between an interviewer and one or more interviewee/s, involving active questioning and listening (Hesse-Biber & Leavy, 2011, p. 94). It is conducted to find out another person's viewpoint, hear their stories and create co-constructed meaning about things that the researcher has not or cannot observe first hand (Hennink, Hutter, & Bailey, 2011; Hesse-Biber & Leavy, 2011; Patton, 2002). It can also be used to seek participant interpretations of events that have been observed. Interviews can be face to face or conducted over telephones, or through social media. They can be open ended or low-structured, semi-structured, or structured (Hesse-Biber and Leavy (2011).

In this study, semi-structured interviews were used (see Appendix H for an example of TJayne's questions). Semi-structured interviews, according to Patton (2002), tend to follow a series of questions or topics in order to ensure that items of interest are covered with every interviewee. The interviewer can then probe, explore and seek clarification on the points raised as required. However, there is scope for the interviewee to pursue items of interest to them, relating to the issue under discussion. This allows for spontaneity and new knowledge to emerge that the interviewer may not have considered (Hesse-Biber & Leavy, 2011).

Interviews can be audiotaped, notes can be taken and/or a summary of points can be produced following an interview. In my case I audiotaped the conversation and notes were not taken while interviewing, as my priority was to maintain eye contact and have a vibrant conversation with my participants. While Patton (2002) acknowledges that note taking during interviews could be beneficial, he warns that quality might be compromised if attention is removed from the participants. Therefore, I wrote up my impressions of the interview in my reflective blog after the interviews.

Interviews with students

Students were purposely sampled in consultation with the classroom teacher for variation in terms of gender, science ability and perceived interest in science. The value of sampling purposefully, according to Patton (2014), is that the cases chosen can "illuminate the inquiry question being investigated" (p. 265). Eight students were interviewed in order to cover this breadth of variables, which was almost a third of the class. TJayne and I initially chose six students and then added another set on the day. One of the students interviewed was dominantly negative and appeared to influence her friend. I wanted to see if that viewpoint was representative or part of the normal range.

Students were asked if they were willing to participate in interviews while explaining that they were under no obligation to do so. Five girls were interviewed, two European/Pakeha, one Pasifika, one Māori and one Asian. The boys were all Pakeha. One Māori boy was asked to participate but he refused, citing shyness. One boy asked to be interviewed so he was included in the data set.

Consulting the students about how they wanted to be interviewed was important for me as it reduced the power imbalance and stress for the students, which Creswell (2014b) considers vital. The students indicated they wanted to be interviewed in pairs. Cohen et al. (2011) considers interviewing in groups is useful as it encourages "interaction" between the participants (p. 433).

All the interviews were transcribed verbatim. The students received a summarised transcript, which included important quotes for them to review and approve. An example is included in Appendix I.

As well as being interviewed in pairs, six of the eight students took part in a focus group (Patton, 2002)[8]. Focus groups according to Hesse-Biber and Leavy (2011) are useful as data is generated dynamically between the participants. This time I wanted to gain a 'collective' view of the learning that had occurred (Cohen et al., 2011) from the students' perspectives, so I read out some of the comments from the interviews and asked for further elaboration. I also gave them their summarised transcripts at this stage for them to read and comment on.

The feedback session included food and orange juice. This was because I felt it was important to thank the interviewed students for their contribution to the study

[8] The other two students interviewed were absent on the day of the focus group.

and give something back to them, so our relationship involved reciprocity (Patton, 2002), thus lessening the feeling of exploitation (Creswell, 2014b). A shared lunch was also held for all of the students involved in the research, so they did not feel left out.

Interviewing the teacher

Broadhead (2010) suggests it is important to engage in reflective, open dialogue with the practitioners involved in the research, in a way that acknowledges their expertise and professional knowledge. Hedges (2010) argues such dialogue should be mutually beneficial because a practitioner's insights can deepen the scope and validity of the research. On the other hand for teachers, participating in research interviews provides opportunities to engage in critical dialogue about their teaching practice and professional development (p. 309). In this study the classroom teacher and I built a "partnership based on mutual understanding and respect" (Groundwater-Smith & Mockler, 2010, p. 166). We critically reflected on our praxis after each lesson (Costa & Kallick, 1993), and planned for the next lesson. These reflections were audiotaped.

Formal semi-structured interviews with the teacher were held three times: prior to commencing the teaching unit, mid-unit and after the unit finished. In the first interview, questions were asked about her experiences with science, drama, Mantle-of-the-Expert, the school and class environment, the students, and pedagogy. In the second interview, we talked about the classroom episodes, and discussed the student learning and teaching approaches. In preparation for the third interview, I listened to all of the post-class discussion/reflection tapes and wrote down pertinent comments. These comments were used to probe her perceptions of the unit and student learning, so her voice rather than mine could interpret what had occurred, which Alton-Lee (2001) considers vital. The class book was used as a chronological prompt. We also discussed my research questions.

4.5 Data Analysis

This section describes how the data was analysed. Data analysis, according to Creswell (2009) is an interactive iterative process, which starts during the data collection. To maximise the inferences raised in the different arms of my mixed methods design, different types of analysis were used. Data was analysed both thematically and statistically. Firstly, thematic analysis will be outlined in terms of data preparation, familiarisation and coding procedures. Then, the types of statistical analyses used are detailed, followed by a description of data integration. Finally, the data interpretation strategies used will be outlined.

4.5.1 Thematic analysis

In thematic analysis, one makes sense out of data (Boeiji, 2010). According to Boyatzis (1998), it is a systematic way of identifying, analysing, making sense of and reporting on patterns or themes contained within data. A theme “captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set” (V. Braun & Clarke, 2006, p. 82). Themes can be generated inductively, linked to the data, or deductively and driven by the theoretical interests of the researcher (V. Braun & Clarke, 2006, pp. 83-84). I used a combination of inductive and deductive analysis with the data examined for emergent themes and those I expected to see based on prior literature analysis (Teddlie & Tashakkori, 2009).

In this section I describe how I prepared my data for thematic analysis; my familiarisation strategies; how the data was coded and how the themes were developed. However, as noted by V. Braun and Clarke (2006), data analysis is rarely ‘linear’ and my analysis was iterative and I moved between the sections freely.

Analysis preparation

As suggested by Creswell (2009) ordering and preparing the data occurred “concurrently” with data collection (p. 185). A log (see Appendix J) was compiled detailing what occurred in each episode and the data collected, with any missing data noted. As O'Toole and Beckett (2010) advise, all data collected was transformed so it was ready to be analysed, filed and ordered. Audiotapes were transcribed; identifiers removed and pseudonyms assigned. The anonymous reflections were collated under question headings. Test results were inputted to Excel spreadsheets. Photographs, teacher reflections, planning, my reflective blog, the class book and student work were filed electronically and in hard copy. Sensitive data was stored under lock and key. A matrix was constructed to manage the large amounts of data generated in the study as suggested by Check and Schutt (2012). The matrix (see Appendix K) detailed the data set(s) used to answer each research question.

The transcription process

I immersed myself in the data and comprehensively transcribed the classroom and interview data, which Patton (2002) recommends as a means to generate initial insight into the data. Pseudonyms were used in the transcriptions, or if I had approval, the children's names were used. When I could identify the child who was speaking in a class discussion, the child's pseudonym was used. Otherwise student, boy or girl was used as an identifier, with A or B added to differentiate between different voices. In the main, the utterances of the children were transcribed. However, if there was a really long pause or emphasis, it was noted in the transcription. In a separate column any thoughts I had whilst transcribing were noted as possible codes (see Table 4.3, p. 119).

Familiarisation

In the familiarisation stage the data is reviewed to discover what is present and to "reflect on its overall meaning" as part of a cohesive whole (Creswell, 2009, p. 185). To augment my familiarity with the data, the learning episodes were examined to gain a broad impression of what was taught and how the teaching was configured. Three main aspects were explored: entry into the episodes, student and teacher positioning during the episode, and the science concepts and practices that were the focus of the episode. For each aspect subsections were developed to further clarify the episode. These are outlined in Figure 4.3.

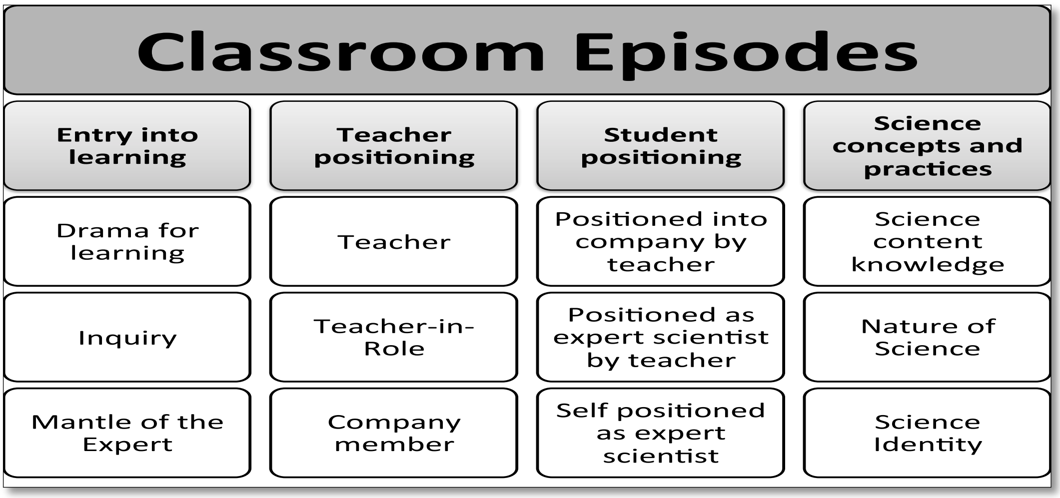

Figure 4.3 Analysis of the entry into learning, teacher and student positionings and science concepts and practices

Entry into the learning occurred through either: drama for learning, inquiry or Mantle-of-the-Expert (see section 3.2.1, p. 61 for a explanation of these terms). This helped me to see if the class was working in the "as if" world of drama or the "as if" world of the classroom.

Under the positioning category, the episodes were examined to ascertain how the teachers and students were positioned or positioned themselves in each interaction. For the teachers, the question was whether they were working as a 'normal' classroom teacher, or involved in the drama using Teacher-in-Role (TIR)[9] or in role as a company member. For the students, the question was whether the teachers positioned them as students, as members of the company or as expert scientists, and whether the students appeared to position themselves as members of the company/ expert scientist.

The science was divided into three aspects: science content knowledge, the nature of science and science identity. In the science content knowledge category, I categorised any talk or sharing of ideas that referred to science concepts. For the Nature of Science (NOS) section, I drew on the the New Zealand curriculum (Ministry of Education, 2007b) NOS categories, and looked to see if students were demonstrating their 'understanding in science', 'investigating in science', 'communicating in science' and 'participating and contributing'. In the science

[9] As already discussed in section 3.2.1, Teacher-in-Role (TIR) is where teachers take on a dramatic role within the drama

identity section, I considered whether the students were demonstrating a science identity by speaking or acting as a scientist, rather than as a school student doing experiments.

A template was formulated on Excel with all of the above categories on the x-axis. The y-axis was divided into one-minute increments. All the transcripts were read and the main teaching components of each episode noted. For instance on Aug. 23, there were four components to my lesson (y axis). They were: a letter from the client, looking for the science in articles about the Wahine; sharing the science (talking about the science found in the articles in a whole-class discussion); and mapping the harbour/Wahine timeline. The lesson was categorised on the x-axis and blocked in colour in one-minute increments. This process enabled me to see what had occurred in each lesson as is seen in Figure 4.4.

The composition score from each episode was roughly divided into four sections and collated on one worksheet. The worksheet (Figure 4.5) shows: entry into the lesson, student positioning, positions taken up and the type of science learning that transpired. Displaying the data in this way allowed me to see what happened on a given day and I was able to use these documents to target specific learning instances over the course of the unit.

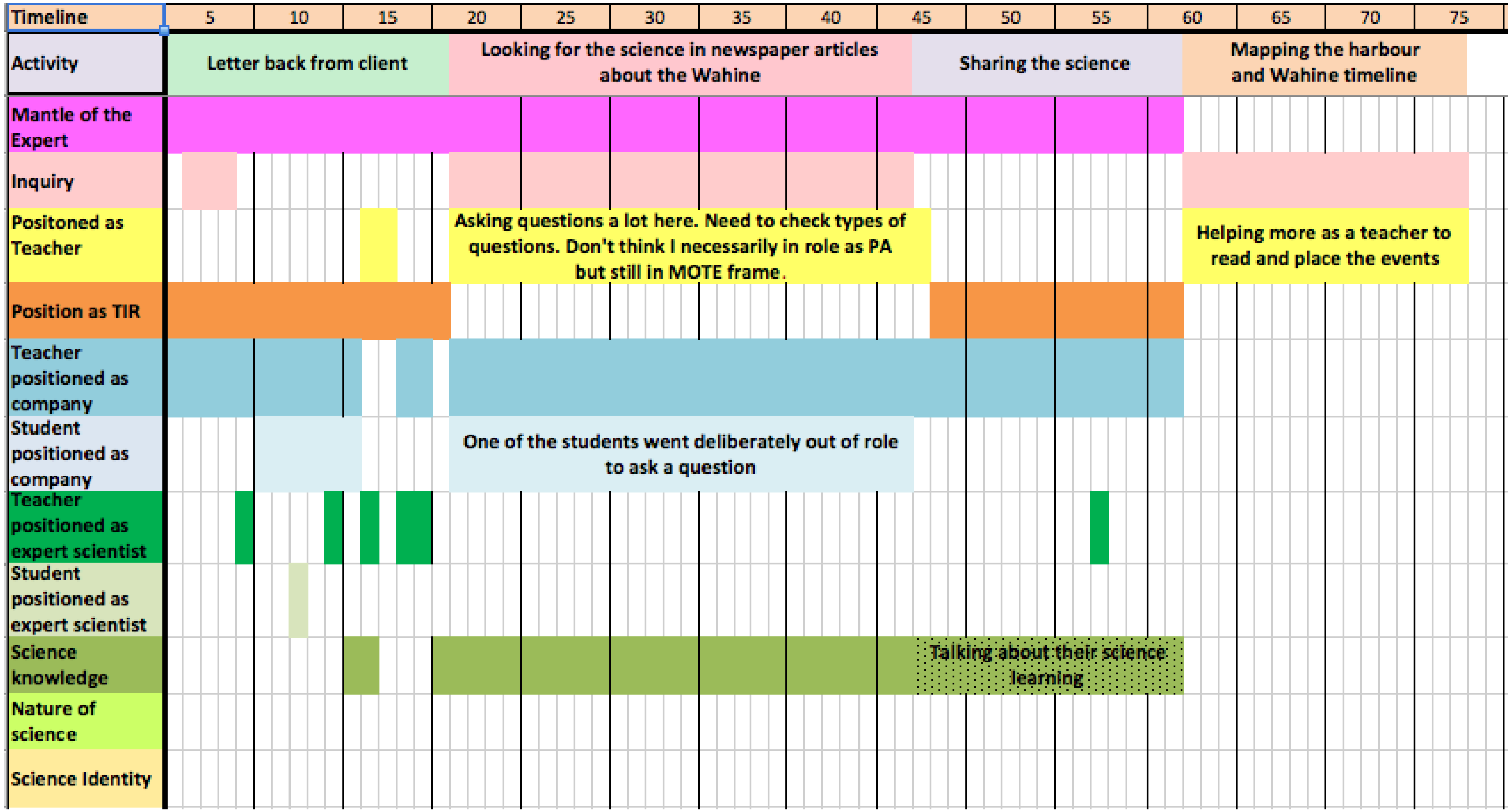

Figure 4.4 Transcription Score Aug. 23

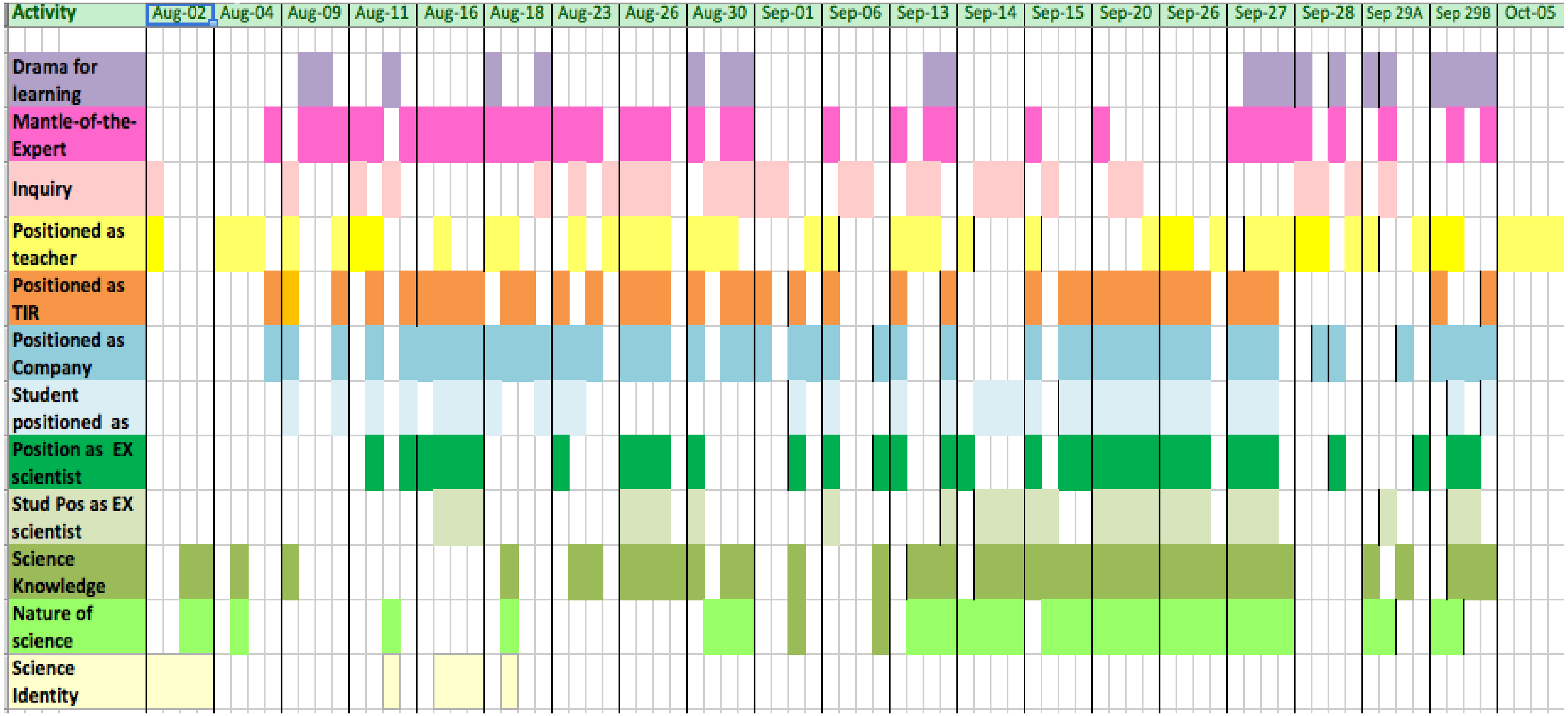

Figure 4.5 **Transcription score entire unit**

Coding the dialogue

This section outlines how I coded the dialogue from the classroom episodes and student and teacher interviews.

Lewins and Silver (2007) term coding as the means by which data is divided and "identified as relating to, or being an example of, a more general idea, instance, theme or category" (p. 81). In practice, that meant reading through data systematically, breaking it into meaningful segments and assigning each segment a indicative code, which is known as open coding (Strauss & Corbin, 1990).

Creswell (2009) advocates coding for expected items based on literature, unanticipated and unusual segments and segments that address a larger theoretical picture (pp. 187-189) and his recommendations were followed. In the first instance, my coding was deductive - moving from theory. Early in the research process I generated a list of key words from the literature and my personal experience in working with Mantle-of-the-Expert. Key words that had emerged during the study as important were also included.

The student interviews were used as a foundation for codes. They were scoured inductively, with the main point/s of each section recorded, trying to see what the data said, rather than looking for what theorists said may be present. Where possible the students' words were used to describe each segment. An example of coding can be seen in Table 4.3 taken from Josh and Tom's interview (J&T, 5/10/11). My supervisors reviewed the coding. Codes were collapsed into one category when similar.

Table 4.3 Example of transcription coding

Speaker	*Time*	*Transcription*	*Comments/Thoughts*
TW		I think so because when I was in a different class and we said we were going to India and I was little so I thought Oh cool we're going to India and I went and told my parents and later on I found out it was just fake and I though awww.	Importance of being honest we work in imagined domains – need to keep kids in loop **Ethical way of learning**

Theme development in this study

Once the initial codes were chosen (both the deductive and the inductive codes identified in the student interviews), I focussed on the episode data (Boeiji, 2010), looking for text to support the codes. All the transcripts from the episodes were examined repeatedly, using the search function on Microsoft Word to look for supporting and negating data. As I wrote, the relative importance of the coding became apparent and the themes emerged. At this stage I was, as V. Braun and Clarke (2006) suggested imperative, starting to define the essence of each theme looking for interconnections between themes.

The derivation of the themes found in this study is shown in Table 4.4. The leftmost column contains the themes identified from the literature. These were compiled prior to data collection. Four themes emerged during the study, which were positioning, purpose, power/agency and passion. I asked the students who were interviewed questions about these themes. Additional themes were drawn from the coded student interviews. These were: exciting learning, learning through doing including through Mantle-of-the-Expert and communicating. Audience, a variant of purpose was also identified within the student commentary. One additional theme emerged later in the analysis when it became apparent that a substantial proportion of the theme positioning related to ethics. Subsequently, the interview transcripts were re-examined for any ethical matters such as that outlined in the example in Table 4.3.

Eventually, the above themes were collated/collapsed into five themes. Three themes are detailed in chapter five: positioned as ‘experts’ to learn science (section 5.2), positioned as ethical scientists (section 5.3), and engaged into learning (section 5.4). The communicating theme is examined as part of the NOS aspect of science in section 7.2.3 and the science futures theme is discussed in section 7.3. Chapter six is not thematic in derivation and looks at shifts in students’ understanding of the science concepts taught in the unit and attitudes towards science.

Table 4.4 Derivation of study themes

Table showing the genesis of themes explored in this research project

Compiled from literature prior to starting unit	Emerged during the unit	Coding taken from interviews	Sub-themes	Location of themes in thesis and main thematic ideas
Positioning	Positioning	Positioning Leading own learning	Positioned into expertise Repositioning the curriculum Students' views about positioning	Positioned as 'experts' to learn science Chapter 5
Context Relevance	Purpose	Purposeful learning	Building an ethical identity through sign An ethical and social purpose for Investigating science	Students positioned as ethical scientists **Chapter 5**
		Ethical (one only) Audience	Heightening ethical behaviour through interaction with 'fictional others' Enacting an ethical identity	
Sense of belonging		Community Equalising Collegial	Working as colleagues	Students engaged into learning **Chapter 5**
	Power/agency	Power sharing		
		Hands-on, experiencing, embodiment; including drama activities, science experiments, interactive, exploring	Doing physical activities	
Fun/aesthetic learning	Passion	Fun, interactive, drama, science experiments variety (passion). (Affectual, emotional engagement).	Having fun learning	
Engagement				
			Useful way to learn science	
Dialogue		Explaining, communicating science**,** socially discussing**,** broadening ideas about science	Communicating	Communicating Chapter 7
		Up-skilling, Learning, careers.	Working	Science futures **Chapter 7**
Student identity in science and science careers		Science careers, personal experiences	Identifying oneself with a science future	

4.5.2 Statistical analysis

This section explains how the quantitative data from the pre and post-assessments were analysed. As already mentioned (see section 4.2, p. 100 and section 4.4.1), the assessments included a mix of multi-choice and short answer questions. To aid in analysis, all answers were quantized into numerical form. For multi-choice questions, incorrect answers = 0, while correct answers = 1. The short answer questions were differentiated on the basis of how correct they were, or how many aspects of the concept were mentioned. For example, if the student was able to describe one component of a tropical cyclone they received 1 mark. If they described four or more aspects, they received 4 marks. Transforming the data in this way aided analysis and integration as the data could be more easily compared (Caracelli & Greene, 1993; Hesse-Biber, 2010a).

The answers were then inputted onto an Excel worksheet. The results from each question were graphed and examined for trends, and changes between the pre-and post-test. Linked questions about the same scientific concepts were examined as a whole, to more fully develop an understanding of students' conceptual understanding.

Simple statistics, such as mean were generally used to show changes. However, more detailed analysis was carried out in a few instances using the statistical programme SPSS. A two-tailed t-test was carried out to test the achievement scores before and after the unit to see whether students' understanding of the science taught had statistically improved. In addition, Cohen's *d* was used to calculate the effect size, which is a "standardized measure of the magnitude of the observed effect" (Field, 2013, p. 79). In education, Timperley, Wilson, Barrar, and Fung (2007) consider an effect size "between 0.20 and 0.40, a small but educationally significant impact; between 0.40 and 0.60, a medium, educationally significant impact; and greater than 0.60, a large, educationally significant impact" (p. 35).

A four-point Likert rating scale was used for attitudinal data in this study, similar to the NEMP assessment (Crooks et al., 2008). Likert scales are a common way of obtaining data about attitudes (Mellor & Moore, 2013) and are flexible, easily understood and useful for merging "measurement with opinion, quantity and quality" (Cohen, Manion, & Morrison, 2007, p. 253). However, the results are not as easy to interpret, may lack sensitivity and the intervals may not be constant (Cohen et al., 2007).

Data integration

Data integration is a vital component of mixed methods research, but according to Bryman (2008) and Patton (2014) it is challenging to do well. The difficulty is that different methods may produce different type of results and use different quality standards, require different expertise and may produce conflicting or convergent results (Patton, 2014). Therefore, expertise is required to integrate them. Hesse-Biber (2010a) cautions that it is important not to "subsume the results of one method under the findings of the more dominant method nor neglect the results altogether" (p. 76). She advises being reflexive and ensuring that you are able to analyse data from both quantitative and qualitative methods.

Creswell, Plano Clark and Garrett (2008) suggest there are three main strategies for data integration. They are "(1) designing, and implementing comparable topics and questions for both arms; (2) transforming the data so it can be more easily compared; and (3) using matrices to organize both sets of data into one table" (p. 73). The first two strategies were used in my analysis.

The advantage of using the same or similar research questions is that it can make comparison of the findings obtained by the different methods easier to analyse (Creswell et al., 2008; Erzberger & Kelle, 2003). In my study, I detailed the data collection method that was used to answer each question in an analytical matrix (see Appendix K). Using the same questions meant that I could see whether the results obtained in one method, were the same in another.

The second data integration strategy was to transform data by qualitizing quantitative data (converting variables into codes) and quantizing qualitative data (converting codes into variables) to simplify comparison (Caracelli & Greene, 1993; Hesse-Biber, 2010a). This integration strategy was used to compare short and long answer questions in the assessments.

As seen in Figure 4.1 p. 99, the quantitative (assessment) data and the qualitative (the observation data – audiotaped dialogue from classroom episodes, interview data, the written report and other classroom artefacts) components of my research were collected and analysed separately. Then, the results from the different methods were merged. For example, when looking at students' conceptual understanding of buoyancy, the findings from analysing classroom dialogue are detailed first. Finally, the findings from the assessments, interviews, and classroom artefacts such as the written reports and Role-on-the-Wall are given and integrated to present a nuanced picture of learning.

Writing the Report: Findings

While findings are what the researcher has found out from the participants in a given context (Taber, 2013, p. 194), presenting raw data would be an error, demonstrating low quality research. Sandelowski and Barroso (2003) describe findings as "data-driven and integrated discoveries, judgments, and/or pronouncements researchers offer about the phenomena, events, or cases under investigation" (pp. 909, 910). Boeiji (2010) considers findings are the products of analysis, consisting of raw and re-assembled refined data, containing "descriptions, theoretical models or explanations" (p. 196). However, it is crucial that findings include both analysis and interpretation, and as such, constitute the results. In my findings, the themes found are described and linked to the evidence from multiple data sources and interpreted but not discussed.

Common errors mentioned by Boeiji (2010) in this stage include: presenting raw data without interpretation or analysis, under analysing, not providing a thick description, forcing a framework or concept to fit the data and over-generalising the data (pp. 150, 151). Therefore, only findings that were well supported with data from multiple sources were included. The quotes were not just provided but interpreted as well, as to offer possible explanations for the finding. Boeiji (2010) also cautions that findings can be 'befouled' by interpretation, with the voice of the participant being subsumed in the voice of the researcher. To mitigate my voice dominating the voices of the participants, direct quotes were used and negative data was sought. My interpretive voice was generally taken from my reflective blog.

4.5.3 Summary of data analysis

This section has detailed the ordering, and analysis of my data. I have described my configuration, noting that I am using both thematic and statistical analyses to answer my research questions. I have explained how I have prepared my data for analysis. I have shown how I familiarised myself with my data and my rationales for coding and theme development. In addition, I have delineated how I statistically analysed my quantitative data and talked about data integration. I also discussed how my findings were analysed, interpreted and written up.

4.6 Ethical issues and validity

This section details the ethical issues deemed important in this study. It also outlines how the validity of my research data and findings were ensured.

4.6.1 Ethical considerations

Consideration of ethical issues is a crucial component of research (Guillemin & Gillam, 2004; Wiles, Clark, & Prosser, 2011). The determination of what is ethical in a given situation is situational and complex (Piper & Simons, 2011). This is why, according to Hesse-Biber (2010a), the researcher must not only address ethical issues prior to beginning the research, but also think and act ethically at all stages of the research process (Guillemin & Gillam, 2004).

The New Zealand university where I carried out my research has strict ethical regulations (University of Waikato, 2008), and require doctoral candidates to apply for and receive 'procedural' ethical clearance (Guillemin & Gillam, 2004) before data collection can begin (see Appendix L). In their application, doctoral candidates have to detail all anticipated ethical issues in their study and what they would do to avoid or mitigate possible harm. In addition, as a registered teacher and co-teacher within the study I was bound by a duty of care from these perspectives as well. There was, however, some tension between the roles of the researcher and the teacher, with the researcher required to balance the needs of the research with the needs of the students and the school (Locke, Alcorn, & O'Neill, 2013).

Ethical considerations are examined under three headings: potential harm, informed consent, and anonymity/confidentiality. However, these aspects do overlap (Bryman, 2012).

Potential harm

Research can potentially harm both the ‘researched’ and the ‘researcher’ (Sikes, 2006). In this study, the most critical area of concern was the research participants (B. Johnson & Christensen, 2012), who were minors at the time of the study (11-13 year olds), and their teacher.

Potential harm to students can be multi-faceted. Taber (2013) considers that harm in an educational setting can include: physical harm, not being valued as a person and pedagogical harm (pp. 228, 229). In terms of physical harm, there were no perceived issues in the research. I wanted to protect the students’ notion of self-confidence, self-efficacy and self-worth. Even though Mantle-of-the-Expert is an approach that values humanity, working in drama can sometimes open up students and they might disclose ‘abuse’. Therefore, protocols were set in place for what to do if something adverse occurred or was disclosed in the classroom (Basit, 2010), which were to talk to the classroom teacher first and/or consult my supervisor.

Pedagogical harm is any “intervention that undermine[s] effective teaching” (Taber, 2013, pp. 228, 229). Pecorino and Kincaid (2008) suggest that pedagogical harm has academic, intellectual, social, psychological and economic aspects (pp. 6,7). One way that pedagogical harm may occur is when generating data is given precedence over teaching and learning. O'Toole & Beckett (2010) suggest it is critical that data generation is not given precedence over teaching. To mitigate this issue, I ensured I was thoroughly planned, and audiotaped the sessions so that my focus was the students and their learning. In addition, the classroom teacher taught alongside me, so there were two teachers making sure student learning was not compromised.

Potential harm to the classroom teacher in the context of co-teaching, as was the case in this study, may include: increased workload (exploitation); concerns over personal portrayal of themselves in the research, lack of confidentiality, and potential abuses of power (Taber, 2013). Other risks particular to co-teaching include: being vulnerable by teaching in front of others and using unfamiliar pedagogical practices (Gallo-Fox, 2010). TJayne and I both were interested in Mantle-of-the-Expert, so had some resonance in terms of pedagogical practice. We had also trained at the same tertiary institute so had some shared epistemological beliefs, which Carambo and Stickney (2009) say is advantageous. TJayne was not very familiar with science teaching but was enthusiastic to learn, while I was interested in learning from her practice, so there was a notion of reciprocity occurring. According to Roth, Tobin, and Zimmermann (2002), one of the main goals of co-teaching is to ensure that the students receive optimal teaching, so we reflected after each lesson to optimise our teaching practice, which Wassell and Lavan (2009) suggest is critical to not only to support student learning but also our teaching and research relationship.

Informed consent

It is a research requirement that every person involved be fully informed about the project and assent to being a participant without undue influence from other people (Halse & Honey, 2010; B. Johnson & Christensen, 2012). Access to my student participants was obtained through approaching a school where my supervisor had a good relationship with the staff, which according to Te One (2010) is a common way of gaining access. I informally spoke to the Principal - the primary gatekeeper (B. Johnson & Christensen, 2012) about the project, and gained access to the school, teachers and students. Please see Appendix M for the information sheet I gave the school about the project.

In the formal consent procedure, as Lewis (2002) advises, I communicated with the Principal, the Board of Trustees, the classroom teacher, the students and their parents. I also visited the classroom and introduced myself to the students. I explained the project, what would be expected of them and outlined the risks and advantages of participating. I mentioned how I would protect them and the information that would be disseminated. I also explained that anyone interviewed would be able to check the accuracy of what was said and they could opt out of the research at any time (B. Johnson & Christensen, 2012). I spoke about formal consent procedures and that I would send two letters home for them and their parents to read and consent forms to sign if they were willing to take part in the study. The students' letter was age appropriate and the parental one slightly more technical, containing a description of the teaching approach. Two consent forms were needed as minors are able to assent but not 'consent' to participate (B. Johnson & Christensen, 2012). The letter to the parents is in Appendix N and the students in Appendix O.

I was given informed consent to proceed with the research by 29 of the 29 students and their parents, but two had conditions attached. The research being part of the 'normal classroom' routine; students were told they could opt out of the research but not the science learning (Nolen & Vander Putten, 2007). I offered the parents alternatives for their child, if they wished their child to not take part in the study, such as doing alternate work, or going to another classroom. Nobody took up that option but two parents requested that I not take photographs of their children. For one child, I was allowed to use his report but no other data.

This research took place in a school in which I was not employed. Therefore, there was not any professional conflict of interest. I had no personal relationship with any students, teachers or community members. Some of the formative comments and summative findings of my research were used to inform the teacher of student learning. This is not however, considered a significant conflict of interest.

Confidentiality/anonymity

Confidentiality is a major consideration in educational research (Cohen et al., 2011; Taber, 2013). The researcher and research participants need to agree about what will be done with the disclosed information from the research participants (B. Johnson & Christensen, 2012, p. 116; Taber, 2013). In this study I stored the data securely, and used a two-letter code instead of student names in the transcripts. Participants were told the information gathered would be used to write my thesis, academic papers and in oral presentations.

Anonymity is not the same as confidentiality. Ensuring that research participants remain anonymous in written text can be problematic, especially within small communities where identities may be able to be deduced (Nolen & Vander Putten, 2007; Taber, 2013). The normal way of preserving anonymity is to use pseudonyms and/or to monitor the level of contextual information included in a study (Taber, 2013). However, in some collaborative research, the teachers (or participants) may want recognition (Locke et al., 2013; McTaggart, 2014). Students were asked whether they wanted to receive a pseudonym or be identified by their first name. If they chose to be identified by their first name, parental consent was gained for this. Pseudonyms were used for all teachers and the school.

Taking photographs is another area where anonymity can be breached and it is vital that the researcher is careful and ethical in the use of visual images (Cohen et al., 2011; Wiles et al., 2011). I obtained full parental consent to take photographs of the participants in the classroom. In addition, I obtained specific consent from the parents and children for any visual images I wished to use in any papers (see Appendix P). However, wherever possible, I have used photographs where facial features are obscured.

4.6.2 Trustworthiness

What counts for validity, rigor or trustworthiness depends upon the worldview one is operating within. When one operates within a scientific inquiry or a positivist worldview, for research to be accepted as rigorous, it needs to demonstrate validity, generalisability and reliability (Gibbs, 2007). However, I am operating within an interpretative worldview, where meaning is produced and reproduced through social interaction (Blaike, 2009). My research seeks to understand the worlds of my participants; so different parameters for judging quality are needed.

To address what counts for 'rigor' in research conducted within the interpretive worldview Lincoln and Guba (1985) proposed the criterion of trustworthiness. The aspects of trustworthiness are: credibility, transferability, dependability and confirmability. These correspond to the scientific inquiry categories of validity, generalizability, reliability and objectivity (Schwandt, Lincoln, & Guba, 2007). To add to the complexity, Schwandt et al. (2007) explained that Guba and Lincoln added the criterion of authenticity, suggesting that "fairness, ontological authenticity, educative authenticity, and catalytic authenticity" also need to be addressed (p. 20).

Since, Lincoln and Guba's (1985) early work on trustworthiness, the field of qualitative research has expanded. Patton (2014) recognised seven different frameworks for judging qualitative studies; therefore it is important I clearly define the trustworthiness parameters I am using.

I am working in Mantle-of-the-Expert, which is a drama-based approach. Consequently I have chosen to use the drama-based parameters of O'Toole and Beckett (2010) as my main trustworthiness criteria. They suggest research is valid when it exhibits "*plausibility, credibility, resonance* and *transferability*" (p. 34). In addition, because this study bridges both drama and science, I will draw upon some of Creswell (2014a) "validity strategies" to convince the reader of the "accuracy of the findings" (p. 201). The main strategies he suggested were: triangulation, member checking, using a thick rich description, noting personal bias, presenting negative or discrepant information, prolonged time in the field, peer debriefing and an external auditor (Creswell, 2009, pp. 191, 192). I will also indicate how O'Toole and Beckett's (2010) criteria aligns with Lincoln and Guba's (1985) trustworthiness criteria.

O'Toole and Beckett (2010) suggest that for research to be plausible, the argument it presents should be strong, supported through multiple data sources with detailed analysis to ensure that the conclusions drawn by the researcher are "believable" and not easily "refutable" (p. 34, 156). This would be comparable to portions of Lincoln and Guba's (1985) credibity criteria, namely that of "triangulation", "negative case analysis" and "member checks" (p. 301) and Creswell's (2009) strategy of triangulation. Therefore, data was examined critically to see if the inferences raised in one method were also present in another method. For example, if growth in science knowledge was shown in the assessments, the written reports and audio transcriptions were examined to see they confirmed this increase in science understanding. Rival explanations were searched for. All inferences raised were checked to see if they were conceptually sound, consistent with literature and supported with examples. Outlying results were discussed and possible causes indicated, thus constructing a believable and not easily refutable argument. I also was open about my data with my participants and checked with them to ensure I had correctly understood what they had said (member checking). I fed back to the class what I had found out at the end of the unit but due to the longevity of the project and where it fell in the school year, many had left by the time I finished analysing the data.

For data to be credible, according to O'Toole and Beckett (2010), it needs to be believable to persons who have no vested interest in the project. While I did not attempt to utilise 'critical friends' in the fullest sense of this term (Costa & Kallick, 1993), I did approach two or three friends to make sure the ‘claims’ were believeable. Schwandt et al. (2007) considers this can be equated to Lincoln and Guba’s “peer debriefing” (p. 19). In addition, I wanted to ensure that my research process was “logical, traceable and documented” (Patton, 2014, p. 685), when examined by people who do not know the project. Therefore, I clearly described the activities that occurred during the teaching unit (see Appendix B for unit plan and Figure 4.4 for my analytical score). I wrote a reflective blog detailing what went on in the classroom during the study (see Appendix Q for an example). In addition, I created a documentation log, showing all the data collected on each day and what was done with it (see Appendix J), so that a clear audit trail could be seen and external auditors could ascertain rigor if required (Creswell & Miller, 2000; Lincoln & Guba, 1985). I also made a permission log so I could document that I had received permission to use figures from other people’s work (see appendix R).

Plausibility and credibility were strengthened in this study by ensuring adequate time was allocated to working within the Mantle-of-the-Expert dramatic frame. Creswell and Miller (2000) claim that prolonged time in the field solidifies evidence, allowing time to ascertain whether the researcher’s hypotheses match the observational data. This comes under Lincoln and Guba’s (1985) credibility criteria. If too short a study was conducted, there might have been insufficient time allowed for ‘productive obsession’ (Heathcote & Bolton, 1995) or ‘flow’ (Roth, 2006) to develop within the commission. As this study took place over a whole term, I consider the time frame between the pre and post-tests was sufficient for the students to understand the concepts being taught.

The third criterion is resonance. For data and research to have resonance, it must demonstrate coherence both within the project and with data from outside the research by “finding echoes of commonality and convergence” (O'Toole &

Beckett, 2010, p. 34). To make ensure my data resonated and was coherent inside my research, I looked for common themes in my data sets. Rival explanations and negative cases were also looked for in order to build a more complete picture of the data. Creswell (2009) suggested "by presenting this contradictory evidence, the account becomes more realistic and hence valid" (p. 192). I have also ensured that I have linked my data to literature, looking first for the themes and findings, which I expected to be there, and then for possible reasons for unexpected data I obtained as Creswell (2009) suggested.

The last trustworthiness criteria category identified by O'Toole and Beckett (2010) is transferability (see also Lincoln & Guba, 1985) or making sure that the findings are applicable in "other contexts" (p. 34). One way of enhancing the transferability of a project, is to write a 'thick rich description' (Creswell, 2009) about the setting, participants and themes, which I did from the information contained in my reflective blog, transcripts, written artefacts and pictures. The value of this according to Schwandt et al. (2007) is that it allows the readers to contextualise the study and consider whether or not the pedagogical approach could be transferred into his or her own setting. As I researched both in drama and science, the findings and inferences raised about Mantle-of-the-Expert could be transferred to the wider drama or science field. I would also expect that inferences raised about learning science through an inquiry approach could be transferred to the wider pedagogical inquiry community.

While I predominantly used qualitative methods to collect data, I did collect quantitative assessment data, which was analysed statistically (see section 4.5.2). This meant that for that data set, different validity criteria were used. Cohen et al. (2011) assert that for a test to be valid it should measure what it was designed to test. Thus, the assessment was modelled on a published NEMP (Crooks et al., 2008) test. Cohen et al. (2007) also suggest that the reliability of the test in enhanced by conducting it in a familiar setting. This test was set in the classroom. In addition, I marked both tests on the same day to reduce marker variation.

In addition to ensuring my research exhibited plausibility, credibility, resonance and transferability and in terms of the assessment data was valid and reliable; I endeavoured to be reflexive. Guillemin and Gillam (2004) assert that reflexivity involves being reflective about knowledge generation as well as knowledge production in research (p.274). The main benefit of being reflexive underscored in the literature is that it potentially enhances validity (Breuer, Mruck, & Roth, 2002; Guillemin & Gillam, 2004). Guillemin and Gillam (2004) further assert that being reflexive has an ethical component; that of being aware of and sensitive to possible ethical tensions that may arise throughout the duration of the research (p. 278).

Breuer et al. (2002) considers reflexivity addresses the subjectivity concerns of the quantitative researchers who assert results should be objective, written neutrally and not contaminated by the views and assumptions of the person conducting the research. S. Hall (1996) suggested knowledge construction is reflexive when the data is derived in an authentic democratic manner; which acknowledges that the lived experiences and theoretical constructs of the researcher are not more privileged than the views of the participants involved in the research and that all participants add resonance to the constructed knowledge. Creswell (2009) terms this acknowledging one’s bias.

Declaring ones positional stance has become a component of methodological rigor, in which the researcher situates oneself in time, place, culture and experience and acknowledges ones power, knowledge and difference (Cohen et al., 2007). However it is more than self-disclosure, “it is about making the research process and decision making visible at multiple levels” (Luttrell, 2010, p. 4). The personal background and inherent biases of a researcher may impact upon research so positional reflexivity is optimal. My personal background was disclosed in the Introduction – section 1.1.

Summary

This section has outlined the mechanisms used to ensure the rigor of my research. It has addressed how the criteria used to assess the reliability and validity of research depends upon which worldviews one works within. I have described the criteria used in my research to ensure its trustworthiness. I have linked O’Toole and Beckett’s (2010) drama-based parameters of plausibility, credibility, resonance and transferability to Creswell and Miller’s (2000) more traditional validity parameters and given examples from my study. I have also mentioned the importance of being reflexive.

4.7 Chapter Summary

In this chapter the philosophical framework underpinning my work has been described; namely interpretivism. My reasons for placing my study in action research and co-teaching were given. I detailed why I was using mixed methods to generate and analyse my data. The research design used was outlined.

The main data collection methods were: assessments, interviews and observations. These were supported through reflective blogging, taking photographs, the anonymous reflection and the use of dramatic participant conventions like Role-on-the-wall to generate data. The thematic and statistical data analysis methods used were described, along with a description of how they were integrated. The ethical issues in the study were detailed, along with strategies for mitigating them. Measures used in this unit to ensure my research was trustworthy were outlined and justified.

The following three chapters will detail the findings obtained in this study. Chapter five looks at findings relating to how Mantle-of-the-Expert supports or constrains the learning of science. Chapter six details shifts in students' understanding of the science concepts taught and examines whether their attitudes towards science changed. Chapter seven outlines development in the nature of science and whether or not students perceive science in their futures.

Chapter Five: Findings - Working in Mantle-of-the-Expert to learn science

5.1 Introduction

This chapter is the first of three findings chapters. It explores findings relating to the following research question:

1. How do Year 7/8 students and their teacher consider that Mantle-of-the-Expert supports or constrains learning of scientific concepts, science processes, and science vocabulary?

The derivation of the themes related to this question was described in section 4.5.1 in Table 4.4. The process took account of core principles of Mantle-of-the-Expert and also what featured in student and teacher commentary. The themes were: positioned as experts to learn science, positioned as ethical scientists, and engaged into learning through Mantle-of-the-Expert.

5.2 Positioned as 'experts' to learn science

The major theme that emerged from the data was to do with how students were positioned as 'experts' to learn science. As positioning is central to how Mantle-of-the-Expert operates (section 3.2.1) is not surprising. Furthermore, developing and enacting this positioning was integral to the unit design. TJayne and the teacher/researcher Carrie - henceforth known as TRCarrie intentionally used language in support of this positioning during classroom interactions. For the research the students and TJayne were directly asked about their understanding and experience of the various positionings available in the unit.

The theme 'positioned as experts to learn science' is broken into three subthemes. In section 5.2.1, data is presented that shows students positioned into an expert role through explicit speech acts from the teacher and sign. In Section 5.2.2 data pertaining to re-positioning how the curriculum was taught to maintain students' positioned expertise is described along with the strategies used to achieve this. Finally, the students' views about being 'positioned' as experts are delineated in section 5.2.3.

5.2.1 Positioned into expertise through sign and explicit speech acts

This section outlines how the use of explicit speech acts from the teacher and sign such as the ‘company noticeboard’, constructing of a floor plan for the company, and making personal CVs positioned the students into the role of scientists in a company known as SEERS (Scientific Extreme Event Reconstructive Services). It is important to note students were not positioned as novices joining a company but as experienced or expert adult scientists with a history in scientific work and a sustained career in SEERS. This positioning process occurred in stages. Initially, the students were positioned into the company and then more fully into their expert scientist identity.

The students were positioned into their roles as experienced or expert scientist members of SEERS through sign on the third day of the unit[10]. The first sign used was a noticeboard (see Figure 5.1) from the company we would be working for in the drama. The artefacts on the noticeboard were carefully chosen to position the students as members of an ethical and responsible company of scientists (RB, E3). The artefacts included: a meeting agenda, an invitation to a party, a recycling notice, a weather map and a letter from a satisfied client.

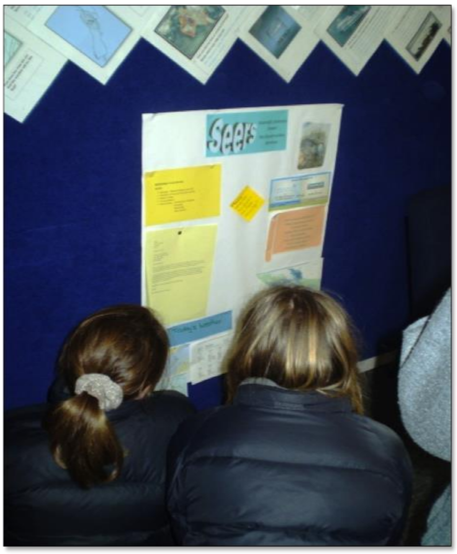

Figure 5.1 Students analysing the SEERS’ company noticeboard

As a first task the students were asked to analyse the content of the noticeboard. Student impressions of the company after analysis were that it was a company with expertise in investigating natural disasters, it was concerned for the environment and appeared to be well organised.

Example student comments were:

[10] Assessments were carried out on the first day. The second day set the scene looking at a YouTube clip of the event, creating freeze frames from pictures of the sinking and meeting someone connected to the sinking through the use of TIR.

Student: A company that studies disasters.

Josh: They are enviro-friendly…they talk about recycling.

Josh: The Company is organised (ET, 09/08/11).

In these comments students used definite articles and concrete nouns such as ‘a company’ and ‘the company’. They did not using possessives, which suggested they might hold an abstract view of the company and had not yet developed any personal commitment to the company. Put another way, students do not appear to have accepted their positioning into the role of company-based experts.

To transition the students from viewing SEERS as an abstract company of scientists, TJayne and I used explicit speech acts to invite the students into full membership in the company. By this, I mean that the teachers explicitly changed how they commented on the company in terms of pronoun usage, moving from speaking about ‘a’ company in an abstract sense, to using the collective ‘we’ and positioning themselves and the students as belonging to that company. This can be seen in the examples below, where the time the dialogue occurred over the course of the lesson that began with the analysis of the noticeboard is noted.

Tom: A company that works well together (ET, 09/08/11, 8 mins).

Josh: They are environmentally friendly (ET, 09/08/11, 9 mins).

TJayne: We work well together (ET, 09/08/11, 10 mins).

Tom: We like to get ahead of things (ET, 09/08/11, 11 mins).

Initially, Tom used ‘a’ to describe the company and Josh used ‘they’. TJayne used ‘we’ instead of the abstract ‘a company’ to start to position the students as being part of ‘our’ company SEERS. Tom started to mirror TJayne in using ‘we’ to describe his connection to the company and indicated that he was willing to work within the offered role.

Another way the company identity was built was through creating a floor plan for the company with the students deciding where everyone in the company would reside and what was needed in the company. An example is given in Figure 5.2.

Prior to the class developing the floor plan, I tentatively invited the students to think about what it meant to be part of the company and to think about the roles that the company would need. They offered a variety of roles.

Shania:	An experimenter (ET, 09/08/11, 14:00 mins).
Brooke:	A receptionist (ET, 09/08/11, 14:10 mins).
Mitchell:	A person where if the computer shuts down (ET, 09/08/11, 14:20 mins).
Alicia:	We need a lawyer (ET, 09/08/11, 18 mins).
Braydon:	Would we need a PhD person or trainer? (ET, 09/08/11, 19 mins).

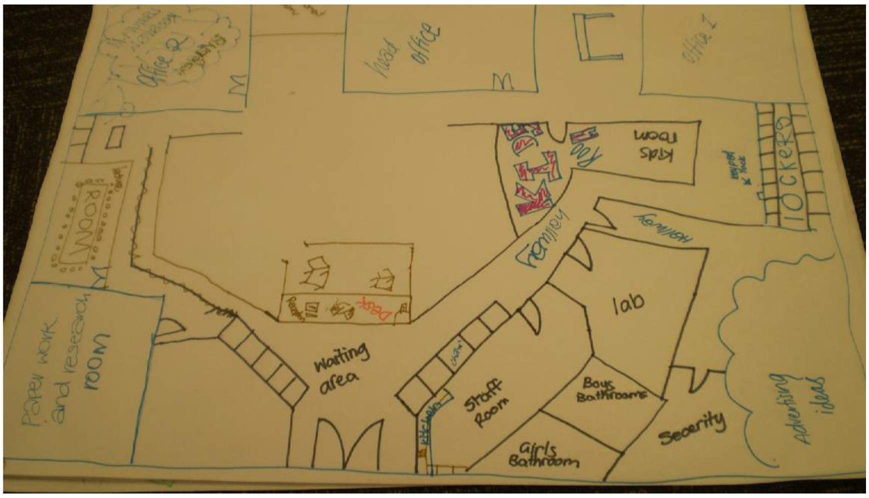

Figure 5.2 An example of SEERS floor plan

Here we see that the first three students spoke generically about the types of roles that would be needed in a science company. Later in the discussion, Alicia and Braydon positioned themselves as a company member using ‘we’, thus acquiescing to the company positioning. The floor plan was constructed to take account of these company roles. As you can see in this floor plan (Figure 5.2), there is a reception area, offices, a paperwork and research room, and a lab.

The following examples taken at different stages throughout the unit show that some students are working and articulating in role as company members through their use of ‘our’, ‘we’ and ‘us’. In the second and third quotes, which are later in the unit, students speak within their expertise and talk about investigating disasters.

Child: Our Company helps after natural disasters so we can reconstruct their cities (ET, 11/08/11).

Hamish: We need to figure out why the Wahine sunk (ET, 18/08/11).

Student: I think they might want us, to test it, how the boat sunk (ET, 01/09/11).

To continue the focus on roles within the company, in their fifth lesson, students were asked to develop a CV. These were effective in supporting students to identify and articulate an identity as someone who was an expert/experienced scientist and member of the company. Here is a selection of comments from the students' CVs showing their science specialities, which they shared to the class.

Alicia: I started working for Malcolm's father as his PA in 1969. I was working one day and some scientists came in and they inspired me to take on a scientist degree. I went to Otago University and became a laboratory technician and a marine biologist.

Taylor: I got a degree from Waikato University and was a scientist and applied for a job with Seers and went on to be a meteorologist for them.

Liam: I studied science at Auckland University before I came to Seers. I left Seers and went to Polytech to become a Lawyer and have recently rejoined Seers.

Will I've got a degree for IT for security on the computer and things like firewalls and things like that so we can lock down. I also am a physicist and I helped out at the Samoan earthquake.

Lucy I helped with the Christchurch earthquake by rebuilding the building and figuring out why they collapsed (ET, 16/08/11).

In these we can see that the students positioned themselves as being expert in science and constructed a history for themselves within the company. Within this process they linked their authority in science to the universities they studied at, the naming of their science degree and the projects they had previously been involved in their time with the company. Hence, it appeared that by midway through the drama, the students had accepted and embraced their positioning as company members. TJayne confirmed this in her midway interview where she identified that belief had been built as shown by student use of the collective pronoun ‘we’ in relation to company tasks and aims.

TJayne: You start to get statements where they feel quite proud of being in the company and they start saying, “we should do this, we should do that,” and that’s I think what shows that they believe in the company, that there is a team (I2, 13/09/11).

Over time, the students moved from being positioned as members of a company of expert scientists, to demonstrating acquiescence to that positioning, to positioning themselves into roles as expert scientists. The positioning was achieved through sign and explicit speech acts. The students indicated their acceptance of this positioning by changing their pronoun usage to identify that they belonged to the company. They outlined possible roles in SEERS and made those roles concrete by constructing a floor plan of the company. Finally, they positioned themselves into roles as expert scientists as shown in the expert scientist identities they constructed for themselves in their CVs.

5.2.2 Re-positioning how the curricular content was taught to maintain student expertise

In Mantle-of-the-Expert students work in role as experts. This section describes how the teaching of the curricular content was repositioned to ensure students were working in an expert scientist positioning.

My notes from a planning meeting with my supervisor Viva (PL, 09/09/11) describe my concerns about how to reconfigure the teaching of the science curricular content to support the positioning of the students as experts. The problem was I needed to devise a way of teaching where the ‘fiction’ of being positioned as an expert scientist was maintained and curricular content was taught, whilst still “protecting them [the students] from the awareness that they do not yet have this expertise” (Heathcote & Herbert, 1985, p. 174). I needed to find a way to maintain the integrity of both the science and Mantle-of-the-Expert.

> I had the basics of the science [experiments organised]; yet, “now we will do the experiments” was not quite in keeping with the [Mantle-of-the-Expert] teaching approach. We had a lengthy discussion about how to approach the science and the ethos of [Mantle-of-the-Expert] without seeming to be contrived or losing integrity (PL, 09/09/11).

Rather than teaching science to novices, the students' positioning as expert scientists meant that how the science curricular content was presented needed to be re-positioned to support the fiction. Two main pedagogical strategies were used in this study to maintain the students' expert scientist positioning. The first strategy was that the students were positioned into an expert collective role. In the second strategy they were positioned as expert scientists. Two examples of the second strategy are given.

In the first strategy (ET, 25/08/11), the 27 students took on a collective or blanket role (modified from Sharp, 2008) as an expert meteorologist known as Albert. I took a low status position, as someone who does not know (a drama strategy used to elicit knowledge). To support their expertise, each child was given a strip of paper with a discrete science fact on it about meteorology or weather symbols. The conversation began with asking them to explain to me meteorology.

TRCarrie: Our company, they're doing this commission for this client…It's looking into the sinking of the Wahine and I don't really know much about that and some of it involves weather…Do you mind if I ask you some questions, since you're such an expert in this? What is meteorology anyway?

Tom: Meteorology is the study of weather (read from paper).

Student A: Low-pressure areas have winds that spiral inwards (read from paper).

TRCarrie: Wow, That's certainly something. What is air pressure?

Student B: Air pressure is the weight of air pressing down on the earth measured at sea level (read from paper) (ET, 25/08/11).

This approach allowed the students to share expert knowledge from the information contained on their strips of paper. This repositioning provided them with information and the chance to use it in dialogue and unpack it in a way that was affirming of their collective role. It enabled the class to construct meaning together about meteorology. It also provided a springboard for the students to talk about related topics such as buoyancy and density (see section 6.2.2).

TJayne "loved" this approach because it ensured every student had knowledge to share and to be involved in the learning.

TJayne: That's something that worked really well. I loved the structure of it. I loved the way that it made sure that every child was on their game and they were listening out just in case their sentence was called (T13/10/11).

Lucy, unprompted and in a post unit interview, also affirmed that this strategy was engaging and inclusive.

Lucy: I prefer to have it the way we did it. It's more exciting and it includes everyone instead of just having paper (L&K, 05/10/111).

The second strategy was the positioning of the students as expert scientists who worked in research teams to fulfil the commission from the client. The client provided an archival box with items that may have come from the judicial inquiry to help the investigation (ET, 01/09/11). Items included: pictures of the Wahine, actual weather forecasts, marbles, instructions for how to make paper boats and a water-damaged sheet describing an experiment to find out why the Wahine sunk on its side using paper boats and marbles. Upon examining the items in the book, students commented they thought the client might want us (the company) to conduct a paper boat experiment and investigate how the vessel sunk.

Girl A: I think they might want us to do the paper boat experiment.

Boy A: They probably want us to see, to test how it, the boat sunk (ET, 01/09/11).

Note both of the students are talking in the plural 'us'. They were in role as company members. Figure 5.3 shows the students conducting the experiment and trying to make a paper boat sink on its side like the Wahine did to fulfil the commission.

Figure 5.3 Students carrying out paper boat experiment[11]

[11] Adapted from "Purpose, power, position: Border crossing between science and drama through mantle of the expert," by C. Swanson, 2015, *Waikato Journal of Education: Te hautaka*

In the second example of how teaching of the curricular content was changed by re-positioning the students as ‘expert’ scientists, students were told that four people were applying for Roger’s old position in the company (ET, 13/09/11). They were shown six lab experiments and told that the applicants had each been asked to carry out the experiments and write down an explanation for the results they obtained. The statements contained a variety of answers about the science concept being tested ranging from basic to complex and an incorrect statement. As valued members of the company who knew science, they assessed the prospective employees’ statements and reproduced the experiments, to see whose science was the most accurate. Once the potential employee was chosen; the students were asked to devise a job interview, where the chosen person would be asked about the science.

Five out of the six groups identified that Judy was using the language and processes of science. For example Judy said that, “The reason why these objects floated was because air trapped inside them lowered the overall density of the object and the combined density was less dense than water.” They noted that her answers were more descriptive and backed up with facts:

Josh: Judy - because she had, her information on hers was backed up with facts.

Student C: Judy because her sentences were more descriptive and have more details (13/09/11).

TJayne discussed this interview learning strategy in her third interview (TI3, 13/10/11). She asserted that it was not just the experimentation that helped the students learn the science concepts but having to debate which person had given the most complete answer. She argued that it was having to be critical in their justifications for choosing one prospective employee over another that motivated and consolidated their learning. TJayne concluded that the way the learning was positioned as part of a decision about whom to employ, made a difference to how the students interacted with the science. She thought this was because they had to examine the ideas, conduct an experiment, justify their decision and act upon the

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information in order to employ the person with the 'best' science answers for the job.

TJayne: The key way that you did that was through those interviews and that is why the experiments were so valuable because alone they wouldn't have consolidated that understanding.

TRCarrie: So the way that we positioned the learning in that particular section made a difference?

TJayne: It made them question who would they hire, who's got the best answer and debate which they feel was best and that's where the learning comes in when you're discussing it, as a team (TI3, 13/10/11).

Taken together the data suggests that repositioning how the curriculum was taught to require the students investigate a prospective employee's statements through experimentation helped guide their science thinking by supporting their learning.

Jess: The little bits of paper helped because like maybe you might have thought it (the science) was something else but it wasn't.

Brooke: Yeah, what Jess said (B&J, 05/10/11).

Positioning the teaching of curricular knowledge to support and maintain the fiction the students were expert scientists was a deliberate strategy. In my planning session Viva and I spoke about flipping how the curricular content was taught on its head to support the students to both explore the science and to consolidate their knowledge in a way that didn't position them as novices.

> We should flip the model on its head. Instead of working from the [traditional model that sees the students as novices] … we will approach from the opposite end. We will start with giving [the students] expert knowledge and status and allow them to explore and build up their knowledge to actualise that status by giving them information and allowing them to work on the linkages. This way of working … gives the students the words and the models and practice to uncover, discuss and consolidate the learning (PL, 09/09/11).

I provided the students with some information and engaged them in learning experiences to use and discuss this knowledge. The aim of this approach was to acknowledge their expertise both as science learners and in their fictional role as expert scientists in a company.

The students' fictional expertise was supported in these three examples by providing them with science knowledge to act 'as if' they had expertise. In the first example – in role as Albert, the students used the information about meteorology they had been given to participate in a class conversation about meteorology. In the second example the students used paper boats as models to discuss and unpack why the Wahine capsized on her side. In the third example, the students were given a variety of possible statements and experiments to explore prior to making a decision that relied on their expertise. These examples of how the teaching of the curricular content was taught by progressively developing and requiring students to take on the authority inherent in having an expert status – first collectively, then as part of a team and finally, as individually accredited scientists as they explored evidence to make a reasoned argument and/or decision.

5.2.3 Students views about being positioned in an expert role

There are two sub-themes in this section. The first relates to students' evaluation of their positioning into an adult identity and is drawn from classroom discourse. The second, taken from the student interviews, relates to student impressions of working in an expert role in Mantle-of-the-Expert in this study.

Positioned into the fiction as an expert

Early in the unit TJayne reminded the class that the role they were working in was an adult role and therefore demanded a high level of maturity.

TJayne: So you've got an adult role right now. And anything we do you're imagining it. It's not happening. But that's part of the fun of it that you are imagining with us. That's this whole way of learning. So I just want to make a reminder of that, that this type of learning takes a high level of maturity (ET, 11/08/11).

In the next session (ET, 18/08/11) students discussed their understanding of working in an adult identity in Mantle-of-the-Expert during a class reflection. The three students who spoke about this aspect explained they were working within their personality but in an adult manner. Two of the three equated an adult role with enhanced learning.

Belinda: You are actually, like, taking on a role as an adult to, like, learn more about what you are learning about, rather than just reading books and stuff.

Henry: You bring yourself into the learning. You are using your own personality.

Mitchell: You learn more out of your personality when you're like older (ET, 18/08/11).

Positioned as an Expert

Some student comments provided an insight into their understanding of being in the fiction as an expert. Hamish presented a succinct definition of Mantle-of-the-Expert as understood by the class that reiterated the notion of playing in an adult role.

Hamish: [In Mantle-of-the-Expert] you put the coat on of the person in the business and play on the role of them (ET, 11/08/11).

Lucy commented on the labelling aspect, asserting that being given expert status enhanced her confidence and personal intrinsic value.

Lucy: By calling us experts, it makes us feel special (L&K, 05/10/11).

Both Cameron and Taylor identified that in Mantle-of-the-Expert you are operating in a dramatic reality as well as in the classroom. Cameron recognised that Mantle-of-the-Expert involves the teacher positioning the students into a role as an expert. He realised that learning through Mantle-of-the-Expert is a process, in which expert status is given, taken up in the mind, made manifest through actions and words and eventuates at the end.

Cameron: [Mantle-of-the-Expert] is to do with getting into role. In the beginning you telling us (that's what you said) that we were told … The mind believes they are an expert so they say stuff like they are an expert. By the end of that they were…. If you say that we are an expert, it is like a confidence boost and we feel more confident in yourself, so you can stand up and say what you know (C&T, 05/10/11).

Cameron also states that it was his acceptance of the expert positioning and subsequent positioning of himself as an expert that made the difference to him becoming an expert, as this mental positioning affected the way in which he conducted himself and the vocabulary he used. It appears that for Cameron being positioned as an expert enhanced both his self-esteem and his self-efficacy as through being positioned as an expert he felt more able to share his understanding with others.

Taylor, while recognising that the “as if” reality can impact on our “as is” reality thought that her confidence was only affected a small amount because she knew that she was operating in a fictional world.

Taylor: If you are not already that confident it can just give you a small boost and not a big. I still don’t know if they could be faking it. It doesn’t act real so you still sort of think about it (FG 17/11/11).

However, a caveat that working as an expert could bring a sense of unwelcome expectation was raised by two of the eight students interviewed, who believed that being positioned as an expert created pressure to know ‘stuff’.

Brooke: I don’t reckon being positioned as an expert helps you become an expert because we, you get told that you are an expert. You think aww should I know all this stuff? And you get like - pressured.

Jess: Yeah (B&J, 05/10/11).

Although the students here identified ‘pressure’ as a negative aspect, the quote also adds to the finding as it indicates an awareness of being positioned as an expert and the understanding that with that positioning comes expert knowledge and a necessity to ‘act’ as if they possessed the knowledge in actuality.

In summary, the students considered being positioned as an adult allowed them to elevate their performance and function, to an extent, as if they were adult and that helped them to learn. In addition, the data seems to suggest that most students meta-cognitively accepted their positioning and worked in the manner of an expert, gaining both self-esteem and self-efficacy. Only two students identified a negative outcome of feeling pressured by being positioned as an expert.

5.2.4 Summary

This section presented data on the theme ‘Positioned as ‘experts’ to learn science’. In the first section, evidence was provided on the use of explicit speech and sign to position the students into a company role. Their acquiescence to the positioning and agreement to work within that positioning was demonstrated through the way their pronoun usage changed to a possessive, plural collective configuration. Repositioning how curricular content knowledge to initiate and maintain the fiction of students being experts appeared to support the students to both share and explore knowledge as they attempted to make reasoned decisions about the validity of the scientific data they were working with in their science investigation. In addition, it appears that being positioned as an adult expert helped most students to act as if they were an expert; thus, enhancing their learning.

5.3 Students positioned as ethical scientists

Another theme generated from the data was the notion of being ethical. The need to be ethical was strongly woven into the design of the research study (see Appendix B) and highlighted by the teachers in classroom discourse. Interestingly, while being ethical is a facet of working in Mantle-of-the-Expert (Edmiston, n.d.-b; Heathcote, 2010a; Heathcote & Bolton, 1995); it has not been highlighted in the research-based literature as a major theme. Section 5.3.1 outlines how sign was used to position the company as ethical. In section 5.3.2 data is presented that shows how an ethical and social purpose for investigating science was built into the learning. Section 5.3.3 outlines how interacting with two ‘fictional others’ built the students’ ethical identities, while data presented in section 5.3.4 demonstrates how an ethical identity was enacted and influenced student learning.

5.3.1 Building an ethical identity through sign

Sign was used to build belief in the company and as such contributed to a sense of the need to be ethical when working as members of the company. Three instances from the early establishment phase of Mantle-of-the-Expert are presented to show how the students’ ethical identities were developed. The first example revisits the company noticeboard, the second defines ethicality from a certificate for ethical science and the third looks at working within an ethical company identity from a puzzle on the company name.

The first example is taken from the episode (ET, 09/08/11) where the focus was on building a company identity through the noticeboard. The children's responses illustrated how they used this sign to deduce the ethical aspects of the company. The students identified that the company was environmentally friendly, and ‘care[d] for others’.

Josh: They are environmentally friendly.

Alicia: Like people who organise charity events – that’s what I thought it was like a whole thing to care for others (ET, 09/08/11).

In the second example, sign was used to build an understanding of the meaning of the word ethical. This episode was initiated by announcing at a staff meeting (a common device used in Mantle-of-the-Expert) that the company had received an award for contributions to ethical science.

Student comments indicated they hadn’t come across the word ethical before, so TJayne and I orchestrated a discussion about its meaning. A representative sample of student comments during the discussion is presented here.

Taylor: Good working standards.

Mitchell: Moral, conscientious, good, honourable, upright [Dictionary definition for ethical].

TJayne: There was one word in that dictionary that I recognise and that was moral. What does that mean?

Alicia: You have to keep the same rules (ET, 11/08/11).

The comments above show something of the pathway the students took to arrive at an understanding that being ethical meant that you worked hard, were honourable and kept to the rules. Discussing and analysing the meaning of the certificate helped the students to understand what being ethical meant and added ethicality to the construction of their collective identity of scientists in SEERS.

After discussing the word ethical, the students then reconstructed a message from Malcolm in the form of a giant jigsaw puzzle (ET, 11/08/11), which contained the name of the company – Scientific Extreme Event Reconstructive Services (SEERS) and the comment: What does our name mean? What type of customers do we attract?

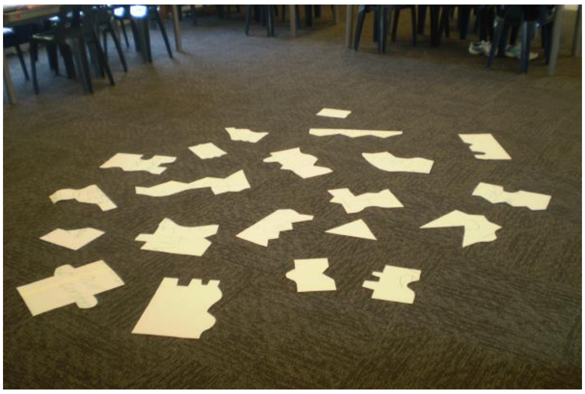


Figure 5.4 Giant jigsaw puzzle

The students tried to puzzle out the meaning of these cryptic questions. Tom thought that our name was indicative of our identity. Mitchell wondered if it meant we did science and were hardworking, moving towards an acknowledgement of the ethical aspects of our scientist identity. Shania brought in the moral caring aspect and the humanistic aspects of giving back.

Tom: I think what he might be trying to say is that our name is like our identity …

Mitchell: Does it mean like doing? … like using science? Like hard working?

Shania: I think that we like to research on things that have affected many people and we like to give them information … so people can understand it better (ET, 11/08/11).

Blair and Monica gave examples from our company's fictional collective past when we helped people after the Japanese earthquake in 2011.

Blair: The Japan Earthquake (2011).

Monica: We helped explain what was going on. We went to see all the children and explained about what was going on (ET, 11/08/11).

While discussion of the award citation helped students to develop an understanding of the word ethical, its meaning remained abstract. Solving the jigsaw puzzle allowed them to make tentative links between the Company and how it acted in society and the values it embodied. The students concluded the company was hardworking and helped others – all ethical characteristics.

In these three episodes, explicit exploration of vocabulary and the use of sign helped the students to construct an understanding of the meaning of the word ethical and the principles underpinning an ethical scientist identity. The examples also show that over the course of the lessons the students moved from recognising ethical characteristics in an abstract company, to dissecting the meaning of "ethical" and identifying that science could be ethical, to linking these characteristics to the company of which they were members.

5.3.2 An ethical and social purpose for investigating science

An ethical purpose for investigating science was built into the unit through the dramatic framing found in the commission and the use of drama role conventions and the dramatic structures used in Mantle-of-the-Expert. The commission context also positioned the task requirements as having an ethical/do good aspect.

The ethical imperative for the commission in this study was first highlighted in the second session of the unit, where Drama for Learning was used to both inform the students about the learning frame and to hook them into the learning. After viewing a YouTube clip of the television news on the day after the vessel sunk, students constructed freeze frames from actual pictures taken of the tragedy and then interviewed someone in role (hot-seated) who was connected to the sinking. Drawing upon historical data, I became the wife (Linda) of a child who was on the Wahine and told the story filtered through time and distance. I spoke of the pain of losing a family member. I said in role:

> I don't think they really followed up on it properly… I sort of wonder whether someone should look at the Wahine again…There needs to be scientific people looking into it (ET, 04/08/11).

Here, Linda articulated the need for a scientific inquiry into the sinking. She inferred that the sinking wasn't looked at properly and the science needed to be revisited.

The ethical purpose for an inquiry into the sinking was reinforced four lessons later, after the students had established their company identity. This occurred when the students received the commission letter from the client (ET, 18/08/11) and were asked to deconstruct it to ascertain exactly what the requirements of the commission were and whether or not the company should take it on as a project. Student comments from a class discussion following group work on deconstructing the commission letter showed that they identified an ethical reason for accepting the job - to re-investigate the science behind the sinking of the Wahine so other similar accidents could be avoided. They realised that the tragedy had affected people and wanted to stop other people from experiencing that ‘loss’.

Student A: They want to study science and see if this can never happen again.

Hamish: Here it says we need to find out why the Wahine sunk.

Student B: We need to research.

Student C: Mr McLennon [Client] is someone who may feel strongly about how the Wahine disaster could have been prevented.

TRCarrie: Why do you think the Government doesn’t want another Wahine to happen?

Student D: Cause all the families will remember the loss (ET, 18/08/11).

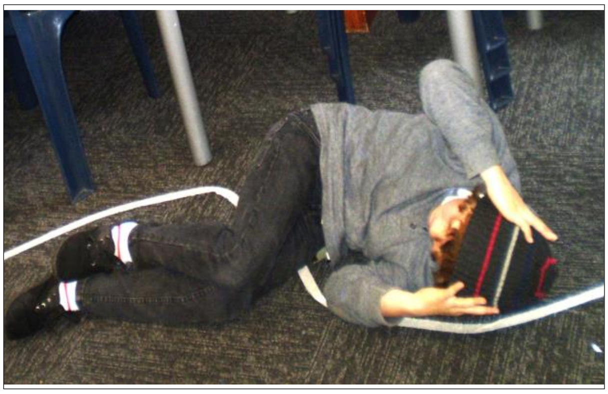
As evidenced by the collegial ‘we’, the students were working in role as members of the company as they endeavoured to understand their commission. They had moved into role as ethical and moral scientists who would investigate the sinking to find answers.

Earlier I described my finding that sign and the dramatic convention of freeze frame/tableau helped the students connect emotionally and in an ethical manner with the final voyage of the Wahine and also visualise themselves on the boat as it sank.

In another example of the use of sign, the learning was contextualised by using masking tape to outline Wellington Harbour (see Figure 5.3), thus creating a sign of the final voyage of the Wahine (ET, 24/08/11).

Figure 5.5 Mapping Wellington Harbour

The students walked through the harbour, stopping at important places and listening to an account of the tragedy read by me slowly with background music.



Individuals in the class depicted what was happening at each stage through freeze frames (see Figure 5.7) and thought tapping as they took the role of different people from the Wahine.

Figure 5.6 Student showing what happened after the vessel hit the rocks

They also had the opportunity to interview the captain, represented by a picture of him, with the teacher and a student Alicia speaking for him in role, about what occurred during the sinking.

Jess: I liked how you guys got that picture and let us like talk to it cause it gave me like a clearer picture how he was thinking (B&J, 05/10/11).

Jess described that dramatic convention as useful for her learning as it gave her a clearer understanding of what occurred when the vessel sank.

In a similar fashion, Taylor, in her end of unit interview, mentioned this boat episode, noting that while fun, it had an ethical purpose because it taught her about the tragedy.

Taylor: I like being in the big boat and us boarding because we kinda had a mix because we had people learning about it also while we were having fun (C&T, 05/10/11).

TJayne, like Taylor, commented on the boat episode where the students imagined they were passengers on the last voyage of the Wahine. She considered it valuable because it connected the students emotionally with the event.

TJayne: I think the best part of it was when we were pretending to be on the boat…It really hooked them in and it got them feeling emotive about what had happened with the Wahine, so there was that emotional connection as well (TI2, 13/09/11).

She felt having an emotional purpose for learning was important, noting that looking at the social aspects of an event 'works well' for her students and connects the learning to the wider community outside of school. By considering how people feel and act, the students are provided with an ethical reason to learn and investigate the science.

TJayne: If you've got a purpose that is emotional I think that with our group of kids that works very well for them…. [In our class we] have always looked at the social aspects and how they would have felt and how the community reacted and those sorts of things. So I think maybe these kids naturally it just comes to them because they have just done it in the past (TI2, 13/09/11).

TJayne considered having an emotional purpose was fundamental to making learning exciting and relevant. In relation to the interview role described in section 5.2.2 she said this:

TJayne: Whereas with this experiment that we just did, it was so much more exciting because we had to do the experiment and find out which interviewee would be able to get this job. So there was a purpose. We had to find out the science and see who had the best knowledge. Whereas before it was just kind of – there's no purpose (TI2, 13/09/11).

She considered that without a purpose, the science was pointless. To her it was putting the science into action that made a difference to the relevancy of the science.

The thread of being ethical and having an ethical purpose for investigating the science behind the sinking of the Wahine was apparent even at the end of the unit when Eli in tribute to those who died, mentioned that people were searching for the truth.

Eli: R.I.P people are researching for the terrible truth behind the sinking of the Wahine (ET, 29/09/11).

The examples above show that a driving reason to investigate the science of the sinking was to give answers to people who had lost someone in the sinking. The students identified that the commission had a strong ethical component in their comments. This implies that they connected emotionally with the scenario.

5.3.3 Heightening ethical behaviour through interaction with 'fictional others'

The third way in which the students' identities as ethical scientists were built was through their interaction with two 'fictional others'. The first 'fictional other' was the company CEO, Malcolm. Malcolm encouraged his staff to be ethical and have high standards. The other 'fictional other' Roger, was a lackadaisical employee.

Malcolm – a positive example of an ethical scientist

Malcolm was never actually physically present in the classroom. He was alluded to by sign – such as in emails and in discourse. Hence, my reason for calling him a 'fictional other'. He was positioned as our absent but active boss through an invitation on our noticeboard to his 60th birthday party, which Mitchell spoke about. I further developed his persona through TIR, giving a reason for his absence but also indicating his involvement in the day-to-day life of the company.

Mitchell: Malcolm works for the company and he's turning 60 (ET, 09/08/11).

TRCarrie: He was away on holiday but he still texts me and emails me all the time (ET, 09/08/11).

I positioned Malcolm as having a positive ethical identity in the classroom through my role as Malcolm's PA. I deliberately used the word ethical and elaborated that ethical people admit to mistakes and work hard. This built on the students' definition of ethical constructed earlier.

TRCarrie: He said to me that he's really proud of the company and he knows that we are ethical; we admit mistakes when we have them and we try and do the best anyway (ET, 11/08/11).\

A series of fictional email messages from Malcolm were delivered to the class. His comments, in the quote below, were relayed in a fictional telephone conversation between him in Vanuatu and myself in role as his PA to the rest of the company. Malcolm was used as a tool by the teacher to both praise the students and encourage them towards deeper thinking and further exploration of ideas and science concepts.

TRCarrie: He sounds like he's grinning from ear to ear; he's saying you've got it but of course he's also saying you need to explore it a bit more (ET, 11/08/11).

In the following quote, from the day we analysed the commission, in my role as Malcolm's PA, I positioned the students in their company role as sensitive ethical and reliable scientists who could be trusted to research science that could be contentious. I also linked to Malcolm and his desire for us to act in this way. It was not just a teacher talking but delivered in role as ethical scientists who care.

TRCarrie: This is quite a privilege actually that the Government thinks that we are capable of looking into this in a sensitive way, in our normal ethical way, so that they don't want another tragedy. . Because I think it would break Malcolm's heart if we didn't look into something and something happened like this again. (ET, 18/08/11).

The 'fictional other' of Malcolm demanded that our science be of a high standard. Around a month later, in role as PA, I used Malcolm to encourage careful, accurate science when the students conducted the paper boat experiment.

TRCarrie: Malcolm has just asked us to make sure that we take it slowly but accurately (ET, 06/09/11).

In this way, Malcolm served as a structural tool, to enhance the accuracy of student work (without resorting to teacher talk) through their positioning as scientists responding to urging from their CEO to finish their work to a high standard. In a similar manner, a week later, Malcolm channelled by TJayne, asked the students to help chose the new employee for the company, and in doing this, endorsed the status of the students as expert scientists. TJayne conveyed his suggestion as follows:

TJayne: So he's [Malcolm] come up with this amazing idea, because you guys are such amazing scientists and you really know what to do. He's asked if you can help out with the interview process (ET, 13/09/11.

Through this action, students, in their company roles as 'amazing' scientists, were not only valued, but also considered expert enough to judge potential employee's science competence.

In her end of unit interview, Lucy highlighted that she worked for the company and Malcolm doing science, which included: experimentation, investigation and communication.

Lucy: Well, I would go home and say we have a company called Seers and we… Well, its science and we work for Malcolm and we do experiments and we are studying the Wahine for this company and we have to write a report (L&K, 05/10/11).

The other seven students interviewed did not mention Malcolm.

To sum up, the teachers used Malcolm as a structural tool to 'manage' the class from within the fiction. He was utilised as an audience to students' learning, instead of the teacher, with the advantage of being 'removed' from the action. In his positioning as CEO, he demanded excellence from the students and this helped deepen their thinking. He also reinforced the students' status as expert scientists. According to Lucy, she worked for Malcolm, the CEO, of the fictional company in the Mantle-of-the-Expert unit that we were studying the science behind the sinking of the Wahine through.

Roger as an example of a unethical scientist to promote ethical science

In contrast to Malcolm, Roger the second 'fictional other' was positioned as unethical through the use of a number of dramatic conventions. The first dramatic convention used to build Roger's unethical identity was a snippet of overheard conversation from the company staff room. Two staff members (students-in-role) were overheard discussing what Roger had been up to (see Table 5.1).

Table 5.1 Overheard conversation script

Overheard Conversation about Roger	
Staff Member One	Have you heard?
Staff Member Two	**What?**
Staff Member One	About Roger.
Staff Member Two	**No, what's he done this time? Played another practical joke?**
Staff Member One	No worse than that! You know how he likes to play around and take short cuts?
Staff Member Two	**Yeah.**
Staff Member One	Well, he… [trail off as if the people are moving out of range of the listener]

After listening to the overheard conversation, students looked at three email messages from the company CEO Malcolm to Roger (Table 5.2). These provided them with further ideas about his work ethic.

Table 5.2 Email correspondence from Malcolm to Roger

Emails about Glow-worm Cave
July 4th Hi Roger, Just a gentle reminder. The science report for the Glow-worm Cave contract is due on Monday week. I haven't seen any preliminary reports. I need to see a copy on Wednesday . *Malcolm*
July 7th Roger, Where is the report for the Glow-worm Cave contract? Please come and see me ASAP *Malcolm*
July 18th Hi Roger, I am dismayed that you sent out the report for the Glow-worm Cave contract without running it past anyone else. I didn't verify it. I need to see you today at 12:30. *Malcolm*

Student commentary indicated that these students identified Roger as a 'prankster' who tended to rush his science; this was the opposite of Malcolm who advised people to take their time and be accurate.

Girl: He forgets.

Tom: He's a prankster.

Girl: He always finishes things at the last minute.

Brittany: His science is quite basic.

Girl: He likes to take short cuts (ET, 06/09/11).

The ramifications of Roger acting in haste and taking short cuts is seen in the newspaper article (Figure 5.7), written by me in the role of a reporter. The article highlighted the ramifications of Roger's unethical science actions on both the people affected by the company's errors and the company's reputation.

Student comment about the article shows that they recognised that the company had been 'slack' and not acted ethically. Their science was inaccurate and they had to re-test because their report to an external client had 'mistakes' and they did not want to lose their job through incompetency.

TJayne: What do you need to learn from this so you won't be going through what Roger's going through and getting the old heave-ho from your job?

Hamish: The Company was slack and they didn't have enough time to test it.

Girl: The report had mistakes.

Girl: They had to re-test (ET, 06/09/11).

Scientific Blunders Delay Inquiry

The inquiry into the Glow-worm Creek caving disaster has been delayed to allow time for the scientific data to be retested. A report was received from a prominent research facility that had multiple errors in it. The company discovered the problem in an audit. The science was retested and the report rewritten to the company's normal high standards.

The company has apologised and compensated the persons concerned. They are looking into the factors that led to the inaccurate report being issued. They have assured us that procedures have been tightened and appropriate measures have been taken to prevent a reoccurrence.

Figure 5.7 Fictional newspaper article showing the consequences of Roger's actions

In addition, the student identified that Roger was not a good representative of the company.

Felicia: Was he [Roger] good for the company?

Girl: I don't think so. I think he was just trying to get it all ticked off (ET, 06/09/11).

In my role as Malcolm's PA, I highlighted Roger's unethical conduct and Malcolm's response to it, bringing the values of the two 'fictional others' into stark contrast.

TRCarrie: I know Malcolm has been really upset over this situation. Actually Roger has decided to leave the company and Malcolm's … really concerned that we don't make those mistakes again (ET, 06/09/11).

Here I sought to convey to the students that Roger had damaged the company's reputation and that ethically the company had to fix up his mistakes and produce good quality work in the future to rebuild their reputation. The following discussion ensued.

TRCarrie: [Malcolm] asked me to ask you, what do you think we need to do to make sure that our science is really worthwhile?

Boy: Make sure it's correct.

Girl: Do it correctly.

Girl: Make sure it works.

Boy: Meet our deadlines (ET, 06/09/11).

Student comment here confirms that the students realised the importance of ensuring that the science was accurate and timely.

This understanding was confirmed in the next episode (ET, 13/09/11), where one of the students brought TJayne, who had been absent, up to date with events. Here, the student clearly identified that there had been mistakes made so we (the company) had to repeat the science.

Student: [Roger] he made a mistake in one of the research departments and the research was all wrong so they had to send it back. So we had to do it again (ET, 13/09/11).

A further example was found in my field notes (FN, 14/09/11)[12] of my reflections from the next day where Shania identified that Roger's way of working was not good for the company.

> We had a lovely discussion about Roger…talking about how much better the company was without him. The slaphappy and unethical manner Roger operated in wasn't good for the company and Shania had recognised that (FN, 14/09/11).

To conclude, Roger was used as a negative example to encourage the students to be ethical, moral and meticulous. Student comments suggested Roger had an impact on their understanding of the consequences of inaccurate science practices and scientists not being ethical in the way they approached their work. This linked their understanding to their identities in role, or at least on their verbal expression of that identity.

Overall, my finding is that the use of 'fictional others' was a useful way of contrasting the difference between acting ethically in science and not acting ethically. The two 'fictional others' appeared to serve to intensify the students' desire to produce accurate science as is shown next.

5.3.4 Students enacting an ethical identity

A further finding relates to the way students chose to enact ethical identities within the drama. The students demonstrated that they were working consciously within an ethical identity through the way they positioned themselves as caring moral people in their CVs, their interactions with the fictional captain of the Wahine, and in their reporting back to the client.

The students' CVs positioned them as ethical moral citizens with a strong sense of social justice as illustrated in the following dialogue when the students shared their CVs.

Liam: I help people with tsunamis.

Brittany: My biggest contribution to the company would be in the Christchurch earthquake.

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[12] In this instance, my audio recorder stopped recording, so I wrote up extensive field notes after the session in addition to my normal reflective blog.

Luke: I contributed by helping peoples around New Zealand prepare for natural disasters (ET, 16/08/11).

These comments highlighted that within their fictional roles, these students didn't just want to just make a difference scientifically; they wanted to impact positively on the lives of people. The science work was not in abstraction but connected to the needs of people.

Another example of the students operating in an ethical identity was through their dramatic interactions with the captain of the Wahine. An initial impression was built about the captain and what had occurred on the day the Wahine sunk by analysing newspaper articles about the Wahine (ET, 23/08/11). This was further developed when they interviewed him a day later (ET, 24/08/11). The students identified that although he had been judged 'not guilty' of causing the loss of life in the sinking of the Wahine, he was a victim of poor public opinion and probably blamed himself for the tragedy.

Brandon: It could have been the captain's fault… Cause in our article it said that the public opinion wouldn't allow him to do any more shipping.

Mitchell: Neither the Master nor the Chief officer of the Wahine was guilty… The court decision found that the charges against the Wahine chief engineer, Wellington harbour and the Union Steam Ship Company of New Zealand were not established [13] (ET, 23/08/11).

Tom: If we do talk to him he probably would say it was his fault because of his survivor's guilt (ET, 24/08/11).

Students demonstrated care and ethical consideration in how they interviewed the captain in role. They did not accuse him but questioned him respectfully about the events when the vessel sank.

Student A: How were you feeling after the Wahine struck Barrett Reef?

Student B: When you realised the ship was sinking – did you do your best to help everyone you came across?

Alicia: Looking back was there anything you would have done differently (ET, 24/08/11)?

[13] Mitchell paraphrased a newspaper article about the sinking of the Wahine taken from a resource into the sinking of the Wahine compiled by Newspapers in Education (1983).

This ethical way of working was extended to report writing. TJayne cautioned the students about ensuring their findings were written in an ethical and validated manner.

TJayne: You are an expert about it. So you have an expert opinion… If you say that I think it was the captain's fault because he was an interesting character, that's not valid. There is no proof behind it. In fact it's a little bit judgemental.

Student C: But if you said, I think that it was the captain's fault because he tried to turn back to Cook Strait because he.

TJayne: And then you'd say why that was a bad thing.

Child: Yes.

Student D: Absolutely (ET, 26/09/11).

This ethical way of working is in contrast to how Roger worked. The students as previously mentioned (see section 5.3.3) realised that they had to 'make sure' their science was correct and be ethical in how they worked and in their interaction with others, such as the captain.

Most of the students attributed blame for the disaster to the cyclone and not receiving a crucial weather forecast (see for example, Tom's report).

Tom: The Wahine disaster was a result of gizelle (Giselle) and a large storm together (WR).

After analysing the data and describing several factors that contributed to the sinking, Brittany, while acknowledging the captain had tried his best had nonetheless misread the seriousness of the situation.

Brittany: If they had asked for weather reports more, the Wahine could still be around today ...I have come to the conclusion, that the Captain is to blame, even though he tried his hardest (WR).

Crystal took an alternate view. After describing the factors that contributed to the sinking, she indicated, that in her opinion, the Captain was not at fault.

Crystal: There were in the middle of a hurricane ...winds a high as ... 122km per hour... water slopped onto the vehicle deck and it tipped on its side... In my expert opinion it is not the Captain's fault (WR).

Although these students reached different conclusions, it can be clearly seen that both were reasoned and ethical in the way they approached their decision, backing up their opinion with evidence from their investigation.

This same ethical consideration was demonstrated when students reported back their findings about the sinking of the Wahine to the client, who visited the classroom in role, at the end of the unit (ET, 29/09/11).

As a way of honouring the people who died on the Wahine and a means of dramatic closure in the unit, we wrote a message on a paper boat. We solemnly stepped forward, spoke the words of tribute, placed the boat in the centre of an outlined shape of a vessel and stepped back to reflect on the 51 lives lost on April 10 1968. A few student comments follow from both the dialogue and the paper boats.

Eli: R.I.P people are researching for the terrible truth behind the sinking of the Wahine.

Tom: A tragic disaster that never should have happened.

Boy: You thought you were safe in the lifeboats but the weather was unpredictable (ET, 29/09/11).

Student*: Never again – now you know what happened.

Student*: We feel really sad for you.

Student*: I'm so sorry about all the families who lost someone in the tragic disaster (*taken from paper boats).

Student comment showed that the students empathised with those who perished when the Wahine sank. They wanted to find the reasons for the vessel sinking, mentioning mistakes made and the effect of the weather. They demonstrated that they were ethical in their actions by the gentle and considerate way they treated the people affected by the tragedy.

This ethical dimension was also seen in the deep thinking that occurred after the tributes were laid, when Viva (supervisor in role as client) questioned the class in role as the company about their motivation for investigating the sinking of the Wahine.

Viva: So is one of the things that you are trying to do at SEERS is to seek the truth? … For you is it important that the story I take back to Wellington contains both, personal story and scientific facts?

Alicia: You've got to make sure you've got the right facts because otherwise you could hurt people like saying it was the Captains responsibility or fault or something like that. And then for the people I reckon it's also important because you have to be respectful of people.

Bailey: Cause if there's families and all like friends who went on there and have died (ET, 29/09/11).

Alicia and Bailey thought both scientific facts and personal stories were important. The students earlier had come to a definition for ethical that you worked hard, you kept the rules and were honourable. They knew they had to ensure their analysis was accurate; they had the 'right facts' and make sure they did not falsely accusing someone. They were also aware that they needed to be honourable and respectful as they were dealing with the 'families' of people who had 'died' on the Wahine. In this way they were operating as ethical scientists, which is more than just being empathetic or sorry for someone.

In summary, the data presented here shows that an ethical moral aspect of scientist student capacity was fostered in these episodes. Students positioned themselves as caring and ethical in the way they interacted with each other, the captain and especially through the care they took in finding out the reasons for the sinking of the Wahine. This ethicality extended to making sure their science findings were supported with evidence so that no one would be falsely accused.

5.3.5 Summary

Establishing and working within an ethical identity was an important theme in the data from this study. The notion of ethicality was built deliberately through sign and dramatic conventions such as TIR and it developed over time. It set the underlying standards for the company and the way the students worked in their roles as scientists and their work in school science. The ethical framing and positioning helped hook the students into science for it provided ethical reasons to find out why the vessel sank and conduct accurate science. Importantly, it connected science to the 'real world' and showed how important science was in people's lives. The need for ethicality was seeded through student interactions with both ethical and non-ethical 'fictional others'. Students were able to explore, in a controlled manner, the issue of whether the captain was to blame for the sinking and look at the issue from multiple perspectives. Being ethical appeared to add both criticality and depth to how the students approached the investigation.

5.4 Students engaged into learning

Another theme identified in the data and evident in the literature (see sections 3.2.1 and 3.2.2) is that student engagement is enhanced when learning is taught through Mantle-of-the-Expert. The sub-themes that relate to this theme scope the various ways that students were supported in their engagement into science. The sub-themes are: working as colleagues, doing physical activities as a scientist might, having fun learning, and a useful way to learn science.

5.4.1 By working as colleagues

The subtheme working collegially resonates with the Mantle-of-the-Expert notion (see section 3.2.2) that students are positioned as colleagues within a company or responsible team as part of a Mantle-of-the-Expert unit. This sub-theme has two aspects: learning as a group process and learning as an inclusive process where everyone has equal status.

The notion that students learn as part of a group process was evident in student comments in the lessons and the interviews. For example, midway through the unit, student A commented that group learning was a constitutive part of Mantle-of-the-Expert during a class reflection on learning science through Mantle-of-the-Expert. He also mentioned that he found it easier to learn in a group because he could 'bounce' ideas off other students.

Student A: Mantle-of-the-Expert is different… You always work in a group in Mantle-of-the-Expert and I find it easier to learn in a group because you are bouncing off ideas and stuff (ET, 18/08/11).

In response, TJayne asked for a physical demonstration if students liked working as part of a group in Mantle-of-the-Expert. Half of the students in the class stood up (about 15).

The class continued unpacking why working collegially as part of a group was advantageous and engaging. Brooke reinforced Student A's idea when she mentioned that when you learn by yourself you are constrained by what you know whereas in a group situation you can draw on others' knowledge and perspectives. Brandon also liked being able to share his ideas. Student B asserted that people can learn more by working in groups.

Brooke: When you are not working in a group you just learn what you can. When you are working in a group you learn to know what others think and stuff about the same thing. Someone else might see something differently.

Brandon: When you are there you can share your ideas with everybody.

Student B: So people can learn more (ET, 18/08/11).

Tom and Student C raised the notion that when you teach you consolidate your own knowledge. Student C extended this idea, commenting that it can even be advantageous when someone holding a different opinion challenges your ideas, because then you can work collegially to find a solution that works for both parties.

Tom: Cause when you're teaching someone you learn more as well. You learn more stuff.

Student C: When you teaching/learning with someone else and you don't agree on something, you have a chance to put ideas together (ET, 18/08/11).

Similarly, Brooke and Jess in their end of unit interview, reiterated that the value of working collegially is that you gain knowledge and consolidate tentative thinking by sharing it with friends and in doing that everyone is helped to learn.

Brooke: We get both opinions and then since we got both of them and we get more from each other and then we learn more.

Jess: Sometimes we ask questions in our mind. We don't know the correct answer to it so if we ask our friend we will find out about that (B&J, 05/10/11).

Lucy and Ofa in their interview also reflected on learning as part of a group process. Interestingly, they drew out the aspect of not always being in groups with your friends, stating that when you are challenged, your thinking is expanded.

Ofa: Like in your groups you don't always have to be with your friends you could be in a group with different other people and you could learn more like not to be in your comfort zone.

Lucy: When they're in their comfort zone they're not actually getting anywhere … when you push them forward they are learning something and expanding their brain (L&K, 05/10/11).

A number of students in their interviews indicated that for them learning as part of a company through Mantle-of-the-Expert was an inclusive process. Tom, Lucy and Jess mentioned that Mantle-of-the-Expert approach includes them in the learning most of the time.

Tom: Like sort of including us (J&T, 05/10/11).

Lucy: When you are in a company things come in and it's really exciting cause everyone gets included (L&K, 05/10/11).

Jess: Including me in …You get included most of the time (B&J, 05/10/11).

Tom, in the final focus group, expanded on this idea, asserting that within Mantle-of-the-Expert students had to be included.

Tom: But with MOTE [Mantle-of-the-Expert] it has to include you otherwise it would be standing there reading out of a book (FG, 17/11/11).

Although Mantle-of-the-Expert has the goal of including all students (see 3.2.1), there are times when students chose not to be included. Brooke indicated that she did not like to 'act'. Jess spoke about the fear of making errors –'mucking up' with Brooke indicating it was the 'public aspect' that was 'scary'.

Brooke: Well, me personally I'm not really a person who likes to pretend or act.

Jess: Cause you don't want to muck up in front of everyone…

Brooke: We are both quite shy and it was the public aspect that was scary (B&J, 05/10/11).

Both Tom and Jess in the final focus interview, reiterated that shyness can be a factor in some students not getting involved in action.

Tom: Some kids like to stand back.

Jess: Cause they're too shy and don't want to say things (FG, 17/11/11).

Another aspect of working collegially in Mantle-of-the-Expert, mentioned by the teacher and students, is that everyone has equal status as members of a company. TJayne highlighted this aspect in her third interview, when she spoke about how in Mantle-of-the-Expert everyone is positioned on the same level. She commented she saw no one bossing another person or being positioned as over someone else. She also remarked that the levelling of power was not about dropping everyone to the lowest common denominator, but of lifting people up to a higher level so they could learn together.

TJayne: There was no one that was bossing anyone around and feeling like they knew more than any other person. I do feel like they were very, very much on the same level, which is very nice. But in a helpful way … so that they made sure that person next to them was at the same stage (TI3, 13/10/11).

Josh expressed an understanding of the levelling effect of working in a 'company' of equals similar to TJayne. He considered that when you are working in a company nobody has higher status than anyone else, which meant for him, greater freedom of expression.

Josh: [When]you're in a company, no person is higher than any other. You can express what you think (J&T, 05/10/11).

Another example that speaks of the importance of being positioned with equal status occurred in the fourth episode (ET, 11/08/11), when we were analysing the message from Malcolm written on jigsaw puzzle pieces. On this occasion, the simple change from teachers sitting on a teacher chair to sitting on the ground in a circle with the students signalled this equality of status. TJayne spoke of this incident, as did two students in different interviews. TJayne explained that the reason she changed her position was that she considered her sitting on a chair was not representative of what she wanted her status to be. Sitting on a chair implied that her status was above the students – not equal to them.

TJayne: I was too much looking down on them and that's not good (ET, 11/8/11, discussion).

Cameron and Lucy mentioned this occurrence as well, giving their impressions of what the teachers changing their physical positioning to be on the same level as the students meant to them. Cameron suggested we (the students and teachers) became more equal because the teacher isn't positioned above them physically.

Cameron: In Mantle-of-the-Expert we are kind of more equal because the teacher isn't sitting up on the chair and we aren't all sitting on the mat. You guys would sit down on the mat next to us and ask us questions and we were all equals (C&T, 05/10/11).

Lucy asserted that an equal physical positioning aided student learning. She identified that when the teachers changed their physical positioning power relationships in the classroom became more equal. Thus students were engaged into the learning because the teacher was no longer talking 'at' the student but talking 'to' the student in the manner of adults.

Lucy: I think when there's a teacher on the chair they are just telling you what to do…'Cause you kind of learn more if someone's talking to you (FG, 17/11/11).

Lucy's ideas about learning more when you talk to someone as an equal, were also mentioned by TJayne who concluded that when teachers were positioned over students, students lack ownership and are less inclined to learn.

TJayne: [Regarding student ownership], it's a bit like positioning isn't it. If we are in a position of power then they (the students) are going to have no ownership or little ownership (TI3, 13/10/11).

The data presented in this subtheme suggested collegiality was a facet of this Mantle-of-the-Expert unit. The students recognised they were working as part of a group process, and considered this helped extend their thinking and broaden their ideas. They also identified that the approach was inclusive. Being positioned as equals was seen as a useful way of supporting students to take ownership of their learning by the students.

5.4.2 By doing physical activities as a scientist might

Learning through physical hands-on activities emerged as a sub-theme in student and teacher interviews. Learning through doing incorporates aspects of learning actively in a physical manner. It has synergies with the embodied improvisational nature of drama (see section 3.2.1) and experimentation in science (see 2.6.1). Student learning preferences will be discussed as well as looking at the perceived benefits of working in this manner.

Five out of the eight students interviewed at the end of the unit commented that their learning was enhanced through physical activities, which included experiments and dramatic activities. These students mentioned 'doing stuff' engaged them more than listening or reading.

Tom: Doing it all first, rather than words (J&T, 05/10/11).

Josh: I agree with Tom. [I] like physical stuff like we can do, like the experiments that we did (J&T, 05/10/11).

Brooke: I'd probably prefer to actually do stuff, than sit there and listen and read about it - to have to actually physically do it (B&J, 05/10/11).

Jess: I, in my personal opinion, quite liked doing the MOTE [Mantle-of-the-Expert] instead of looking at the board. There were the activities (B&J, 05/10/11).

Lucy: Hands on work (L&K, 05/10/11).

This preference for 'physical stuff' was also seen in a conversation with a small group of boys late in the unit when they were preparing a PowerPoint presentation for the client (ET, 29/09/11) with Josh and Bob preferring physical stuff like experiments to drama. However, Cameron, like Jess above, enjoyed physical activities in the drama.

Josh: I just don't like drama … I like the physical stuff, like the experiments and stuff.

Cameron: I like the freeze frames.

Bob No, I don't like them. I only like the moving around (ET, 29/09/11).

Both Tom and Brooke claimed that an interactive aspect was important to keep them involved or engaged in their learning.

Tom: If you are interactive the mind's always there, it's not like drifting off.

Brooke: It keeps you involved ... It's like not going in one side and out the other … Like when you stand up and actually do it, you sort of absorb it (FG 17/11/11).

TJayne agreed, acknowledging that being interactive helps students learn, especially in the afternoon. She noted that the students were more engaged when the Mantle-of-the-Expert was in a 'doing' stage, rather than a discussion.

TJayne: I think that in the afternoons the kids need a different type of learning programme. One that's really interactive. And when we were at that stage of the mantle when it was really interactive it was **perfect.** And the kids were really enjoying it. It was just those early stages where we were sitting down with discussions where the kids got a little bit less engaged (TI3, 13/10/11).

Lucy asserted here that using her 'body' and 'doing science' in an inclusive manner (Mantle-of-the-Expert) helped her learn science. She also noted that active learning was preferable to reading and writing.

Lucy: When it's just learning [about science] it's kind of a bit boring, cause it's pages and you have to read it and write down answers. In Mantle-of-the-Expert you stand up and you just do it. Using your body and everyone gets involved and it's fun (L&K, 05/10/111).

Josh and Tom identified that working in Mantle-of-the-Expert involved physical experiences in the 'now immediate time' and the learning was experienced through 'first-hand experiences'. Learning in a physical embodied way, Josh asserted, created a body memory that enhanced recall.

Josh: I guess the one we did on the Wahine report because there was moments there that we remembered 'cause our body remembered because we were doing it.

Tom: We had first-hand experiences.

TRCarrie: So that makes a difference when you feel that you've been there?

Josh: Yeah, you are not just reading information off the computer.

TRCarrie: So do you think drama might make an advantage for some things like that? Why?

Josh: Yip, I think it comes back to you experienced it (T&J, 05/10/11).

From this we can see that the data suggests that active learning engages students into learning and is preferred by the students to learning through listening and reading. The data also suggests that that some students thought that moving physically helped them absorb and remember the learning due to anchoring the learning to a specific physical memory.

5.4.3 Having fun learning

This theme includes data on why the students and their teacher considered working through this Mantle-of-the-Expert was ‘fun’ and what made them ‘excited’ or ‘engaged’ to learn.

Over three quarters of the students (21/27 or 77%) identified in their post assessment that they enjoyed learning through Mantle-of-the-Expert, either “heaps” or “quite a lot”. Data from the anonymous assessment (AA, 05/10/11), indicated that the main three reasons for enjoying working in Mantle-of-the-Expert were: because it uses drama (7/27), helps in learning (7/27) and is fun (6/27)

The dramatic and fun aspects also featured in teacher and student comments.

TJayne, in her midway interview, highlighted that her students were excited about learning in Mantle-of-the-Expert.

TJayne: They are really excited about this form of learning [Mantle-of-the-Expert] (TI2, 13/09/11).

Cameron and Taylor asserted it was the drama that made it fun.

Cameron: Yes because it’s more fun.

Taylor: We [Cameron and Taylor] like drama (C&T, 05/10/11).

Taylor mentioned that doing Mantle-of-the-Expert was an enticement to attend school.

Taylor: It gives us a purpose to come to school (C&T, 05/10/11).

Jess advocated doing Mantle-of-the-Expert because it is ‘exciting’ to take on other roles.

Jess: I would say do Mantle-of-the-Expert because it then it makes the children feel excited that they’re another person and not just themselves (B&J, 05/10/11).

Ofa cited that the variety in activities was engaging.

Ofa: I liked learning different stuff every day (L&K, 05/10/11).

Lucy too, spoke about having 'fun' doing Mantle-of-the-Expert. She considered that working in Mantle-of-the-Expert hooked her into the 'action'.

Lucy: I was excited coming to school … [It] gets us into the action (L&K, 05/10/11).

Tom considered that the teachers purposely make Mantle-of-the-Expert 'more fun' because they choose the learning frame.

Tom: When you work in [Mantle-of-the-Expert] teachers make the learning more fun because the students have to do this thing (J&T, 05/10/11).

Brooke, whilst initially saying she was excited about working in Mantle-of-the Expert, indicated that she became less engaged as the unit became more routine.

Brooke: I was excited at the beginning but then as we started to do it, it started to become like a daily thing (B&J, 05/10/11).

One other reason identified as an enjoyment factor was that the context was relevant to student's lives as New Zealanders. Tom thought having the unit in a New Zealand context was important and related it to a sense of national pride and belonging.

Tom: Cause it makes you - like this country is this big (small gesture thumb and forefinger) in a world that is this big (expansive gesture) and it makes us feel stronger than we are (J&T, 05/10/11)

The New Zealand context allowed the students to talk to their parents and other people about the tragedy. During our final presentation to the client the School Principal Chris (pseudonym) spoke about what he remembered on the day the Wahine sank.

Chris: I can remember the day clearly. Cause the day, it was exactly like this - none of us could believe that a ship could sink in Wellington Harbour (ET, 29/09/11).

While, Kitt, another teacher and the mother of a child in the class commented that as it was New Zealand based, they could discuss the event together.

Kitt: My daughter has been talking about it at home… The first thing was, "Oh Mum do you remember about the Wahine? Do you know anything about it? Was it back in your day?" (ET, 20/09/11).

The data demonstrates that students were invested into the learning, and in their position as company members serving the client (section 3.2.1). They showed this in multiple small interactions with TJayne and me. One example was Mitchell who came into class after we had practiced making paper boats with some enormous paper boats to use for the experiment from the client the next day (see section 6.2). In addition, my reflective blogs from episode 9 and 10 detail other occurrences of what I saw as investment or even obsession into the learning that occurred when the audiotapes were not running. These include: searching for information at home, talking to parents, bring in items related to the Wahine, reading the class books on the disaster from the National Library and forgetting to stop learning to go to choir and unsolicited statements of enjoyment. These instances showed that the students did not want to stop learning and were actively looking for information for themselves and telling their parents about what they were doing.

> One of them hunted over the weekend for something related to weather that he had mentioned in class last week. Another showed us a symbol for a cyclone that he had found. TJayne mentioned that the books on the Wahine had arrived and they were reading them at silent reading time ... We the teachers totally forgot choir- so did the students. We were too busy making cyclone models and finding out about cyclones from Albert (RB, E9).

> One of the boys ... had been talking to his mother about the Wahine and she showed him a book which had events that occurred on each day in history and he showed me the entry for April 10th 1968 ... I had a totally unsolicited comment from one student at the end of the class who came up to me and said, “I had fun today!” (RB, E10).

Another aspect of learning in Mantle-of-the-Expert that was engaging for the students was writing their reports for the client. This activity was a time when TJayne thought that the students were obsessed – the highest category on Heathcote’s (n.d.) engagement continuum. TJayne gave the example of Tom approaching her and wanting to write his report for the client.

TJayne: I think they wanted to do the writing… They were motivated to do that. Tom for example was so excited to do it. “When are we going to write the report? ... Some of them, definitely [were obsessed]. You could tell just because the room was so quiet they were focussed (TI3, 13/10,11).

TJayne, considered that the quietness of the room demonstrated the students' obsession with writing their report.

When TJayne and I examined the reports, (as written about in my reflective blog), TJayne noted that the writing the students did for the client was of a high standard and demonstrated a deep level of understanding about the science. She mentioned that Louise's writing was more mature in style and quality than normal.

> She was pleased with the depth of understanding and writing demonstrated ... Louise ... had written a report that was very mature and she thought initially that someone else wrote it, as both the style of the writing and the quality was different to what she expected. (RB, 26/09/11).

TJayne also identified that Brandon and Kaleb's work was also of a higher than expected standard with Kaleb writing with 'focus'and demonstrating at least investment if not obsession.

TJayne: [Speaking about his report]That's quite good for Brandon (ET 26/08/11, Discussion).

TJayne: [Kaleb] with his report he's doing a really good job of that. So that shows a lot of focus there (ET, 27/08/11, Discussion).

Obsession can also be seen in the photograph in Figure 5.8, where the boy was fully absorbed with his writing and had written a considerable amount of information.

Figure 5.8 Student writing his report

TRCarrie: [Referring to Figure 5.8] Doesn't that look like an engaged kid? I mean he's got the dictionary, he's working hard and he's got virtually a page of work.

TJayne: Maybe it is because he is very much engaged with the drama side of it and he just really soaked into that and because of the fact that it was based on the drama that he got into it. And other kids aren't like that, aren't as dramatic (TI3, 13/10/11).

Another classroom teacher, who worked with reluctant writers, noticed that they were very motivated to write.

TKitt: They couldn't wait to get started actually (ET, 20/09/11).

The inclusion of science experiments was also indicated as a reason for student enjoyment. Fifteen out of the 27 students (56%) in the anonymous assessment (AA, 05/10/11) identified a science experiment as their favourite moment in the unit with the most common activities being making a paper boat and testing how it sank and cyclones. TJayne, in her mid-unit interview highlighted why she felt students were engaged by science experiments.

TJayne: The 'hands on' nature of science, definitively (TI2, 13/09/11).

Jess who self-identified as not a 'big fan of science' found the 'potato boat' experiment 'cool', which indicated she was engaged in science at that moment. Ofa also enjoyed that experiment.

Jess: I'm not really a big fan of science but I quite liked the experiments 'cause they were all so fun … I liked that potato boat. It was cool (B&J, 05/10/11).

Brooke liked the model of cyclones using two soft drink bottles taped together (ET, 30/08/11).

Josh and Tom both found the experiments enjoyable because they helped them deepen their understanding of buoyancy. Their understanding of fun, therefore, occurred not only on an emotional level but also on an academic level because they added to their scientific knowledge.

Tom: Probably the test of density because there was a lot of them, especially the fruit. Because they were objects we use nearly every day, so just finding out how dense they are.

Josh: I liked learning how the centre of gravity and buoyancy of how the boat changed (T&J, 05/10/11).

The data clearly shows that the students enjoyed science experiments, especially the physical aspects. They were able to name their favourite science experiment. Most students also considered that Mantle-of-the-Expert had a positive impact on them learning science. This would be commensurate with the teacher's view that they had enjoyed the unit. It was also interesting that both Tom and Josh recognised that it was not just the 'doing' but the 'minds on' thinking about the science concepts that they enjoyed.

5.4.4 Useful way to learn science

One of the key questions asked in this study was whether Mantle-of-the-Expert could successfully be used to teach science with Year 7/8 students. TJayne recounted the doubts she had previously held, as she wondered whether her students would be able to imagine themselves in role. However, she was pleased to note that the students could work imaginatively, citing that the realistic framing was 'perfect' for them.

TJayne: I often questioned this age group with Mantle because I felt that they found it a lot harder to get into role or imagine that everything was happening ... [but] ... the mantle that we used was perfect for our age group, like it was realistic, very realistic, which I loved (TI3, 15/10/11).

Just under three quarters (19/27 or 70%) of the students in the anonymous assessment (AA, 05/10/11) considered Mantle-of-the-Expert "helped" or "maybe helped" them learn science. However, one commented that he would have liked to "get strate [straight] to the science." Two mentioned that they didn't understand the science much and one was emphatic that it did not help her learn science.

TJayne evaluated the students' learning of science through Mantle-of-the-Expert in her third interview (see chapter six for an indepth analysis of their science learning). She considered writing the report for the fictional client in Mantle-of-the-Expert useful as it provided a way for the students to link practical work to theory.

Jayne: I feel like the report was an excellent way to consolidate that understanding. Like they had the hands-on practical work and then they had to get down to the theory (TI3, 15/10/11).

Tom considered that Mantle-of-the-Expert had a specific use in the classroom – to enhance learning in a fun way.

Tom: With drama it's just plain fun. With Mantle-of-the-Expert it's learning with fun. So there is a bit of a difference (T&J, 05/10/11).

Cameron spoke about the usefulness of the approach, indicating that you could have fun, do drama and any other 'topic' you wanted.

Cameron: [In] Mantle-of-the-Expert you can have fun, you can act, do drama and you can still do all the topics (C&T, 05/10/11)

Lucy found the approach useful for finding out answers in science. She mentioned that she enjoyed both the science and the drama.

Lucy: I would say yay! Cause I like experiments and I like finding out answers by using drama cause science has got some drama in it (L&K, 05/10/11).

Taylor considered the approach was useful as it encouraged people to learn because it included drama, science and research in a fun way.

Taylor: It is really fun, so when people come, so you wake up you go, you think we are doing science today. You are doing a bit of drama, which is really fun and a bit of research so everyone wants to come to school and do it. Everyone wants to learn (C&T, 05/10/11).

To Brooke, being able to learn through a variety of different activities like 'drama' and 'experiments' was appealing.

Brooke: You get to do different things in Mantle-of-the-Expert, like learn drama and experiments and talking to a picture and things like that (B&J, 05/10/11).

Brooke, however, did not consider that learning science through Mantle-of-the-Expert was different to learning science any other way. She considered that Mantle-of-the-Expert's main use was to make learning 'more fun'.

Brooke: It didn't make a really big difference to me 'cause I think last year we did science and it felt different but at the same time I think … I don't think the company is a big part of it. It is just something to make it more fun (B&J, 05/10/11).

While Cameron and Taylor advocated a balanced approach, saying you need to have a mix of learning and fun/drama.

Cameron: It's good to have a balance - so you are not constantly doing drama so you don't get sick of it and drying your eyes out through (reading) hundreds of books.

Taylor: You have to have a balance of learning and fun (C&T, 05/10/11).

While both the teacher and most of the students considered that Mantle-of-the-Expert could be a useful way to learn science, there were some disadvantages identified in the anonymous assessment (AA, 05/10/11). Of the 27 responses, four people wanted more drama and seven wanted less. Two students considered there was too much science and three too much writing. The other respondents either gave a unique reason or were not sure what to say.

5.4.5 Summary

The findings suggest that teachers and participants in this study felt that, overall, Mantle-of-the-Expert was a useful way of engaging learners in science.

The students considered that working collegially was engaging. They noted that it increased their access to ideas and expanded their thinking of concepts previously unthought of through discussion. The data also identified that learning and engagement were enhanced when the teacher and students work together at the same level.

Using physical activities was also recognised as engaging for the students, as it was preferable to learning through reading and listening. It also appeared to help them comprehend and retain learning.

Having fun was clearly identified as an engagement factor by most students in this Mantle-of-the-Expert unit. What was considered fun varied, with some students favouring drama, others the hands-on aspects of science or writing the report to the client.

In addition, most students considered that Mantle-of-the-Expert was a useful way to learn science through. TJayne proposed that the students were engaged because the unit was 'realistic'. The approach was useful as it could explore more than one curriculum area and incorporates both fun and learning.

5.5 Constraints for learning and teaching within this Mantle-of-the-Expert

There were a few constraints noted by the classroom teacher that may have influenced student learning in this study. In this section, I discuss TJayne's concerns over student engagement and explore the factors that she thought impacted student learning. I also outline the aspects that she considers are challenging in terms of using Mantle-of-the-Expert as a pedagogy approach.

Student engagement

The first area that she addressed related to student engagement (see section 5.4.0). As already mentioned the engagement continuum progresses from:

Attention ➔Interest ➔ Engagement ➔ Investment ➔ Obsession (Heathcote, n.d). According to Heathcote (Heathcote, 2010b; Heathcote & Bolton, 1995) in an ideal Mantle-of-the-Expert unit, we would hope to see most students at the obsession stage. In the pre-unit interview, TJayne described a previous microbiology-based Mantle-of-the-Expert, where the students were passionately engaged into the unit, and loved being scientists and doing science. She positioned her students as being very excited about science.

TJayne: They were <u>so passionate</u> about it. They were so engaged. If you asked them (we did a term reflection) what did they enjoy the most, it was being scientists and taking a fair test and taking swabs and using agar plates… I think naturally our kids are very excited about science (TI1, 25/07/11).

At her mid-unit, interview TJayne spoke about her impressions of student engagement into this study. She thought that it took a long time for the students to believe in the drama. This was not unexpected, as belief building is a process, as was shown in section 5.2.1.

TJayne: [It was] disappointing ... that the kids took so long to build belief (TI2, 13/09/11).

She identified that the students were teacher pleasing in the early stages. However, she considered that their belief in the scenario and engagement was heightened when both actual resources (newspaper articles) and fictional resources (through the drama) were used.

TJayne: I felt ... they were very much just trying to please us as teachers ... But then we got into the [newspaper] articles and they started to understand it a little bit more and then we went into a bit more drama and they started to really believe in it (TI2, 13/09/11).

Once students gained belief and the unit progressed, Jayne identified that students became more engaged, as her reflections on the lesson prior to the second interview noted.

TJayne: I actually did notice that with him [being engaged] ... Looking around the room, thinking about kids. I think today was a really good session. The only one I would say could possibly be [not engaged] was Jess [who] started to look elsewhere (TI2, 13/09/11).

When I spoke to TJayne after the unit, she felt we had engaged the students. When we evaluated their engagement at the end of the unit she identified that not all of them reached Heathcote's (n.d) continum of engagement 'obsession' stage. This she attributed to some of them not being 'completely' in role.

TJayne: They weren't that obsessed; which is the goal in mantle - to get to that obsession. I still didn't feel like the kids (some of them) were completely in role (TI3, 15/10/11).

TJayne offered several suggestions in her mid-unit (TI2, 13/09/11) and post-unit (TI3, 13/10/11) interviews as why the students were not as obsessed as she thought they should be.

One constraint, identified in her mid-unit interview, was that she considered the students lacked ownership over their learning because they were not having as much 'free-flow inquiry' as she thought necessary.

TJayne: I think it's (free flow inquiry) important [in Mantle-of-the-Expert] because then the kids have a lot of ownership over it [learning] (TI2, 13/09/11).

She also considered the students were not fully embodied in their role as scientists. While they were experts in science and were able to doing the science experiments in an expert manner, they did not own the experiments as their experiments. To her this meant that they were not the ones driving the research, which may have lessened their personal ownership.

TJayne: They absolutely loved the experiments but I don't feel like that they had, "I'm a scientist this is my experiment." I don't feel like they had ownership over it ... There were times when they were acting as experts [in science] … they were an expert at doing the experiment and getting the learning from it (TI3, 15/10/11).

Another constraint was the timing of the lessons. This study took place mainly in the afternoon, which TJayne recognised a time when students needed an "interactive" or more physical programme. Her reflection was that the time the unit was run was not ideal for the students to be totally focussed.

TJayne: I think that in the afternoons the kids need a different type of learning programme. One that's really interactive … I think umm maybe if we did it at a different time (TI3, 13/10/11).

As already described in section 5.4.2 having an interactive/physical programme was identified as enhancing engagement.

Another possible reason for students not being as obsessed, was that the lessons were not continuous. TJayne considered that not being able to be reflexive to the needs of the drama and the needs of the students meant that at times momentum was lost and it may not have run as well as it could have run.

TJayne: I actually think the continuity that you do it in .. I've talked to N & A about it. They'll do it all morning and middle or they'll do it all middle block and afternoon like depending on what the tension is you know and how engaged the kids are with it. It seems to run really well and keeps the momentum going (TI3, 13/10/11).

Brooke commented this constraint in section 5.4.3, mentioning that over time the Mantle-of-the-Expert became 'routine'.

Another constraint identified was the busyness of the term, which meant TJayne was unable to have extra Mantle-of-the-Expert sessions with the students when the researcher TR Carrie was not present.

TJayne: Ideally if there wasn't as much going on last term such as spring fair and speeches and all those sorts of things (TI3, 13/10/11).

Other pedagogical challenges

TJayne also looked at other pedagogical challenges that may occur when working in Mantle-of-the-Expert.

One aspect highlighted in the mid-way interviews was whether learning science through Mantle-of-the-Expert puts more pressure on the teacher. TJayne considered that organising the materials took time but acknowledged the approach helped ‘consolidate’ understanding because it occurs in the ‘immediate now’ time, which positions them as if the action was happening in front of them, which adds immediacy to the learning.

TJayne: It [Mantle-of-the-Expert] is definitely more demanding for materials. But it definitely helps consolidate their understanding because they are seeing it happening right in front of them (TI2, 13/09/11).

However, when we discussed the challenges of resources further, she decided it was the science rather than Mantle-of-the-Expert that was more demanding as to what was needed to support the students’ understandings of science concepts.

TJayne: It [science] requires a lot of materials for them to really understand (TI3, 15/10/11).

As well as being demanding in terms of materials, TJayne also indicated that working in Mantle-of-the-Expert is demanding in terms of creativity, time and courage, which she defined as being willing to let the kids go and trust that they can lead their own learning.

TJayne: A lot of creativity and time and a lot of I don’t know what the word is - I think it’s courage. You gotta be able to just let go of the kids and trust that they will be able to lead it and that’s really hard to do (TI2, 13/09/11).

According to their teacher there were a range of factors that led to students not being fully engaged in this unit. These included: pressures of time, lack of continuity, excessive extra activities and students not having personal ownership of their learning. TJayne noted that it took time to organise the resources. She also identified that to teach in Mantle-of-the-Expert required creativity and courage.

5.6 Chapter Summary

This chapter has presented the themes highlighted in the data from the classroom episodes, interviews, student artefacts and the researcher blog, supplemented with data from student assessments when the focus was on the construction of a Mantle-of-the-Expert unit.

The importance of positioning in Mantle-of-the-Expert was highlighted as crucial in building belief in the fictional context of the drama and establishing an identity as an expert scientist in the company. Students were positioned into role as company members through teacher use of explicit speech acts and through sign. Their changing pronoun usage from abtract 'the company' into personal collective pronouns, such as 'our company,' demonstrated agreement to working within the fictional company roles. The data further showed that students moved from acceptance of being positioned as company members into self-positioned roles as expert scientists as they constructed their identity through making dramatic artefacts. It additionally appears that operating in an adult expert position was useful in enhancing some students' self-efficacy and learning.

A prominent theme in this study was 'Positioned as ethical scientists'. The data presented showed that ethicality was built gradually through students' interactions with sign, dramatic conventions and the use of teacher in role. Being ethical underpinned how students acted in their scientist roles and this affected their work in the classroom. This orientation provided an imperative to investigate the science behind the sinking of the Wahine as set out in their commission for the client but also the people who had been affected by the disaster and research ethically, as it connected 'real life' to the classroom. Interacting with the 'fictional others' - Malcolm and Roger - gave the students a reason to work diligently and strive for excellence. Students also explored the notion of criticality in terms of their interactions with the 'captain' and the need to ensure that they had evidence to back up their findings.

Students' engagement into learning was evidenced through students' commitment to the drama and the learning. Being collegial opened up an inclusive space where teacher and students worked together. This led to rich discussion and expanded student access to a range of ideas. Learning through physical activities hooked the students into learning as well as aiding, according to the students, their comprehension and retention of science ideas. The drama[14], science and writing were all recognised as being ‘fun’ and engaging for the students. Their engagement was also seen as a commitment to the tasks and the way they wanted to fulfill the commission to the client by invetigating the sinking of the Wahine and writing their report to the client. Most students also considered that they were more engaged in science when Mantle-of-the-Expert was used in learning. Also identified as valuable was framing the drama in realistic contexts.

While learning through Mantle-of-the-Expert was perceived as enhancing learning, the teacher identified some constraints. They included the amount of resources she needed (especially in science) and the necessity to be courageous and creative. In addition, she felt that in the staging of the unit, other demands on student time meant less inquiry than she desired, which may have affected student ownership and student obsession in this particular unit.

[14] ‘Drama’ here means using dramatic conventions such as freeze frame and teacher in role.

Chapter Six: Findings – Learning Science concepts

6.1 Introduction

The chapter examines whether working through Mantle-of-the-Expert and being positioned as expert scientists re-investigating the sinking of the Wahine, helped students to learn and communicate the targeted science concepts of buoyancy, stability, cyclone formation and isobar map interpretation. Although there were more science concepts addressed in the unit, only these ones are focused on in this thesis because of limitations of space.

The main learning objective for this unit was for students to be able to use the concept of buoyancy (and the related concepts of floating, sinking and stability) to give scientific reasons for the sinking of the Wahine. I was particularly interested in these concepts because Flockton and Crooks (2000) state that concepts of buoyancy and floatation tend to be "beyond the reach or experience of almost all year 8 students" (p. 39).

Definitions and conceptual understandings were drawn from the "big ideas" about buoyancy on the inner cover of *Understanding buoyancy: Why objects float and sink* (Ministry of Education, 2003). The big ideas I deemed important relating to buoyancy and stability in the context of this study are set out in Table 6.1. Definitions of buoyancy used in this study are given in appendix S. As the buoyancy ideas are taken from a Ministry of Education book, they are linked to curricular levels[15], which are indicated by **L1, L2, L3** and **L4.** The objectives in the stability big idea 4 are not curricular levelled.

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[15] The NZC (Ministry of Education, 2007) has eight levels. Year 1 and 2 - level one, Year 3 and 4 – level two, Year 5 & 6 – level three and Year 7 and 8 – level four. Levels five to eight are for secondary students.

The following two research questions are explored throughout this chapter and in chapter seven.

2. What shifts in students' written and verbal use of science concepts, nature of science and science vocabulary occurred over the course of a nine-week Mantle-of-the-Expert unit?

3. How do the year 7/8 students in this study see themselves in science now and in the future?

This chapter focuses on the first part of the research question 2, and presents data to illustrate shifts/changes in students' conceptual understanding and vocabulary maturation closer to the scientific norm. It also looks at the student attitudes towards the science portion of research question 3. Shifts in students' understanding about NOS and science careers are outlined in chapter seven.

Shifts in students' conceptual understandings are triangulated across oral data drawn from whole class discussions as well as from their assessments, interviews and written reports.

Table 6.1 Science concepts explored connected to buoyancy and stability in this study

Big Idea 1	**An object floats if it is less dense than the water it is floating in**
1A	An object that is light for its size compared with water will float in water **(CL1)**
1B	Usually an object with air trapped inside it will float **(CL1)**
1C	We can make a sinking object float by changing its shape to increase its volume **(CL2)**
1D	The less matter contained in a given volume of a subject , the less dense it is and the more likely it is to float **(CL3)**
1E	The combination of mass and volume determines whether an object floats or sinks **(CL4)**

Big Idea 2	**An object floats when its weight is equal to the weight of the water it displaces**
2A	A floating object usually lies on top of the water **(CL1)**
2B	When we put an object in the water, it pushes the water out of the way. (We call this "displacement".) **(CL2)**
2C	When two objects float, the heavier object displaces more water than the lighter one does **(CL3)**
2C	An object sinks if the weight of the water it displaces is less than the weight of the object **(CL4)**

Big Idea 3	**An object floats in water when the upthrust balances the object's weight**
3A	Sinking is a type of falling **(CL1)**
3B	An object sinks unless something holds it up **(CL1/2)**
3C	An object floats when it is held up by water **(CL2)**
3D	The combination of upthrust and weight determines whether an object floats or sinks **(CL3)**

Big Idea 4	**The stability of a vessel refers to its ability to stay upright in the water**
4A	The vessel tips or is unstable **
4B	The placement of increased weight affects the stability of the vessel **
4C	When the centre of gravity changes the vessel becomes unstable **
4D	'Free Surface Effect' contributes to the sinking of the Wahine (any allusion to this phenomenon) **

* CL = Curricular Level 1,2,3 or 4 in the New Zealand curriculum

** Big Idea four – Stability is my work and hence is not linked to curricular levels.

*** Science Concepts Overview. [Adapted from] *Building science concepts 38: Understanding buoyancy: Why objects float and sink* (inner cover) by Ministry of Education, 2003, Wellington, New Zealand: Learning Media. Reprinted with permission.

6.2 Buoyancy explored orally at four signposted episodes

This section sets out dialogue from four episodes at different stages in the unit where buoyancy and stability were a particular focus to illustrate student conceptual development. Student learning was examined in terms of the factors that affect the floating and sinking of objects in water - the forces acting upon the object and its density and volume. In addition, the concepts of free surface effect and centre of gravity in relation to the Wahine's capsize are detailed under the big idea of stability.

YouTube viewing: Episode Two (ET, 4/8/11)

This episode took place on second day of the unit when we introduced the unit to the class. It occurred after viewing a YouTube clip of the television news on the night the Wahine sank. Students proposed reasons for the sinking. The following comments are excerpts from their discussion relating specifically to buoyancy. Brittany described what had occurred without any reference to science concepts.

Brittany: The Wahine hit a rock and got a hole in the hull (ET, 04/08/11).

Mitchell identified the vessel lost air after it was holed. Alicia clarified that it didn't lose all the air entirely; perhaps alluding that it took the vessel some time to sink.

Mitchell: The air went out of the Wahine when it got holes in it and the water started flowing in.

Alicia: It wasn't full of water. It had some air inside (ET, 04/08/11).

Will provided an explanation that used ideas to do with pressure and air being thinner or compressed, which indicated an awareness of science-related vocabulary and ideas albeit somewhat confused. Will mentioned the water was compressing the air. By mentioning pressure, he was alluding to big idea 2B displacement – when you put an object in water it pushes the water out of the way. He seemed to have the idea that the water forces the air out.

Will: When you push it out, there's all the air, but there is more water pressure, so the water is going to be able to force the air out and because air is thinner it's going to compress the air and maybe the

> compressed air punctured a hole which is where. So maybe the water flowed in and moved to the side (ET, 04/08/11).

Mitchell, Alicia and Will identified that for a boat to float it has to have air inside it (1B). I have linked this understanding to big idea 1, which focuses on density and achievement objective 1B - usually an object with air trapped inside it will float, because these students recognised that when the vessel was holed, water flowed in and air escaped, making the boat heavier and leading to its eventual sinking.

Shania, Taylor, Will and Student A mentioned that the vessel tipped because it had more water on one side than on the other (4A). Shania alluded to the stability of the vessel and the influence of a shift in its centre of gravity (4C). However, she hedged her authority by saying, "I'm kinda guessing".

Shania: Every ship has something that goes down the middle… I'm kinda guessing that the water went on one side and it filled up with water and the other side was filled with less water. And that's why it tipped over (ET, 04/08/11).

In this episode, the students generally used simple vocabulary to explain what they had viewed on the video-clip. They showed an awareness of the vessel needing air to float. There was a vague reference to displacement. One child could be seen to be tentatively talking about the centre of gravity in layman's terms. The students recognised that the vessel tipped because of the added mass of the water on one side. On the whole, the way they talked about buoyancy was set at curricular level one.

Collective role as Expert Meteorologists: Episode 10 (ET, 25/8/11)

This conversation about buoyancy took place within a larger discussion about meteorology, three weeks into the unit. The aspect of buoyancy explored was big idea 1 - density, in particular the concept that objects containing air usually float. Shania indicated she was grappling with understanding about how forces operate on objects when she gave the example of a flutter board always popping up in the water. She wondered if this was caused by pressure. This aspect of upthrust (big idea 2) was not picked up and developed by either the teachers or the students in this lesson.

Shania: When you have a flutter board[16] it always pops up. Is it to do with pressure (ET, 25/08/11)?

Student A explained that the ‘popping up’ of the floater board was due to it being filled with air (1B).

Student A: I think I know why – it’s filled with air and not water!

Student B offered the reverse of this statement, noting that an item will sink if filled with something heavy (1A). He then linked this to ships floating because they are filled with air (1B).

Student B: If it is filled with something heavy it sinks. But if it is filled with something light like air it floats cause that’s why ships float, cause they’re filled with air (ET, 25/08/11).

Alicia, Will and Tom mentioned that if you expel air out of your lungs you would sink (1B). Tom used a simile to make comparisons, “If you don’t have air you will just sink as a rock” by giving an example of an object not containing air (a rock) sinking.

Alicia: If you blow your air out [when scuba-diving], then you sink.

Will: An experiment that I did once … submarines … I had the idea of going under water and blowing out all the air, expelling as much air as I can so I was like blowing out and I starting sinking (ET, 25/08/11).

Overall, student comments suggest there was an understanding that objects without air sink, indicating some knowledge of the reciprocal nature of floating and sinking in relation to air being present and what student B described as being ‘filled with something heavy’.

In role as classroom teacher I probed student understanding about how changing one’s shape (volume) can affect whether one floats or sinks within the context of learning to swim, using physical gestures to support my words. Student C unequivocally stated that you sink when your shape is vertical.

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[16] Floater boards are buoyancy devices used in teaching people to swim. Alternate names are kickboards, or swimming boards.

TRCarrie: Is there something to do with our shape as well [to make us sink]? ... If you are in the school pool like that [*showing with body a person who is standing straight]* what happens?

Student C: You sink (ET, 25/08/11).

I probed further, giving another example of floating in the starfish formation (body splayed out). Student D's response that, 'the weight is spaced out', indicated he could be thinking both in terms of mass and volume but not necessarily using scientific terminology. This would imply his thinking was related to learning objective 1E – the combination of mass and volume determines whether an object sinks or floats.

Student D: The weight is more spaced out; cause when you are like this [*showing straight up*] your weight is down. When you are like this [*showing starfish shape*] your weight's spread out evenly (ET, 25/08/11).

Although earlier Shania had seemed secure in her knowledge that 'things filled with air float', in what follows we see she was still wrestling with other aspects of buoyancy. She could not understand why a polystyrene kickboard floated because she equated objects that contain air as being able to float and she thought the kickboard was filled with a rubber substance, not air.

Shania: I'm just a little bit confused 'cause I know that things filled with air float but why do polystyrene kick boards float, cause they don't have air in them ... [and] are filled with this rubber substance (ET, 25/08/11).

When I suggested that we (the company) should test the buoyancy of different types of substances, Shania suggested we look in particular at objects that are the same weight but made of different substances. This comment indicated that she was aware that some objects with the same weight float, while other objects do not and that she had an inkling that it was to do with the substances they were made from, indicating some knowledge of density (1D – the less matter contained in a given volume of an object the less dense it is and the more likely it is to float). However, she was not able to fully describe this phenomenon.

Shania: Get two different things the same weight and see what sinks and what floats (ET, 25/08/11).

From the data presented here, it can be seen that most students realised that objects filled with air generally float (1B) and by extension boats, which are filled with air float. However, they also identified that if items are filled with something heavy they may sink (1A). They also identified that the shape of an object affects its ability to float (1C). Shania showed through her questioning that she was actively trying to come to an understanding of how the substance an object is made of (or how dense the substance is) affects its ability to float (1D, 2C). Thus, while many students were articulating ideas about buoyancy at level one, a few students tentatively described concepts at higher curricular levels.

The paper boat experiment: Episode 11 (ET, 06/09/11)

Approximately two weeks later in episode 11, the students explored notions of stability and buoyancy, looking in particular at displacement and touching on aspects of volume/shape. Students in role as expert scientists were responding to a request by the client to reproduce the sinking of the Wahine, using marbles and paper boats (ET, 06/09/11).

The sequence began with me asking students about the placement of the mass/marbles in the paper boats. Shania indicated that she placed them equally on both sides of the paper boat.

Shania: One, two (evenly) (ET, 06/09/11).

Girl A remarked that when the marbles were placed equally, the paper boat went straight down.

Girl A: It just went straight down (ET, 06/09/11).

I asked the students in another research group how they managed to make the sinking of the paper boat replicate the sinking of the Wahine. Mitchell described how he placed the marbles unevenly.

Mitchell: The Wahine was on its side and how you compare, just a marble on that side and two marbles on that side (ET, 06/09/11).

Student A identified that one side of the vessel had more weight.

Student A: One side had more weight (ET, 06/09/11).

The students who spoke recognised that the placement of the marbles affected the way the paper boat sunk and how stable it was (big idea 4). They recognised that increasing the weight on one side affected the stability of the vessel (4A/B).

Mitchell was so enthusiastic that he made some enormous paper boats at home and experimented with them. He told me that it took a much larger number of marbles to sink the bigger vessel.

Mitchell: The big boats that we had, we had like 45 marbles [to sink it] (ET, 06/09/11).

I asked the boys in Mitchell's group if the size of the boat mattered in terms of the mass it could bear before it sank. Boy A indicated that a bigger boat is more spread out than a smaller boat (1C). He also noted that the weight could also be spread out.

Boy A: The boat's more spread out, so is the weight (ET, 06/09/11).

Student B identified that the vessel was just a 'bigger' version of the same shape.

Student B: Bigger (ET, 06/09/11).

The discussion indicated that the students considered the size of the boat only mattered in terms of how many marbles it took to sink it, in this case 45. The proportion of weight relative to the scale of the paper boat was also important - as the boat got bigger the amount of weight it was able to bear before sinking increased. While the boys noted that as the paper boat got larger both its shape and weight were more spread out; they did not appear to have a grasp of the scientific terminology regarding volume (or the amount of space an object occupied) (1C, D and E). They used everyday language to describe what had occurred.

Students were asked to draw waterlines on the paper boat so they could observe what happened when additional mass (marbles) was placed onto the paper boat in order to explore the notion of displacement. When I asked the class what happened to the waterline when more mass or cargo was added to the boat Lance explained the waterline rose but Conrad thought it went down. Conrad also spoke about pressure; he may have been alluding to big idea 2B - when we put an object in the water it pushes the water out of the way.

Lance: It [the waterline] went up to the side of the boat.

Conrad: It went down… because there was pressure (ET, 06/09/11).

Student C asserted that it was the boat going down because of the added mass, which he termed weight.

Student C: It wouldn't be the water that rose up, it would be the boat going down, because you put a big weight onto the boat, which makes it go down (ET, 06/09/11).

Student C recognised that the vessel sat lower in the water after mass was added. This relates to learning objective 2C - when two objects float, the heavier object displaces more water than the lighter one does and 2D - an object sinks if the weight of the water is less than the weight of the object. They observed that more water was displaced and although the vessel was still floating in it, more of it was below the water surface.

Shania gave an everyday example of what happens when mass is added, in relation to people getting into a spa pool and identifying that when lots of people get into a spa pool, the water rises up.

Shania: You know if you see like a spa and then lots of people get in it and the water rises up…

Student D identified that what was happening was displacement.

Student D: Displacement.

This sequence concluded with Will linking the concept of displacement and people getting into a spa, with the learning under discussion – the waterline on the boat. Displacement (2B) in this context was reflected in the boat going down with increased mass and the water rising above the waterline.

Will: [Displacement is] actually both because when you are putting weight onto the boat, the boat goes down and water also goes up.

Near the end of this episode I put the question to the class: Why do boats float? Student E responded using the scientific term buoyancy, rather than the everyday term 'float'. The notion of air being a factor in floating was again highlighted (1B). However, this was coupled with a misconception that air helps items float because air rises. The same student recognised that what items were filled with affected whether they floated or sank (1D) with steel drums being full of steel and boats full of air. This student is representative of those who offered comments at this point in the unit in that she/he used a mixture of science and everyday language and common sense to explain what was observed.

Student E: The reason boats float is to do with buoyancy. Boats are filled with air and big steel drums are full of steel and that’s why steel drums sink and ‘cause air rises, cause that’s why boats float (ET, 06/09/11).

To sum up, modelling the sinking of the Wahine with a paper boat and marbles and subsequent discussions enabled students to explore stability, displacement and the volume/shape aspect of density. Students noted that when the mass on the vessel was increased, it sat lower in the water and eventually sank (2C). They recognised that where they placed the marbles affected whether the vessel sank straight down or unbalanced and sank on its side (4A/B). They began to think about displacement (big idea 2), using the waterline to visually see the boat displacing more water as mass was added (2B) and the everyday example of the spa pool. Students used both everyday and scientific language to discuss the experiment and explore buoyancy. Their comments about buoyancy and displacement were generally at level two and above in this section.

Preparation for writing the report: Episode 14 (ET, 15/09/11)

This episode occurred at the end of the unit, when the students, in role as expert scientists, were planning their reports detailing their findings for the client. The students worked in research groups to generate and record their understandings of what caused the Wahine to sink on sheets of A2 paper. Then the whole class gathered to construct a collective understanding. The student research group sheets and the classroom dialogue were examined to ascertain the breadth of understanding and vocabulary used by the students in describing buoyancy, stability and free surface effect. Figure 6.1 is an example of a group sheet.

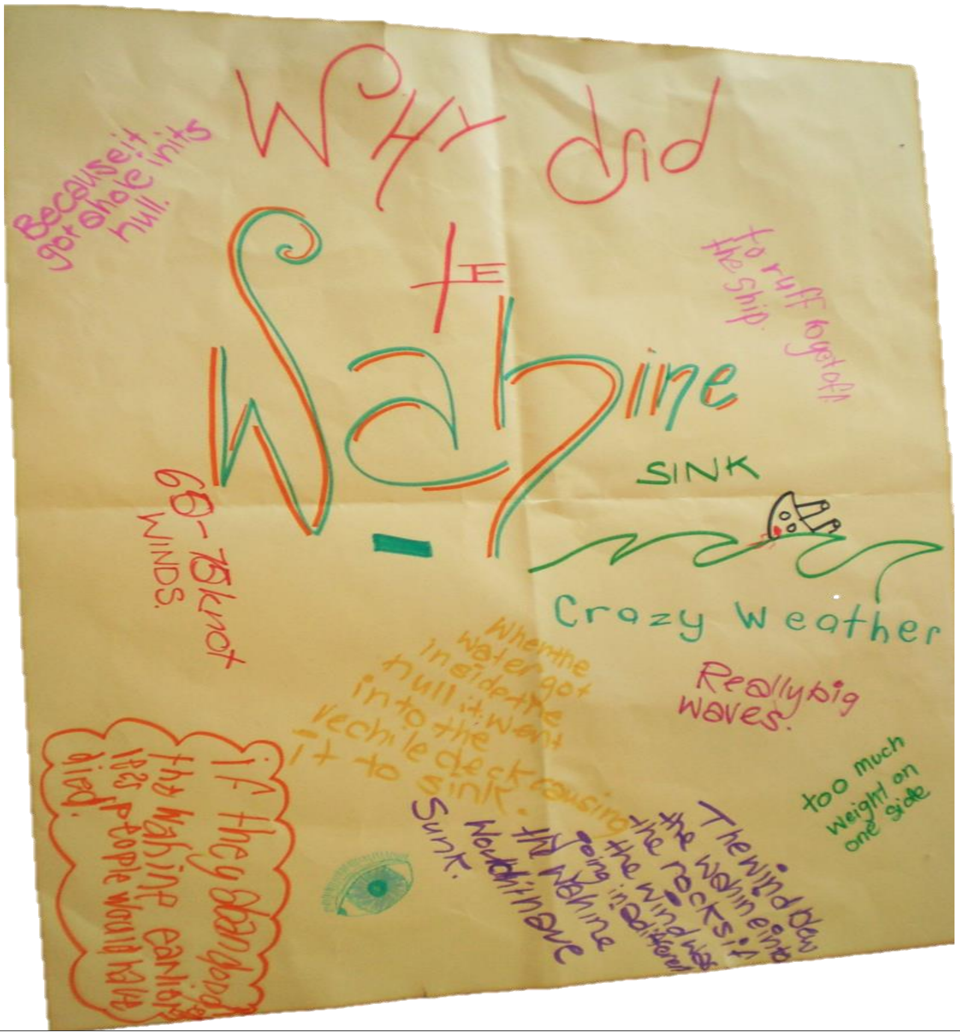


Figure 6.1 Example of a research group's collaborative reasons for the sinking of the Wahine

The reasons for the sinking of the Wahine given by the student research groups were collated into six categories: general sinking, weather related, density, stability, free surface effect and other (see appendix T). All of the groups considered the extreme weather was a significant contributor to the sinking; five of the six groups mentioned water entering the vessel and the loss of air (1B) after the holing as a contributing factor. Four of the six groups mentioned density on their sheets. For example, Group five wrote, “When the Wahine became full of water which meant the inside was more dense” (1D). Five groups mentioned that the vessel sank because it became unbalanced and tipped/capsized due to having too much weight on its right/starboard side (4B). The students did not link this with a change in stability. Three groups mentioned water got onto the vehicle deck, causing ‘free surface effect’ (4E), which the official board of inquiry into the sinking of the Wahine had suggested was the “immediate cause of the capsize” (Lambert & Hartley, 1969, p. 204).

Then, the students shared their ideas about floating and sinking in a whole class discussion. Big idea 1 – an object floats if it is less dense than the water it is floating in - was the big idea that was most frequently used by the students to explain floating and sinking. Several representative comments relate to objects either being light for their size or containing air. For instance, Student A remarked that pumice is ‘very light’ (1A) and contains ‘air’ (1B).

Student A: Pumice is made of a very light thing. It’s got more air bubbles throughout it (ET, 15/09/11).

While Tom considered pumice floated due to the presence of ‘air’ (1B).

Tom: Pumice is ... filled with air, so there are holes in it … and it floats on the water (ET, 15/09/11).

Boy A noted that even when some of the holes in pumice were filled up with water; it could still float (1B). He was somewhat confused about why pumice floated, constructing a synthetic conception, asserting that it was the air above the water that helped it float, rather than being light for its size (1A).

Boy A: Pumice has holes and if you put it in the water, they keep filling with water and if there’s still air in the top some of it will be under water (ET, 15/09/11).

Taylor claimed things filled with air float ‘really well’ and are buoyant (1B),

Taylor: Buoyancy is floating and something that is filled with air floats really well (ET, 15/09/11).

Students also talked about density. Student B alluded to matter, when he suggested that objects with ‘more stuff’ in them would not generally float (1D).

Student B: They were full of stuff (ET, 15/09/11).

Boy F, referred to the boat becoming denser (1D) when water entered the boat, while Hamish claimed the boat tipped (4A) because the density (1D) was increased on one side due to the water filling up the boat on that side.

Boy F: Water started flying in and made the boat denser.

Hamish: The water filled up causing one side to be denser and tip to one side (ET, 15/09/11).

Will identified that the additional water increased the Wahine's density (1D). He also mentioned mass (1E) and attributed the tipping of the vessel to the unequal placement of water (4B)

Will: The Wahine sunk on its side because there was more water on one side than the other. There's more density or mass and it was going to weigh that side down and cause it to tip (ET, 15/09/11).

There were a few other comments about weight adding to the heaviness of the vessel. Both Boy E and Taylor identified that water getting into the Wahine made the vessel heavy, alluding to the fact that the Wahine was unable to bear its weight in the water (1E/3C).

Boy E: Water got into the Wahine and it got too heavy.

Taylor: Once water gets into the [boat], it starts sinking because it gets really heavy (ET, 15/09/11).

Will demonstrated sophisticated thinking talking about displacement (big idea 2) and upthrust (big idea 3). He asserted that if objects 'lighter than water' (1A) were used to build boats, they would float and if objects weigh more than water they sink (2D).

Will: Boat building, people use steel with that. And actually if you use something with less, that's lighter than water – it's not gonna sink... So you are going to have to get something that weighs more than water … to sink (ET, 15/09/11).

Girl B linked Will's statement to density when she agreed that 'water and other things were denser than air' (2D).

Students also discussed the stability of the vessel. Shania mentioned that water getting in affected the weight (everyday term) of the vessel, causing it to tip (4B).

Shania: The water and weight was on one side causing it to tip on its side (ET, 15/09/11).

Will considered the boat lost buoyancy because the 'density was increased' when the water flowed in (1D). He attributed the boat tipping to having more water on one side than on the other (4B). He also alluded to 'free surface effect' by talking about the water moving from side to side (4E).

Will: The boat became less buoyant because the density was increased because the water started flowing through and it was flowing from one side to the other because there was more water on one side than the other, it tipped over (ET, 15/09/11).

Shania similarly mentioned water on the vehicle deck (4E), which was the main reason why the vessel eventually could not stay upright.

Shania: When the Wahine got into the harbour it struck the bottom making holes, which got water into the vehicle deck, which caused it to capsize (ET, 15/09/11).

In summation, the 17 students who spoke in this episode demonstrated a greater depth of thinking than in the first lesson about buoyancy. They explained that the buoyancy of the vessel was affected when "water got into the Wahine" after hitting Barrett Reef. They recognised that objects containing air and less dense than water would likely float. In this episode only a couple of students mentioned displacement and upthrust. Students identified that when extra water was added to the vessel it became heavier. The placement of the water on one side led to it tipping. Two students alluded to free surface effect. While a few students still described buoyancy with level one concepts such as 'air', a greater number of students were using descriptions set at level two of the curriculum and higher.

Development of student conceptual understanding in terms of the big ideas

To gain another perspective on the students' understanding of buoyancy and stability, the dialogue from the four episides explored earlier in this section, was collated into tables looking at the big science ideas under examination. The first three tables explore the three 'big ideas' of buoyancy density (Table 6.2), displacement (Table 6.3) and upthrust (Table 6.4), while, Table 6.5 examines stability and the related ideas of centre of gravity and free surface effect. I will examine the student statements in terms of the achievement objectives and link to curricular levels where available.

Several factors are apparent in Table 6.2, which documents ideas related to density. Student comments from two episodes were compatible with 1A - an object that is light for its size compared with water will float in water. Students in all the episodes recognised that ‘having air’ helped objects float, which is compatible with objective 1B - Usually, an object with air trapped inside it will float. In two episodes students recognised that how the object was shaped affects its floating ability, which links to 1C - We can make a sinking object float by changing its shape to increase its volume. The students referred to weight being ‘more spread out’. In the later three episodes, six students used dialogue that related to 1D - The less matter contained in a given volume of a subject, the less dense it is and the more likely it is to float. In the first two episodes students were using more everyday words like heavy; by the later two they were using more complex words like density and buoyancy.

Table 6.3 looks at displacement. Displacement was not discussed in the You-Tube episode. Students expressed the level one understanding 2 A - floating objects usually sit on top of the water in the Meteorology and Report episodes. In the Paper Boat episode (ET, 06/09/11), there was discussion about displacement. Shania, speaking about what happens when people get into a spa pool expressed her understanding in terms of learning objective 2B - when we put an object in water, it pushes the water out of the way. She commented, “You know if you see like a spa and then lots of people get in it and the water rises up.” Other students working at 2C and 2D identified that when more weight or mass was added to the vessel, the boat sat lower in the water. The understanding expressed was more in the nature of what occurred rather than a concrete articulation of the science concept. In the Report episode (ET, 15/09/11), two students expressed an understanding of displacement that was close to 2D – an object sinks if the weight of the water it displaces is less than the weight of the object. For instance, Will asserted that for something to sink it has to weigh more than water.

Table 6.4 presents the findings relating to upthrust. No students commented that sinking was a type of falling (3A). One person in the Report episode commented that the air held the vessel up for awhile (3B), indicating level one / two thinking. Nobody used the term upthrust, but one person mentioned the support of the water (3C) in a very vague way, perhaps indicating a very weak level two understanding in the first expisode. All of the other comments related to the level three learning objective 3D - the combination of upthrust (the support force of the water) and weight (the downward pull of gravity) determines whether an object floats or sinks. The students spoke about the impact of increased weight on the boat floating. In the Report episode student were using mass and density rather than weight to talk about boats sinking, which seems to show development in knowledge of scientific terminology.

Table 6.5 records discussions about the stability of the vessel. In the YouTube episode (ET, 04/08/11), two students talked about the Wahine tipping in isolation thus meeting the criteria of learning objective 4A. However, most of the eight students from three episodes who offered an explanation of why the vessel unbalanced, indicated that the weight of the vessel was increased on one side, due to the water getting into the boat, making it denser. This linked to learning objective 4B - Mention made of placement of increased weight affecting stability of vessel. One student in the YouTube episode (ET, 04/08/11) alluded to the centre of gravity, stating, “Every ship has something that goes down the middle”. Two students in the Report episode (ET, 15/09/11) mentioned ‘water on the vehicle deck’ as a factor in the vessel sinking, alluding to ‘free surface effect’. One student used the term ‘capsize’- a more sophisticated word for tipping in the Report episode (ET, 15/09/11).

Table 6.2 Student understandings of Big Idea 1 over the course of the signpost episodes

Big Idea 1 An object floats if it is less dense than the water it is floating in

Episodes	**Achievement Objectives**			
	1A **An object that is light for its size compared with water will float in water. L1**	**1B** **Usually, an object with air trapped inside it will float. L1**	**1C** **We can make a sinking object float by changing its shape to increase its volume. L2**	**1D** **The less matter contained in a given volume of a subject, the less dense it is and the more likely it is to float. L3**
You-Tube		It [the boat] had some air inside.		
Meteorology	Get two different things the same weight and see what sinks and what floats.	I know that things filled with air float If you blow your air out, then you sink.	The weight is more spaced out.	If it is filled with something heavy it sinks. But if it is filled with something light like air it floats.
Paper Boat		Boats are filled with air If you don't have air you will just sink as a rock.	The boats more spread out, so is the weight.	The reasons boats float is to do with buoyancy. Boats are filled with air and big steel drums are full of steel and that's why steel drums sink.
Report	Air and a little bit of water can float. The air's light so they can stay above the water	Actually if you use something with less, that's lighter than water – it's not gonna sink. Is [Pumice] still floating if it's not touching the bottom but it's under the water a bit? – "Yeah". Buoyancy is floating and something that is filled with air floats really well because air is very light and something. Once water gets into that thing it starts sinking because it gets really heavy.		The boat filled with water creating more density. Boat held up because it is less dense than water. Water and other things are denser than air. A stone will always sink cause it's a stone. Pumice is made of a very light thing. It's got more air bubbles throughout it.

**1E: The combination of mass and volume determines whether an object (or the system containing more than one object or material) floats or sinks, was not used in this snapshot of student understanding.

Table 6.3 Student understandings of Big Idea 2 over the course of the signpost episodes

Big Idea 2: An object floats when its weight is equal to the water it displaces				
Episodes	**Achievement objectives**			
	2A **A floating object usually lies on top of the water** **L1**	**2B** **When we put an object in water, it pushes the water out of the way. (We call this " displacement".)** **L2**	**2C** **When two objects float, the heavier object dispaces more water than the lighter one does.** **L3**	**2D** **An object sinks if the weight of the water it displaces is less than the weight of the object.** **L4**
You-Tube	-	-	-	-
Meteorology	When you have a flutter board it always pops up.		Get two different things the same weight and see what sinks and what floats.	
Paper Boat		You know if you see like a spa and then lots of people get in it and the water rises up. (Shania)	If the boat when you are putting in its weight, actually both because when you are putting weight onto the boat, the boat goes down and water also goes up. [After more mass was added] it [the waterline] went up to the side of the boat. It wouldn't be the water that rose up, it would be the boat going down, because you put a big weight onto the boat, which makes it goes down.	It [the boat] went down… Because there was pressure.
Report	It wanted to go down if you put weight in it. It would it go sink? It didn't sink – it would just float. [Pumice] … it's filled with air, so there's holes in it … and it floats on water. Pumice has holes and if you put it in the water, they keep filling with water and if there's still air in the top some of it will be under water.			Boat building, people use steel with that. And actually if you use something with less, that's lighter than water – it's not gonna sink... So you are going to have to get something that weighs more than water and weighs more than the earth well oh to sink Once water gets into that thing [boat] it starts sinking because it gets really heavy

Table 6.4 Student understandings of Big Idea 3 over the course of the signpost episodes

Big Idea 3: An object floats in water when the upthrust balances the object's weight

Episodes	**Achievement objectives**			
	3A **Sinking is a type of falling. L1**	**3B** **An object sinks unless something holds it up. L1/2**	**3C** **An object floats when it is held up by water. L2**	**3D** **The combination of upthrust (the support force of the water) and weight (the downward pull of gravity) determines whether an object floats or sinks. L3 ###**
You-Tube Meteorologist Paper boats			It wasn't full of water. It had some air inside.	[The boat] is heavy. If it is filled with something heavy it sinks. One side had more weight. It [Pimsoll line] went down… Because there was pressure. If the boat when you are putting in weight, it's actually both because when you are putting weight onto the boat, the boat goes down and water also goes up.
Report		It tipped over and the air was trapped on one side, which probably held it up a little longer than it would have, while the water filled up the other [side].		There's more density or mass and it was going to weigh that side down and cause it to tip. When the water got inside the hull it went into the vehicle deck causing it to sink. The water filled up causing one side to be denser A stone will always sink cause it's a stone

The level four Big Idea was not explored in this unit or included in this table.

Table 6.5 Students' understanding of Big Idea 4 over the course of the signposted episodes

Big Idea 4: The stability of a vessel refers to its ability to stay upright in the water				
Episodes Achievement objectives				
**	**4A** **Mention of tipping or stability**	**4B** **Mention made of placement of increased weight affecting stability of vessel**	**4C** **Centre of gravity**	**4D** **Free surface effect was alluded to**
You-Tube	The Wahine it tipped over. The Wahine was just slowly going down on its side	Maybe the water flowed in and moved to the side.	Every ship has something that goes down the middle… I'm kinda guessing that the water went on one side and it filled up with water and the other side was filled with less water. And that's why it tipped over.	
Meteorologist	-	-	-	-
Paper Boat		The Wahine was on its side and how you compare, just a marble on that side and two marbles on that side. One side had more weight		
Report		Too much weight on one side. The water and weight was on one side causing it to tip on its side. The water filled up causing one side to be denser and tip to one side. The Wahine sunk on its side because there was more water on one side than the other. There's more density or mass and it was going to weigh that side down and cause it to tip. The boat became less buoyant because the density was increased because the water started flowing through and it was flowing from one side to the other because there was more water on one side than the other. It tipped over and the air was trapped on one side which probably would have held it up a little longer while the water filled up the other [side].		When the Wahine got into the harbour it struck the bottom making holes, which got water into the vehicle deck, which caused it to capsize. When the water got inside the hull it went into the vehicle deck causing it to sink.

**** As stability was not taken from the Building Science Concepts books – no curricular levels were given**

Summary of student learning about buoyancy over the four episodes

It is apparent from the dialogue in the four episodes that students were wrestling with understanding buoyancy and the associated ideas of density, mass/weight, volume/shape, displacement, upthrust and stability. In addition, they were exploring what causes vessels to float and sink through the example of the Wahine. Examples from everyday life such as school swimming, pumice and spa pools were used as a conceptual bridge by the students when seeking an explanation for what occurred when the Wahine sank. These examples illustrate that students were linking their prior knowledge to the phenomenon being explored. Using the YouTube video, the in-role expert discussions and experiments gave students some concrete information and evidence to use to aid their reasoning about buoyancy.

These four classroom episodes provided a snapshot of the collective thinking of the class regarding buoyancy. The science explored in the different episodes highlighted different aspects of floating and sinking, and the episodes built on each other to deepen students' knowledge about buoyancy. In terms of buoyancy, the students showed more familiarity with the density component of buoyancy than the displacement or upthrust aspects.

The data presented shows that the students were beginning to use scientific terms to describe what occurred in the experiments and to the Wahine. Students became more definite in their word choice. In general, students in the first episode displayed a basic understanding of buoyancy and used 'everyday' words. For instance, they spoke of the vessel getting holes and losing air. By the end of the unit, students were using more scientific words (e.g. density, mass, buoyancy and capsize) rather than words like 'tip' when talking about floating and sinking. In addition the complexity of their oral discussion increased. Students used several of the components of buoyancy such as the role of air and density to describe what happened, rather than just one. However, it must be noted that in some instances their understanding of a concept or the meaning of a word appeared incomplete. In other instances they appeared to add aspects of a concept to an exisiting conception producing a synthetic conception.

Findings show that the students' understanding of the scientific concepts taught developed over the duration of the unit. For instance, in the first episode, the main scientific reason given by the seven children who commented for the vessel sinking, was that the vessel became heavy because water got into the vessel and it lost air and tipped over. Mention was made of stability in terms of tipping and there was one allusion to centre of gravity. This meant that the students were predominately working at level one of the curriculum (1B). By the end of the unit, the discussion about buoyancy was more extensive; 17 students took part; it covered more aspects of buoyancy and stability, referring to density and displacement. In terms of density student levels of understanding ranged from level one to level four. Two students used an emerging level 4 understanding of displacement to explain why boats float and sink.

6.3 Buoyancy understandings: pre and post assessments, student interviews and reports

Here data from student assessments, student interviews and reports is presented as a complement to the earlier classroom episodes to provide further evidence of shifts in student understanding related to buoyancy and stability. An example of a student report is in Appendix U. A page showing how I collated the data contained on the reports can be found in Appendix V.

The section sets out evidence of changes in student assessments about: the role of air in whether materials float or sink; changes in mass/weight as a reason for sinking; the effect of density on a vessel's buoyancy and the effect of displacement. It also outlines student understandings related to stability, whether the students mentioned the boat tipped, the centre of gravity and free surface effect. In addition, I provide evidence that all students were able to give valid reasons for the Wahine sinking.

The role of air in whether materials float or sink

The role of 'air' is a big idea in buoyancy (see big idea 1B) and the notion that the Wahine sank because the vessel (in the words of the students) 'lost air' was clearly seen in the classroom dialogue (see section 6.2) and in the student pre and post assessments, investigation reports and student interviews.

In Question Nine in the pre and post assessments (see Appendix E), students were shown a picture of a steel ferry and a steel ball and asked: Both of these objects are heavy. Why does a boat float and a steel ball not float? Students were given a choice of an answer that referred to ‘air’, ‘displacement’ or ‘volume’ as I wanted to see what idea they were most familiar with. There was also an incorrect answer. The most common answer chosen by 15/27 students in the pre-unit assessment and 18/27 in the post-unit assessment was d) “the boat floats because there is air inside it.” This refers to the idea that usually an object with trapped air inside it will float (1B). This was the simplest of the options given, at level one of the curriculum. While the changes were not marked, as the number of students choosing the correct answer only rose by three, it is telling that by the end of the unit no one chose the incorrect answer.

Six of the 25 students mentioned in their reports that air (1B) was an important contributor to the vessel floating. For example, Mitchell spoke of ‘trapped air’ keeping the Wahine afloat, while Shania indicated when the ‘trapped air’ was ‘let out’ the vessel sank.

Mitchell: Trapped air in the Wahine kept it afloat (WR).

Shania: Trapped air helps boat to float so when the Wahine got hole in it, it let out the air so the Wahine sunk (WR).

Six of the eight students interviewed post-unit also mentioned that boats having air inside them contributes to their buoyancy. Taylor simply stated that boats float “because they have air inside them” (C&T, 05/10/11). Lucy exhibited a more complex understanding of buoyancy stating that a floating object stays on top of the water (2A) if it has air in it (1B). Conversely, if there was no air in the boat she explained it would be heavier than the water and sink (3C). In this Lucy demonstrated an understanding of displacement, density and upthrust.

Lucy: The boat has air in it and more air stays on top of water and if an object has no air in it, it will sink because [having] no air is heavier than water (L&K, 05/10/11).

Changes in mass / weight as a reason for sinking

Eleven out of 25 students in their reports used the terms weight and/or mass to describe what happened to the Wahine when she was holed and water came into the vessel. Four representative examples follow. Louise spoke about the water ‘adding’ more weight/mass to the vessel, denoting a ‘filling up’ rather than just weight, while Steven mentioned creating mass – adding ‘bulk’ rather than weight. These two students may have had some knowledge of matter.

Louise: The water also helped the Wahine sink because it added more weight/mass on one side (WR)

Steven: All the water went into the boat and created too much mass on one side (WR).

Bradley’s answer indicated some confusion about the meaning of mass. He used mass as an equivalent word for weight, not realising that mass relates to the amount of matter in a body.

Bradley: When the mass gets too heavy the boat starts to tip and then sink because of increased mass (WR).

Liam spoke about mass and volume (1E) and used a scientific explanation taken from an experiment in his report.

Liam: The less mass contained in a given volume, the less dense an object is, and the more likely it is to be less dense than the water it is floating in (WR).

Only Cameron mentioned increased ‘weight’ (1D/2C) as a factor in the sinking. However, all students implied that additional weight / mass contributed to the disaster. For example, Ofa, talked about the vessel being ‘filled up’, implying extra mass was added.

Cameron: I guess when the rocks punctured the hull on the starboard side all of the weight …. All of the vehicles in the vehicle deck added with the weight of the water slowly it went onto the side and sort of dragged it down (C&T, 05/10/11).

Ofa: The Wahine sunk because the weather and the killer rocks made a big ugly hole in the boat. Then the boat filled up with water (L&K, 05/10/11).

If we look at Question Eight in the assessment we can see that although students have some idea that the heaviness of an object compared to its size affects whether it floats or not, they are not totally sure about the reason for this occurrence. In Question Eight in the assessment (see Appendix E) students were shown a picture of a beaker of water with similarly sized pieces of polystyrene and steel nuts with the polystyrene floating and steel nuts at the bottom. The question asked was, "Why do the pieces of polystyrene float and the steel nuts sink in a beaker of water?" The simplest definition from the "big ideas" science concept for buoyancy, that "an object that is light for its size compared for its weight will float" (Ministry of Education, 2003, p. front inner cover) was used for the correct answer. In the pre-assessment 21/27 students chose this answer. However, in the post-assessment, this answer dropped to 13, which may indicate that seven students were not secure in their thinking and guessed in the pre-assessment.

Density

Looking at Assessment Question Eight again in terms of density may shed light on the students' drop in proficiency. Evidence from the pre and post-unit assessment Question Eight indicated that the students were wrestling with the concept of density. This confusion can be seen in the assessment data on question eight introduced above, where the incorrect answer that included the word density "the polystyrene pieces are denser than the steel nuts" was chosen by five people in the pre-unit assessment and by 13/27 in the post-unit assessment. This incorrect statement on density was included to ascertain whether students understood the meaning of density. It would appear given the level of post-unit responses that the students recognised the word as linked to the unit but they did not understand what it meant. This supposition would appear to be backed up by Brooke's interview comment, when she spoke of being comfortable with boat's floating because they have 'air' in them (1B) but she was not sure if materials floated (stayed up) because they were more or less dense.

Brooke: Because they've got air in them and the air doesn't sink and it's like more or (and I always get confused with the more or less) it's either more or less dense which makes it stay up (B&J, 05/10/11).

However, the students were able to use the term 'density' correctly when they related it specifically to the Wahine's sinking. Ten of the 25 students in their reports stated that density increased when the Wahine was holed and water flowed in. This relates to 1D - The less matter contained in a given volume of an object, the less dense it is and more likely to float. It suggests that these students realised that when the boat became denser, it was less likely to float. Tom's comment illustrates this point. He begins by noting that the water entering the vessel increased its overall density (1D), which led to it tipping (4B). He shows that he is working at level two because he explains density in terms of 1C – we can make a sinking object float by changing its shape to increase its volume.

Tom: When [the Wahine] hit barriert reef [Barrett Reef] making a small hole letting water in increasing the density on one side making it tip on its right side. We at S.E.E.Rs did experiments to test density using fruit. The potato sunk because it was dense but then we hollowed it out and it floated because it was less dense than before (WR).

On the other hand, Liam used a quote from one of the lessons to support his understanding about density (see earlier). Namely, the objects float if they are 'less dense than water' thus indicating he was working at Level four (1E).

Liam: I found out for an object to float "it has to have less density than the water it is floating in" (WR).

When asked specifically about why the Wahine had sunk in the post-unit interview, Taylor implied that the vessel sank because it became denser.

Taylor: Because there are holes in the bottom so the water went in and created more density (C&T, 05/10/11).

Tom showed that he had a deeper understanding as explained why the density of the vessel is decreased, due to it having hollow parts, which are filled with air (1B).

Tom: [Boats float because] they have air in them and they have hollow parts, which decreases the density of the object (J&T, 05/10/11).

Josh used 'spread out' to convey the notion of having increased surface area (1C), indicating at least a level two understanding of density.

Josh: Because it's more spread out across the water (J&T, 05/10/11).

Similarly, Jess showed some understanding of mass and volume, using the word 'spaced' to express how the object is configured affects whether it floats or not (1C).

Jess: Because it's like spaced out so it has enough room to float (B&J, 05/10/11).

Although many students in Question Nine in the assessment mentioned 'air' was a factor in boats floating, only 2/27 students in the pre-unit assessment chose the option c), "the shape of the boat is more spread out so it floats". This comment refers to 1C and 1D and talks about lightening the density of the vessel by spreading out the matter. While the number of students who chose this doubled in the post-unit assessment to four, it would appear that an understanding of the impact of volume and mass on buoyancy is only held by a few of the students.

While TJayne considered that the students had a good handle on materials that float and sink and what type of shape an object needs to be to float, she felt that they were less confident with the concept of density. She thought that 80% would have been able to recognise that if an object is denser on one side than the other it will affect the stability of a vessel.

TJayne: I feel that without even looking at half of their books, they've got a good understanding of what type of materials float and sink and of what shape they need to be. I would say maybe 80% of them understand that when an object is more dense on one side [it will overbalance and sink] (TI3, 15/10/11).

Displacement

While displacement is an important component of buoyancy, it was not a major part of the study. It was addressed briefly in one classroom episode (ET, 06/09/11), (see section 6.2, the Paper Boat experiment), in one question in the assessment and was mentioned by one child in the student interviews.

In Question Nine in the pre and post-unit assessment, students were asked why boats float and steel balls sink. Option b) - "the shape of the boat displaces enough water to hold its weight" was about displacement (big idea 2). It also included aspects of 1C - We can make a sinking object float by changing its shape to increase its volume, by mentioning the volume aspect but using the everyday word shape. Seven of the 27 students chose this answer in the pre-unit assessment, while five chose it in the post-unit assessment. It was one of the three possible correct answers indicated by students in this assessment and set at level two of the curriculum.

Cameron also mentioned displacement in his interview, asserting that boats displace water (2B).

Cameron: They [boats] have air inside them and the water displaced around them to keep them afloat (C&T, 05/10/11).

Unstable / Tip

Twenty one of the 25 students mentioned in their report that the vessel leaned/listed or tipped on one side. Three representative examples are given here. Both Tom and Lucy mentioned the water went onto one side, and the vessel tipped (4B). Lucy also mentioned the vehicle deck, where water moved freely leading to 'free surface effect'.

Tom: It hit a rock and water came through … It made it tip onto one side cause the hole was on one side (J&T, 05/10/11).

Lucy: Water went in and the vehicles went on one side with the water ‘cause it squashed it over. And it tipped the boat over (L&K, 05/10/11).

Josh explained how he used a paper boat experiment to demonstrate how the Wahine unbalanced (4A/B).

Josh: We put the paper boats into a large container of water and gradually added marbles to one side and sure enough it tipped to one side just like the Wahine (WR).

As well as mentioning the stability of the vessel (4B), Cameron also alluded to the centre of gravity, asserting that due to the increased weight, the vessel ‘couldn’t float it back up to straight position so it just kept pushing it over and over’ (4C). The fact that the weight was concentrated on one side changed the centre of gravity in the vessel and it was unable to right itself and capsized.

Cameron: I guess when the rocks punctured the hull on the starboard side all of the weight …. More water was coming in and its buoyancy couldn’t float it back up to straight position so it just kept pushing it over and over. All of the vehicles in the vehicle deck added with the weight of the water slowly it went onto the side and sort of dragged it down (C&T, 05/10/11).

Centre of Gravity

Eight of the 25 students either explicitly mentioned or alluded to the ‘centre of gravity’ in their written reports. Luke mentioned that the water pooled on ‘one side’, which affected the stability of the vessel (4A). He then referred obliquely to the centre of gravity by saying the water stopped the Wahine from bringing itself back up (4C).

Luke: When the Wahine had a hole in the side it caused water to go on one side. This stopped the Wahine from staying upright and turn on it’s side so the Wahine was unable to bring itself back up (WR).

Josh mentioned that the water entering the vessel affected the vessel's 'buoyancy and centre of gravity' (4C). The way Josh used the word buoyancy was consistent with the definition given in appendix S, as it is "the ability of an object to float".

Josh: Straight away the water rushed into the boat through the hole on one side. This upset the buoyancy and centre of gravity (WR).

While Hamish explained that the boat's centre of gravity (4C) was upset when it became unstable (4A/B).

Hamish: The water changed the stability of the boat causing it to tip on its side and changing its centre of gravity (WR).

Free surface effect

As already mentioned, the final factor in the Wahine's sinking was the free surface effect of the water moving on the vehicle deck. The exact term 'free surface effect' was not given to the students.

Jess and Brooke in their interview spoke about the vessel becoming unstable being due to the uneven filling of the compartments (stability tanks), alluding to 'free surface effect' (4E).

Jess: Didn't it like flood nine of the compartments?

Brooke: Suddenly it started to fill up the compartments or some of them on the starboard side so it rolled over slowly (B&J, 05/10/11).

Six of the 25 students identified in their reports that free surface effect was a factor in the Wahine's sinking. This was clearly illustrated by Eli and Lucy, who spoke of the water on the vehicle deck moving 'freely'. According to Lucy, the moving water changed the vessel's centre of gravity, causing the vessel to list and sink.

Eli: The water was allowed to move freely on the vehicle deck (WR).

Lucy: When the Wahine got its hole, more weight was added and the water was allowed to move freely around the vehicle deck. This caused the boat to list and her centre of gravity moved and the boat was unable to stay upright (WR).

Jess critically analysed the sinking of the Wahine, arguing that it was the unbalancing of the vessel (4A) due to the unequal filling of the buoyancy compartments in the Wahine, not necessarily the water entering the vessel that led to the capsizing of the Wahine.

Jess: So in my opinion, when the Wahine had one side full and the other side empty, it caused the Wahine to get unbalanced. But if all 13 of the compartments had been flooded at the same height then the Wahine might not have sunk (WR).

Students' understanding about the scientific reasons for the sinking of the Wahine

When the students' written reports were analysed for giving scientific reasons for the sinking of the Wahine, several factors were apparent. All 25 students gave valid scientific reasons for the sinking. In addition, 24/25 mentioned aspects of buoyancy and stability as affecting the vessel's buoyancy. The student who did not mention buoyancy or stability, stated that the hull was damaged and attributed the sinking to the cyclone and problems with the radar. In addition, 24/25 students used buoyancy and stability terminology in their reports (see appendix V for examples) to explain why the Wahine sank. The words used varied from 'air' to talking about 'buoyancy', 'weight', 'centre of gravity', 'unbalanced' and alluding to 'free surface effect'. More proficent students' explanations included multiple reasons and demonstrated knowledge about science concepts at a higher curricular level.

Summary

When the assessment, interview and written reports were examined for understanding about buoyancy and stability, several factors were apparent. All students were able to give scientific reasons for the Wahine sinking in their reports, with only one student not mentioning buoyancy or stability. In addition, the assessment data showed that all students by the end of the unit were able to provide a valid reason for boats floating.

The aspect of buoyancy that the students used the most in describing buoyancy in terms of density, displacement and upthrust was density. The most popular explanation used was that objects must contain air to float with 18/27 choosing this option in their assessment. It was also mentioned in most of the interviews and in a quarter of the written reports.

Students also attributed the sinking of the Wahine to increased weight and/or mass from the water. A few students had some knowledge of mass talking about ‘filling up’ rather than heaviness. In addition, 10/25 students identified in their reports that when the water entered the vessel, it made it denser. However, student understandings about density do not appear to be secure, for in the post-unit student assessments 13/27 chose an incorrect answer that included the word density, which perhaps indicates a developing understanding about density albeit containing misconceptions .

Other factors important to this study were to do with stability. Twenty-one out of the 25 students recognised that if the vessel had more weight on one side than the other it would tip over. Six of out of 25 students wrote about the centre of gravity changing due to the increased mass/weight and uneven placement of the water. The effect of water on the vehicle deck was mentioned by eight of the students; this was recognised as the culminating reason for the sinking.

In addition all students were clearly able to identity scientific reasons for the sinking of the Wahine in their reports. Twenty-four of the 25 considered that when the buoyancy and stability of the Wahine was compromised, the vessel sank.

6.4 Cyclonic weather

The second phenomenon studied was cyclones. Main understandings for development were of the genesis, lifecycle and effects of tropical cyclones and students’ ability to relate this knowledge to Cyclone Giselle. Data were examined for insight into student explanations of these aspects, how a cyclone contributed to the sinking of the Wahine and student understanding of isobar weather maps. Map interpretation was of interest as a lack of an accurate up-to-date weather forecast may have been a contributory factor in the sinking of the Wahine (Lambert & Hartley, 1969, p. 204).

Knowledge of how a cyclone is formed

Students were asked in the pre and post assessments to write their understandings of how cyclones form. Words given to help were: eye, depression, spiral, thunderstorm, sea, wind, warmth, rain, tropics, low pressure and rising air.

A possible four marks were awarded for the explanations. For students to get one mark, (a basic understanding) they had to identify one correct aspect of cyclone formation in logical manner. Two correct parts (a partial understanding) - two marks, three correct aspects (good understanding) - three marks and four or more correct features gained full marks for comprehensive understanding. The data from the assessment is given in Figure 6.2.

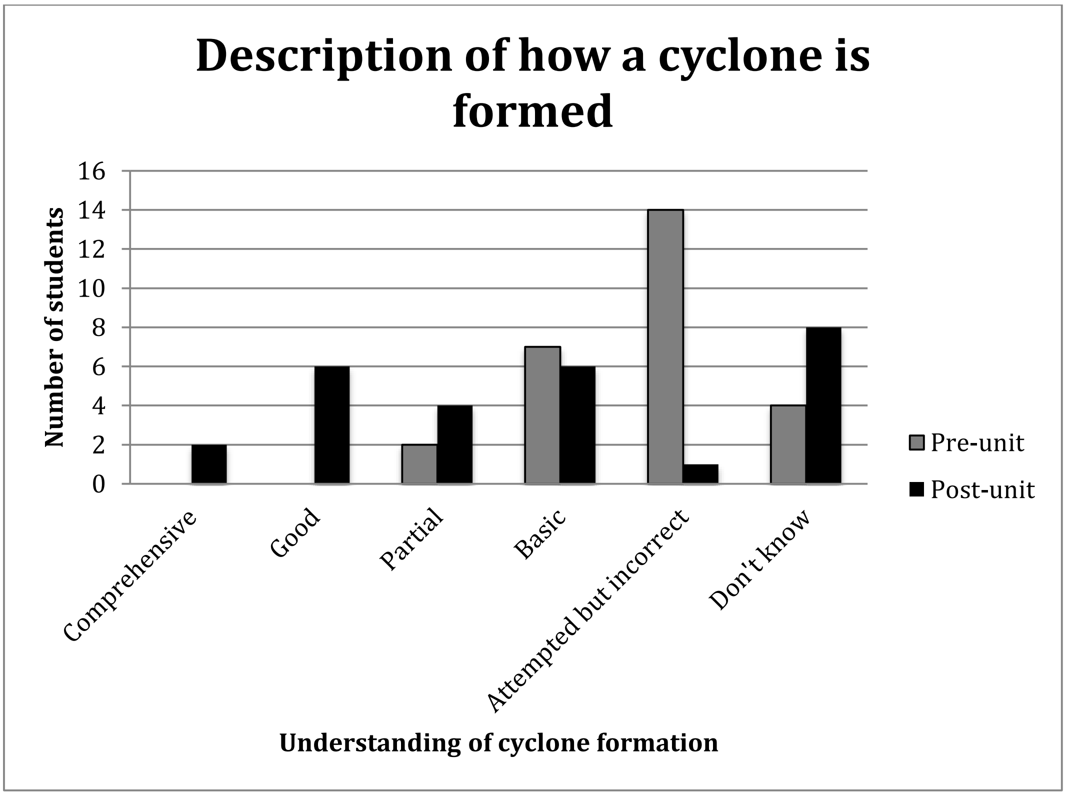


Figure 6.2 Students' understanding of cyclone formation

The following examples from the post-unit assessment show the range in student understanding about cyclone formation at the end of the unit.

For example Ofa only had one idea, a basic understanding.

Ofa: In the **tropics** (PostAB).

Cameron talked about two points, low atmospheric pressure and an 'eye', thus he showed partial understanding.

Cameron: The **eye** is a **low-pressure** area (PostAB).

Shania showed a good understanding of how cyclones form. She mentioned spirals of winds that form in the tropics. She also spoke of cyclones having one eye, which she linked to Greek Mythology.

Shania: The cyclone is a **spiral of wind** which is formed in **tropical places**. Each cyclone has one **eye** like the Greek mythical creature Cyclops which is how its name was formed (PostAB).

Brittany's example was comprehensive. She described eight components of cyclone formation and linked these to the New Zealand context.

Brittany: A cyclone is formed by **rising hot air**. A **thunderstorm** will soon form and the **winds get stronger**. They like **hot water** in the **tropics**. Sea sprays everywhere. In the **eye it is calm**. The winds go in a **spiralling shape**. They need **hot water** to keep strong**,** which is why they don't go to NZ much. (Comprehensive understanding) (PostAB).

In the initial assessment only 33% (9/27) of students were able to provide either a basic or partial explanation as to how cyclones were formed. No one accurately described cyclone formation.

In the post-unit assessment 66 % (18/27) of the students had some idea of cyclone formation, with 30% (8/27) having either a good or comprehensive understanding of the process. This improvement in students understanding was also identified in student interviews and their reports to the client.

Speaking and writing about cyclones

Another unit aim was for students to gain an understanding of the typical characteristics of a cyclone, which are: extreme winds, torrential rain, storm swells and low visibility. Figure 6.3 details the cyclone related vocabulary used in the assessments. It can be clearly seen that the words used to describe cyclones doubled between the pre and post-unit assessment with a correspondent increase in the variety and complexity of terminology chosen. Apart from the word wind (six in the pre-assessment – five in the post-assessment), all other words were used more frequently in the post-unit assessment.

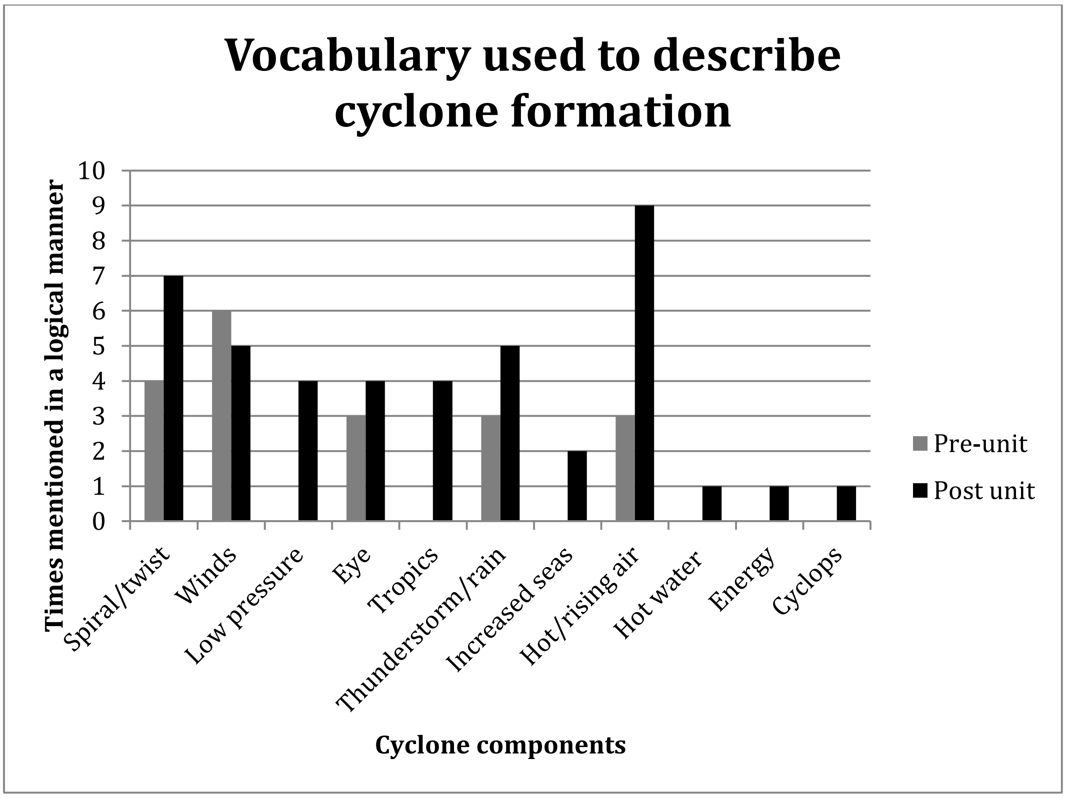


Figure 6.3 Terminology used by the students to describe cyclone formation

Students also used more science words in class/ group discussions, in written notes and in their reports.

For example, the following are two of the examples the class identified of extreme cyclonic weather when they examined newspaper articles from when the Wahine sunk.

Alicia: There was a heavy swell at the time (ET, 23/08/11).

Eli: The weather was causing the seas to be rough … strong currents (ET, 23/08/11).

Students described the characteristics of cyclones in discussions held prior to writing their reports to the client. Kaleb spoke about the intensity of the winds using nautical units of speed.

Kaleb: 65 -75 Knots winds (ET, 26/09/11).

Trent indicated that the winds during Cyclone Giselle were some of the most severe ever recorded in New Zealand.

Trent: The winds that were there were one of the most severe in New Zealand history (ET, 26/09/11).

In data taken from a presentation to the client (ET, 29/09/11), students talked about the effect of Cyclone Giselle on the seas and the consequences of the weather. For example, Josh spoke about the effect of poor visibility, noting that it was a factor in the Wahine hitting the rocks.

Josh: Cyclone Giselle made the visibility low and it hit into the rock (ET, 29/09/11).

Steven mentioned that Cyclone Giselle caused a severe storm and extreme winds.

Steven: Cyclone Giselle hit Wellington. So it was stormy and windy (ET, 29/09/11).

All of the students mentioned the effect of the weather on the sinking of the Wahine in their reports. 21/25 mentioned both the effect of Cyclone Giselle and described the characteristics of cyclones in their reports (WR), however the complexity of language used varied.

Alicia for example, wrote poetically using metaphors and similes to describe rough seas, and fog.

Alicia: The seas quickly turned into a washing machine … blanket of fog … roaring seas (WR).

Brandon spoke of high winds, enormous waves and currents and poor visibility.

Brandon: Winds of upto 60-75 knots from Cyclone Giselle … causing ginomes' [ginormous] waves and currents … poor visability (WR).

Brooke's characteristics were similar but she firmly attributed 'part of the incident' to Cyclone Giselle.

Brooke: Part of the incident was caused by the weather…Cyclone… poor visibility, and the waves were very big … winds 60-75 knots (WR).

Steven identified the location, and added in that the winds were erratic, suggesting that the Wahine 'hit the rocks' because of that factor.

Steven: The Cyclone Gizelle [Giselle] had just hit Wellington and wind speeds were 60-75 knots fast! The waves were straight up and down and the Wahine was spinning in circles because of the wind. This is why the Wahine hit the rocks (WR).

Josh mentioned high winds, rain, 'massive' swells and low visibility.

Josh: The cyclone engulfed the harbour with wind speeds of up to 75 knots as well as torrential rain and massive swells. The hurricane made visibility low … air filled with foam and spray (WR).

As seen in the examples above, the students described the key aspects of cyclones: telling of hurricane force winds, lack of visibility due to spray and rain, sea conditions and swell. As well as describing the effects of the cyclone, 7/25 students clearly attributed blame to Cyclone Giselle, such as the example from Louise here. Steven and Brandon above also mentioned Cyclone Giselle in their reports.

Louise: Without Cyclone Giselle, this dramatic disaster would not have happened (WR).

The students in the examples given were clearly able to speak and write about the effect of cyclones. They used a wide variety of vocabulary in their written reports.

Cyclone understanding of the interviewed students

Student comment from the eight interviewed students highlights an interesting point. Not all of the interviewed students were able to talk about cyclones and cyclone formation in an abstract sense. Josh commented that he hadn't learned a lot about cyclones. This was confirmed in his assessment as he wrote that he 'didn't know'.

Josh: I personally didn't learn a lot [about cyclone] (J&T, 05/10/11).

Josh: Didn't know (PostAB, 05/10/11).

In a similar fashion, Brooke indicated she didn't understand cyclones. Her answer in the assessment was limited.

Brooke: Not really (B&J, 05/10/11).

Brooke: Hot air and cold air mix together (PostAB, 05/10/11).

While Cameron did comment that he found it difficult to learn about cyclones, his answer in the post-assessment was solid, indicating he understood some of the key ideas as he talked about the eye of the cyclone, gale force winds and hot air.

Cameron: It [cyclones] was kinda hard (C&T, 05/10/11).

Cameron: A cyclone is formed when hot and cold air collide. Mixed with hail and gale force winds, the warm and cold air start to mix in the clouds. The eye is the only calm area (Post AB, 05/10/11).

The scenario was different when they were asked about Cyclone Giselle. Brooke explained that the reason she could now answer was because we concentrated on Giselle.

Brooke: I think it's because we actually focussed on Giselle and not on other ones (B&J, 05/10/11).

Jess commented her understanding came from a conversation she had with me about Cyclone Giselle combining with a polar blast and intensifying.

Jess: Because for me when I wrote my report I learnt more about it because you told me how she met up with the other one coming from the North. I don't know how they are formed or anything (B&J, 05/10/11).

It appeared from Brooke and Jess' responses that context made a difference in their ability to respond and why their answers about Cyclone Giselle were more complete. They did note that the unit had concentrated on the Wahine and Cyclone Giselle in particular. This example indicates the importance of linking to student's prior knowledge and making sure that questioning is contextualised in contexts that students have worked within.

To sum up, there was clear evidence from multiple data sources that students had deepened their understandings both about how cyclones form, and the effects of cyclonic weather. Contextualising the learning appeared to enhance student recall, and their desire to engage with the topic.

Student comment about weather interpretation

The students in this study explored weather isobar maps (ET, 25/08/11) when working in collective role as Albert who explained Meteorology to the PA (Teacher-in-Role).

All eight students interviewed identified that prior to the unit they didn't understand weather symbols and couldn't interpret the forecast from the isobar map. Two of them noted that their parents had tried to help them understand the forecast but they still couldn't understand. Taylor for example, admitted that she had never understood weather symbols.

Taylor: Before we started this unit, I never actually understood the weather symbols (C&T, 05/10/11).

Cameron thought the isobar lines were a glitch and didn't represent anything.

Cameron: I thought it was a glitch in the computer when they did it with the wavy lines (C&T, 05/10/11).

Josh had tried to understand weather maps but even with help from his father had been unable to comprehend what was happening.

Josh: [It was] confusing. I asked Dad what was it was and he couldn't really explain it (J&T, 05/10/11).

Seven out of eight students interviewed noted that after the classroom teaching they were able to understand most of the weather map on the TV forecast. Taylor related that she could now understand isobar maps and was so enthusiastic that her mum was getting annoyed with her talking about them.

Taylor: Now I can actually understand them and my mum's kinda getting tired of me saying what the symbols are (C&T, 05/10/11).

Josh was pleased he could interpret the weather for himself.

Josh: But now like, now that we've learnt about the isobars and all the symbols and all that we can see what's happening ourselves (J&T, 05/10/11).

Cameron commented being able to interpret weather was useful in terms of making wise decisions about a day's activities.

Cameron: It is useful because … if it is going to be like windy and rainy you could make a stronger shelter or move to higher ground (C&T, 05/10/11).

60% (15/25) of the students stated in their reports that not receiving up-to-date weather forecasts was a factor in the Wahine sinking, and mentioned the importance of obtaining accurate and timely weather forecasts. For example Brooke spoke about the importance of vessels receiving up-to-date weather forecasts to stop other tragedies like the Wahine occurring

Brooke: To avoid this happening again we need better communication with the weatherman (WR).

Josh identified procedures in place at the time of the sinking that contributed to the sinking, like having to request additional forecasts if you were concerned, rather than just receiving updates as weather changes.

Josh: Because of procedures in place at the time the crew was not informed of the hurricane, for a weather update the vessel had to request it (WR).

The students interviewed spoke about not knowing how to interpret weather maps before undertaking this study. Most identified that by the end of the unit they could interpret some aspects of the weather isobar maps and it had proved an engagement factor with them and their parents. Some students commented that knowing how to read weather forecasts was valuable and recognised that not having an accurate forecast could have deadly consequences, as was demonstrated in the sinking of the Wahine.

Summary

Student understanding about tropical cyclones improved. Two thirds of students demonstrated at least a basic understanding of tropical cyclone formation in the post-unit assessment compared with one third at the beginning. The vocabulary used in the post-unit assessment was more complex and varied than in the pre-unit assessment. These postive changes in conceptual understanding were confirmed in the written reports, where students recognised the impact on the Wahine sinking of Cyclone Giselle, and were able to describe key cyclone characteristics.

Students had a more complete understanding of the effect of Cyclone Giselle than cyclones in abstraction because they had learned specifically about Giselle. Students could interpret some aspects of isobar weather maps and recognised that not receiving up-to-date weather forecasts was a contributing factor in the sinking of the Wahine.

6.5 Changes in students' achievement in knowledge of science concepts and attitudes towards science

This section outlines the students' overall achievement on knowledge of buoyancy and stability, cyclones and weather prediction from the pre and post assessments (see Appendix E), rather than changes in individual questions. It also examines students' responses to the two attitudinal questions (see Appendix D).

Results comparing total science concepts assessment scores

Individual student's total marks from the pre-unit assessment part B on conceptual understanding were compared with their marks from the post-unit assessment to see whether the shifts in science understanding observed in class activities and detailed in sections 6.2, 6.3 and 6.4, were reflected in changes in understanding as measured by the unit assessment task. Twenty seven students were assessed using the same pre and post assessment items with a total of twenty seven marks possible.

Figure 6.4 illustrates the students' overall pre-unit assessment marks alongside their post-unit marks. Looking at Figure 6.4 it can be observed that 26 out of 27 students attained higher scores at the end of the unit. One student (Student C) had a lower score in the post-assessment (5 compared with 8 in the pre-unit assessment). The range of marks for the pre-unit assessment was from 3 - 11. In the post-unit assessment the scores were more spread out, ranging from 5 – 24, with over half of the class (14 students) clustered between 10 and 14. Four students had marks between 15 and 19, one student (D) attained 24 marks and another (S) 20 marks. Student D was particularly interested in the Wahine, which perhaps explains the shift in her mark.

Table 6.6 outlines the descriptive statistics for the pre and post-unit assessments.

Table 6.6 Descriptive statistics of pre-unit and post-unit assessment answers in terms of mean and standard deviation

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-unit Assessment	9.04	27	2.62	0.51
	Post-unit Assessment	14.44	27	4.10	0.79

A paired sample two-tailed t-test was used to determine whether the changes in achievement scores that occurred between the pre and post test were significant. The results showed that the average scores improved significantly from pre to post-unit assessment,

$t(26) = 7.98$, $p = 0.0001$, (CI 4.0, 6.8).

The Cohens *d* effect size was d =1.6 which, according to Timperley et al.'s (2007) criteria means that Mantle-of-the-Expert had a large, educationally significant impact on student learning of science in this study. Taking into consideration the work of Hattie (1999), who considers that an effect size of 1.0 is commensurate with "advancing student achievement by one year" (p. 3), an effect size of 1.6 gains further significance.

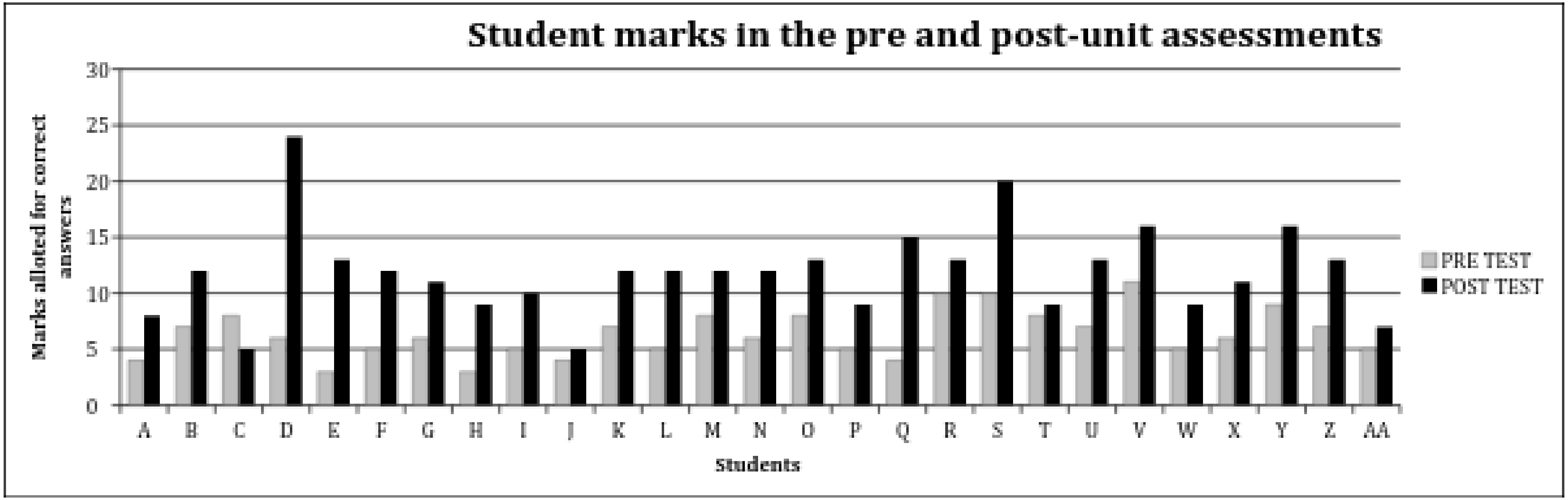


Figure 6.4 Comparison of individual student pre-unit and post-unit assessment[17]

[17] A – N are the girls' results. 0-AA are the boys' results.

Science Attitudinal Data

The notion that student attitudes towards science become increasingly more negative as they progress throughout their education is a well-recognised issue in science education (section 2.4.1). On the other hand, Mantle-of-the-Expert has been reported to improve student attitudes (section 3.2.1) towards the subject they are learning. Twenty-five students completed the two pre and post-unit attitudinal assessment (part A) questions.

Student responses to the question, "How much do you like doing science?" are presented in Figure 6.5.

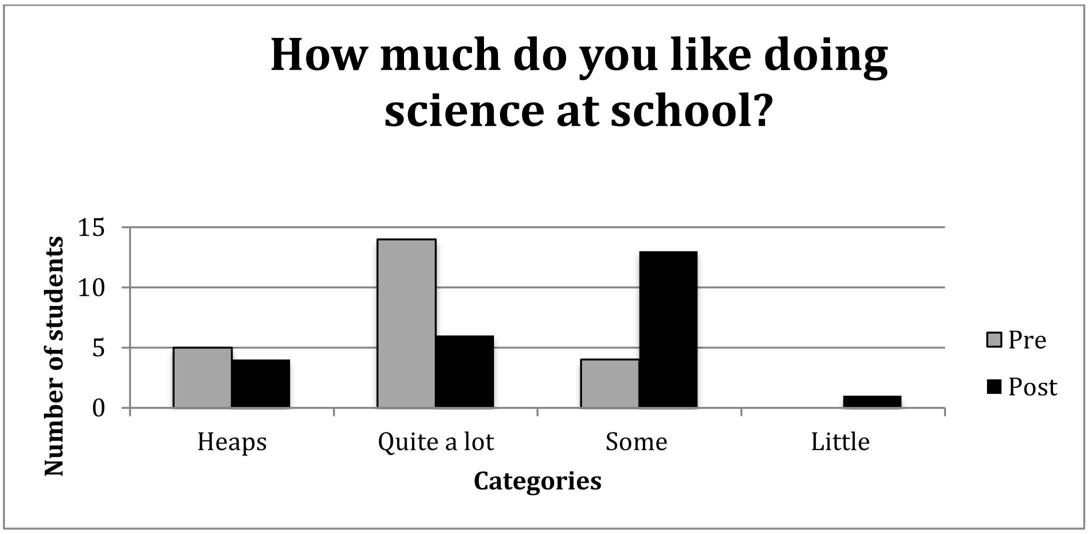


Figure 6.5 Students' attitudes towards school science

The data in figure 6.5 shows that the students' attitudes towards school science shifted towards the less positive end of the scale between the pre and the post-unit assessment. The number of students who liked science "heaps" dropped from five to four. Students who liked it "quite a lot" dropped from fourteen to six but the number of students who somewhat enjoyed science rose from four to thirteen. One student now identified that he liked science only a little.

The second attitudinal question probed student self-efficacy with the question, "How good do you think you are at doing science?" (see figure 6.6).

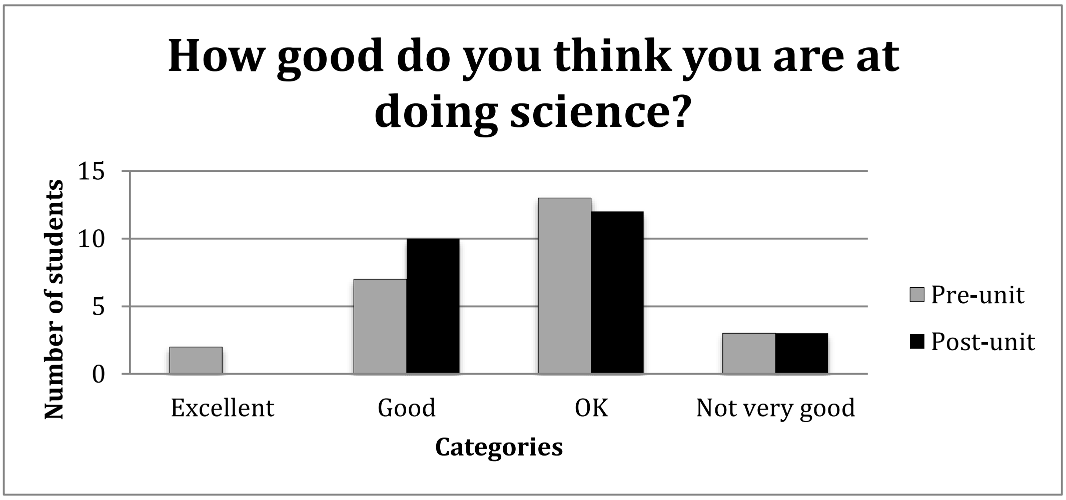


Figure 6.6 Student appraisals of how good they are at science

Overall, out of 25 students who completed this question, a paired pre and post analysis found that 14 students reported the same level of self-efficacy at the start and the end of the unit. Six reported less self-efficacy: two students who previously placed themselves in the "excellent" category moved to the "good" category; three students moved from "good" to the "OK"; one student moved from "OK" to the "not very good". Five students reported more self-efficacy: four students moved from the "OK" category into the "good" category, one student moved from the "not very good" to the "OK" category.

Please note: further analyses using attitudinal questions were not done because the total number of students who completed this assessment was very low (n = 25).

In most instances, student attitudes towards school science towards science did not improve and in some instances declined. For around half of the students their perception of their abilities in science remained unchanged, of the rest half reported a gain and half a decline in their self-efficacy.

6.6 Chapter Summary

This chapter has focussed on the development of students' conceptual understandings about buoyancy, cyclone formation and weather prediction. Data came from the pre and post assessments, interviews, classroom dialogue transcripts, classroom artefacts and student written reports. The data presented shows that student understandings of science concepts developed over the duration of the study.

Student conceptual understandings about buoyancy deepened. By the end of the unit, the number of students taking part in classroom discussion about buoyancy had more than doubled. It can be clearly seen through the dialogue outlined that student understandings about buoyancy were articulated at higher curricular levels at the end than at the beginning of the unit. Science words were used in addition to 'everyday' language to explain phenomena. Seven of the eight students interviewed were able to talk about buoyancy in their interviews. All students demonstrated at least a basic understanding of buoyancy in their assessments, recognising that objects that contained air were more likely to float. All students were able to give a scientific reason for boats floating. All 25 students were able to give valid reasons for the Wahine sinking in their written report. Only one did not mention aspects of buoyancy or stability. Similarly 24 of the 25 students used buoyancy and stability terminology in their reports to describe what had occurred on the vessel. 15 of the 25 students used evidence from the experiments to validate their findings.

Students' conceptual understandings about cyclones improved slightly over the unit with students demonstrating greater competency in describing Cyclone Giselle than cyclones in abstraction. Students were more able to interpret weather isobar maps after the unit than in the beginning. Of interest was the fact that six out of the eight students interviewed shared their 'new knowledge' with their parents.

When the overall scores from post-unit assessment on science knowledge about buoyancy, stability, cyclones and weather prediction were compared with the overall scores from the pre-unit assessment, students improved at statistically significant levels.

In this study, most students' attitudes towards school science either remained unchanged or declined. Half of the students' perceptions of their self-efficacy in science did not change over the duration of the unit. However, a quarter of the students reported a gain in their self-efficacy, while the other reported a decline.

Chapter Seven: Findings – Nature of science and science futures

7.1 Introduction

This chapter presents findings related to parts of the two research questions detailed in bold below.

2. What shifts in students' written and verbal use of science concepts, **Nature of Science**, and science language, occurred over the course of a nine-week Mantle-of-the-Expert unit?
3. How did Year 7/8 students in this study come to perceive science now and **in their future**?

In terms of research question b, the focus is the NOS, as science concepts were explored in Chapter six. The findings related to student interactions with the NOS are outlined in section 7.2. Section 7.3 presents findings to do with students' consideration of a career in science and their knowledge of science-based careers. It answers the second part of question c.

7.2 Nature of Science

This section presents findings relating to how student actions and interactions embody aspects of the Nature of Science, as it is outlined in the NZC (see section 2.3.2). Three of the four categories of NOS in the NZC: 'Understanding in science', 'Investigating in science' and 'Communicating in science', will be used to explore students' interaction with the NOS. The fourth category – 'participating and contributing – will not be detailed in this section, as it has been already explored in section 5.3, which looked at the positioning of the students as ethical scientists and how they "brought a scientific perspective to decisions and actions" (Ministry of Education, 2007c). Students were not formally assessed on specific aspects of the NOS. Here, I provide examples of changes in how the students viewed the work of scientists, investigated in science in their positioning as scientists and communicated their understandings about science.

7.2.1 'Understanding about science'

The 'Understanding about science' achievement aims in the NZC online states that students will: learn about science as a knowledge system, the features of scientific knowledge and the processes by which it is developed. They will also learn about the ways in which the work of scientists interacts with society (Ministry of Education, 2007c). This section focuses on students' ideas about what scientists do. The dramatic convention Role-on-the-Wall was used to extend student ideas about scientists and the tasks they do. Their views in this activity are compared to those given in their assessments and in their post-unit interviews.

Students' pre and post ideas of what scientists do

Students were asked in their pre-unit and post-unit assessment "What sort of things do scientists do?" Their responses were collated and graphed according to frequency and gender (see Figures 7.1 and 7.2). Only ideas mentioned by at least two students were included in the tables below.

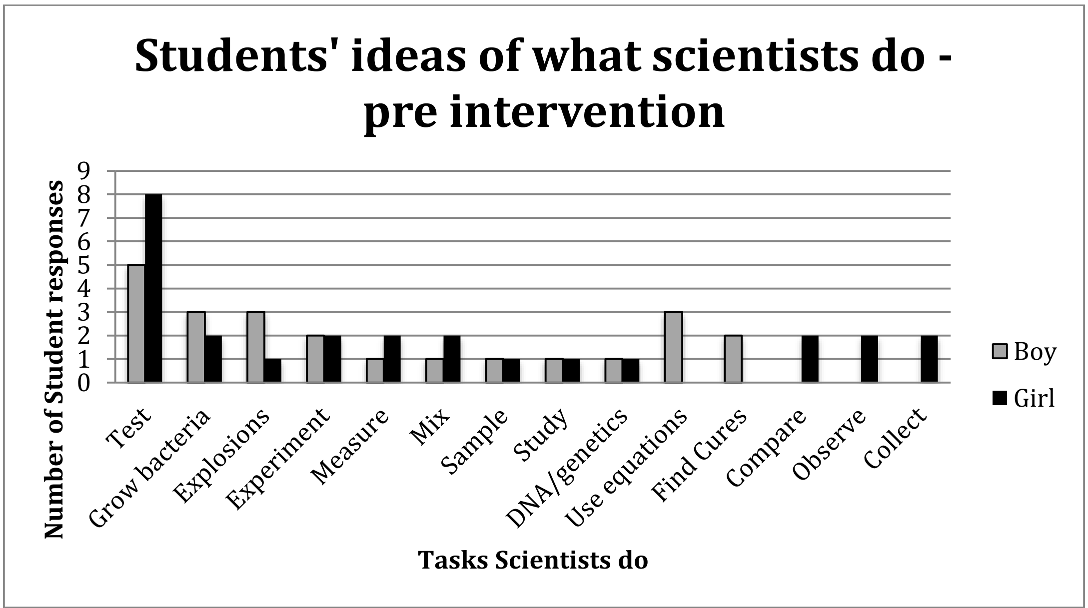


Figure 7.1 Pre-unit student ideas about the tasks scientists do

Data from the pre-unit assessment (figure 7.1) showed that both genders consider testing is the main task scientists do. Other common activities were: growing bacteria, explosions, experiments, measuring, mixing, sampling, studying and DNA/genetics. The boys had two ideas not shared by the girls – using equations and finding cures. Girls' unique tasks were comparing, observing and collecting. One girl had no knowledge of any tasks scientists do.

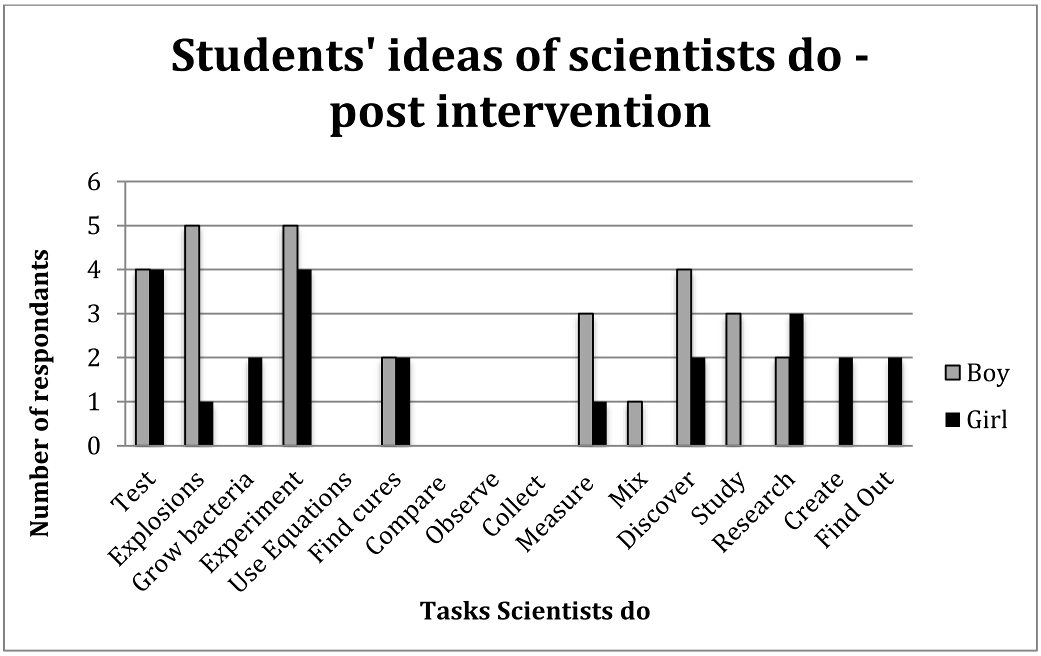


Figure 7.2 Post-unit students' ideas about the tasks scientists do

In the post-assessment data (Figure 7.2), the activity identified by the most students (nine) was doing experiments, rather than testing. Only two girls mentioned bacteria in the post-unit assessment. Explosions were still popular, mentioned by five boys and one girl. New activities mentioned by both genders were finding cures, discovering, researching and measuring. Only the boys thought studying was what scientists do. Girls mentioned two more categories, which were to create and find out. Four categories deemed important pre-unit were no longer mentioned - equations, compare, observe and collect.

The nature and frequency of the various tasks chosen changed slightly between the pre and post-unit assessments but not in a significant way in terms of the students identifying a large number of new tasks. There did not appear to be discernable gender differences in pre or post views.

Extending student ideas of who scientists are through 'Role-on-the-Wall'

The dramatic convention, 'Role-on-the-Wall' was used in the third classroom episode (ET, 11/08/11) to extend students' thinking about the tasks scientists do and the characteristics scientists might possess. The exercise was framed as professional development for the students in their role as company members. Working in five groups, the students “drew an outline of a scientist and in the middle … [wrote] what type of personality characteristics a scientist has and on the outside what they do” (RB, E4 continued). A representative example of the Role-on-the-Wall exercise is given in figure 7.3.

Figure 7.3 An example of a Role-on-the-Wall of a scientist

A stereotypical scientist image predominated although the five pictures drawn of the scientists varied. There were four male scientists and one female scientist. Four out of five had wild hair. Two wore lab coats and two had a beaker.

In coding the words in student ‘Role-on-the-Wall’ pictures, I created a composite Role-on-the-Wall graphic (see Figure 7.4) by sorting the statements into what scientists are and what they do and then categorising these. There were four categories to do with what scientists are: academic, personality, thinking and what they are. The categories for what scientists do were: practical skills, communication, theoretical and other.

Comparison of assessment data and 'Role-on-the-Wall' data looking at what scientists do and are

The data from the assessment question about 'what tasks scientists do' was re-cut, with all the student answers being coded into the categories chosen for the outside section of the 'Role-on-the-Wall' graph.

Students' understandings of the characteristics of scientists and the tasks they do became more complex as the unit progressed. In the pre-unit data (shown on the left side of Figure 7.4), students mentioned generic skills used in science, such as predicting, observing, sampling and testing. Some skills were practical like sampling; others involved deeper thinking such as reflection. A student identified that science includes mathematics. Items in the 'other' section ranged from naming the equipment used in science, to explosions and holistic concepts such as environmental issues and creating new products. Nobody mentioned communicating knowledge.

Data from the 'Role-on-the-Wall' drama (middle of the graphic organiser in Figure 7.4) revealed several interesting factors. Most striking was the increased number of items in the communication category; seven compared to zero in the pre-unit assessment. The ideas in the theoretical section, such as infer, appear to be more complex than those given in the pre-unit assessment. The comments in the practical skills and 'other' section were similar to the pre-test. However, two codes in the other section in the post-test were coded in internal categories in the composite 'Role-on-the-Wall' - that of creation and taking risks.

In the post-test data (shown in Figure 7.4 on the right), students also used complex words such as hypothesis in the practical skills section. Statements such as 'repeat tests' and 'look for different answers' imply a degree of criticality. A few students gave examples of science specialties like chemistry. The word 'learn' was added to the theoretical section. The 'other' section still included explosions. The 'take risks' statement was identical to what was mentioned in the

‘Role-on-the-Wall’ exercise. In the communication section, one person mentioned scientists ‘teach’.

The answers from the internal area of the person shape in the middle section of Figure 7.4 suggest that through their in-role work students deepened their understanding of what a scientist identity involves. They recognised the type of thinking needed to be a scientist and identified certain types of personality traits that (apparently) scientists have. They suggested scientists were intelligent. They identified seventeen characteristics, which seemed to indicate adventurous tendencies such as courage and risk taking as well as a propensity for being methodical, organised and technological. The quality of ideas portrayed in this data, I suggest, is more indicative of scientists working in a science laboratory than students doing science in schools, as characteristics such as courage, risk-taking and even ‘thinking outside the box’ are not normally required for working in science in a classroom.

Student understandings of what scientists do and are

Pre-unit Assessment of the tasks scientists do	'Role-on-the-wall' data looking at what scientist do and are	Post-unit Assessment of the tasks scientists do

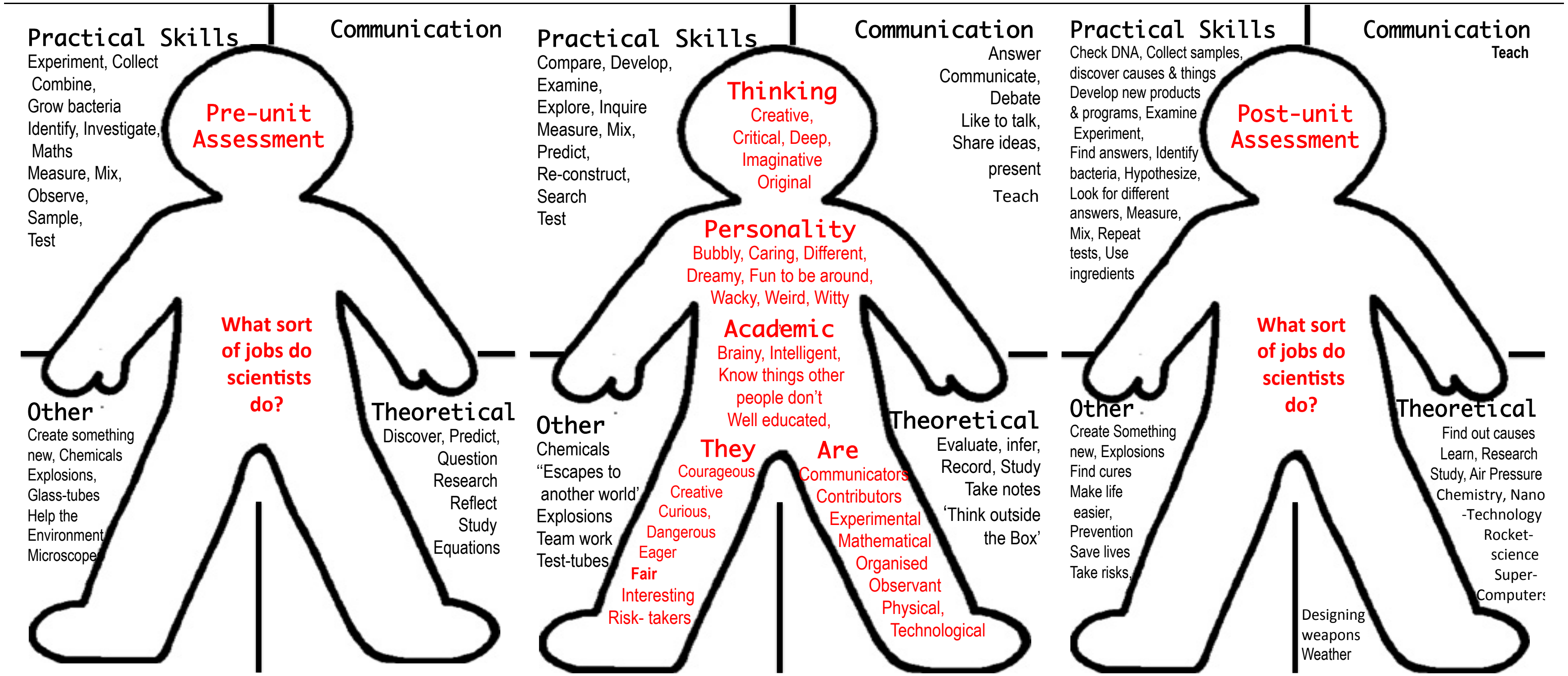


Figure 7.4 Comparison of the student understandings of what scientists are and do

After constructing the Role-on-the-Wall, TJayne invited students to share their understandings at a 'team meeting' (ET, 11/08/11). Some of their responses are given to illustrate the wide range of characteristics they considered scientists have. Student A noted that the use of technology was a facet of being a scientist. Crystal suggested 'scientists develop or make stuff'. Student B identified that scientists should be logical. Some students provided more elaborate descriptions of scientists. For instance, Tom considered that scientists 'explore stuff' to answer the questions they generate from their observations.

Tom: Observant and eager to explore stuff and find out the answer [to] the question (ET, 11/08/11).

Lucy extended Tom's reflections noting that scientists question evidence, indicating a degree of criticality.

Lucy: Curious – questioning evidence (ET, 11/08/11).

Boy A focused on more personal characteristics, stating that scientists are 'interesting' and 'fun'. He also identified that they are creative and imaginative, indicating he had moved beyond the stereotype of scientists as boring.

Boy A: Interesting, fun to be with ... creative, imaginative (ET, 11/08/11).

Bradley extended the imaginative thread, implying that to be a 'good' scientist one needs to imagine things that are not currently possible.

Bradley: [They] imagine the things that aren't possible and experiment with things that are (ET, 11/08/11).

Taylor too addressed the thinking of scientists, stating they needed to think beyond the first answer.

Taylor: Infer ... think beyond the first thing, like the meaning (ET, 11/08/11).

Liam also considered that scientists think 'outside the box'. He commented that they had to be courageous to do this.

Liam: They think of scientific stuff and be courageous and think outside the box.

Tom linked being courageous with 'trying new things' while to Shania it was associated with using 'dangerous chemicals'.

Hamish and Alicia talked about how scientists need to communicate their understanding. Hamish considered that sharing knowledge was vital, as it allowed scientists to hear about other theories and to test their own and combine as required. Similarly, Alicia asserted, that rigorous debate was important, because theories need to be proved to silence questions raised.

Hamish: Share our knowledge and to test and combine and get other theories.

Alicia: Debate … Cause, kind of people might have other ideas and they might question what you are doing (ET, 11/08/11).

The students displayed a sophisticated collective understanding about who a scientist is and what they do through developing the 'Role-on-the-Wall' of a scientist. Students described tasks scientists do such as observe and also mentioned how to test and defend their theories. When asked about their responses in role as scientists in the class discussion, they deepened and explained their initial ideas to include aspects such as being creative as part of scientists' work. It appears that using 'Role-on-the-Wall' both elicited and enriched the students' thinking about scientist identities by encouraging them to recollect that scientists have inner and outer attributes.

Student views of scientists at the end of the unit

Student interview comments after the unit supported the finding that students' perceptions of scientists changed. Taylor's perception of science a year ago was limited, science involved chemicals and scientists wore glasses.

Taylor: When I was little, (last year – giggle) I just thought of science as a whole lot of chemicals and people with glasses (C&T, 05/10/11).

Cameron inferred that being a scientist is more like the science identities they worked within and the tasks they did throughout the unit than the 'nutty professors' he imagined as a child.

Cameron: When you are younger you always think of scientists as nutty professors creating dinosaurs in their dungeon … But then we grow to 11, 12,13 and you start to realise that when you do stuff like this, it is more than just walking around with a lab coat and clipboards and taking notes and things (C&T, 05/10/11).

Lucy's understanding was quite sophisticated, mentioning both the theoretical and the practical aspects of being a scientist.

Lucy: [Scientists] research and find out quite a lot about the topic and then they figure out what [they] are finding out the answer for and then they experiment (L&K, 05/10/11).

Summary

Data presented shows that by the end of the unit students' ideas about the tasks scientists do had increased in sophistication. There was no discernable difference between the genders in ideas about the tasks scientists carry out. The initial student line drawings of scientists were largely stereotypical and of test-tube holding males with wild hair. However, the follow-up on the 'Role-on-the-Wall' activity indicated students had deepened their understanding of the tasks scientists do and the characteristics scientists have when compared with ideas presented in the pre-unit assessment. Data from the interviews confirmed that by the close of the unit, students had refined their views about what scientists do and can be to include aspects like communication.

7.2.2 'Investigating in science'

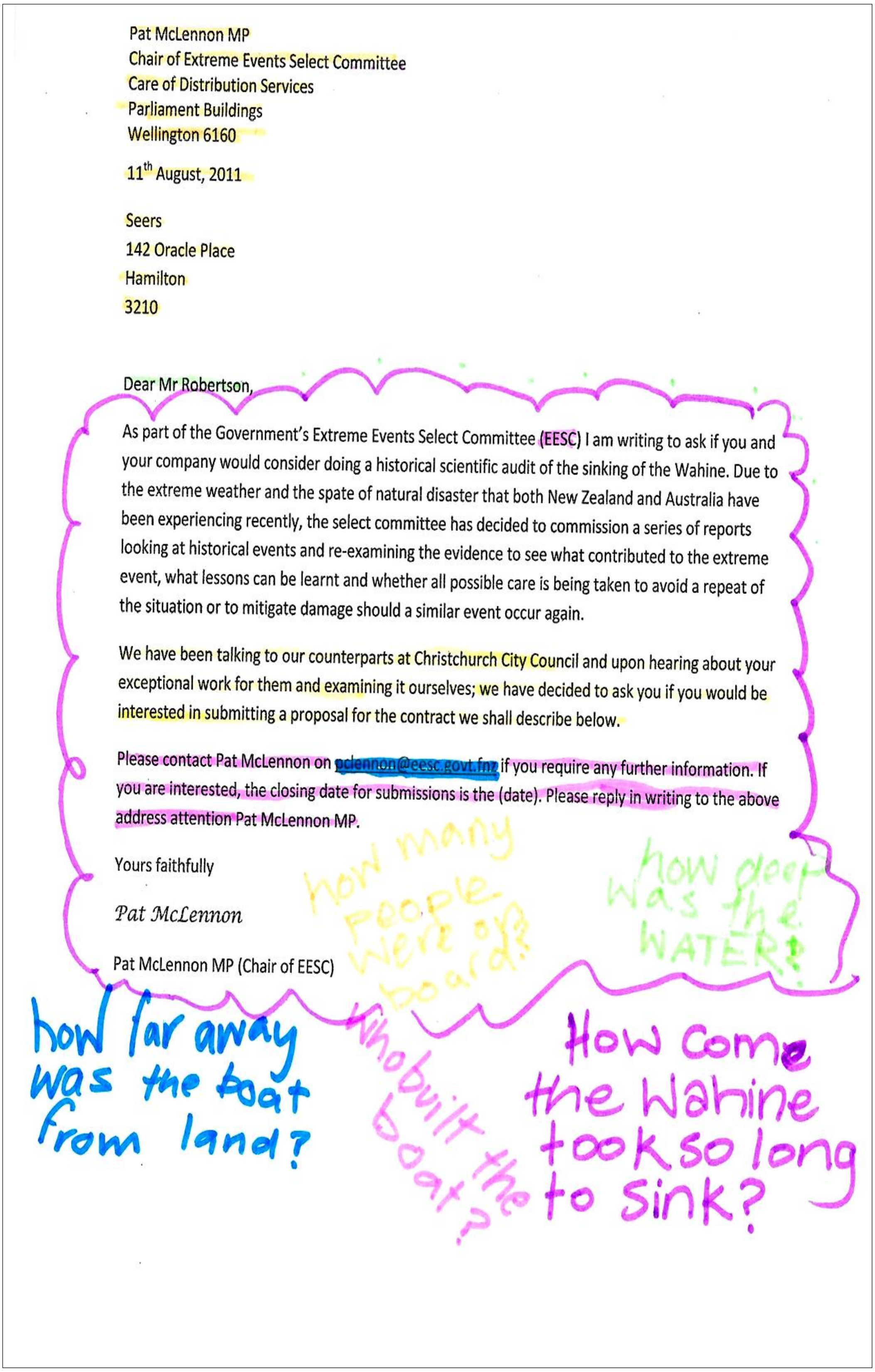
The achievement aim for investigating in the NZC online describes that students will: carry out science investigations using a variety of approaches: classifying and identifying, pattern seeking, exploring, investigating models, fair testing, making things, or developing systems (Ministry of Education, 2007c). In this section data is presented to show how Mantle-of-the-Expert aided students in carrying out a scientific investigation. The part played by experiments will also be looked at closely.

Investigating science through dramatic inquiry

Inquiry is a key facet of Mantle-of-the-Expert (Abbott, n.d.; Aitken, 2013), with the main investigative questions being derived from the commission and subsequent discussion on how to meet the clients' needs. In this study students' science investigations proceeded from the need to meet the commission, which is one way students working in Mantle-of-the-Expert work in scientific inquiry. This way of working is in tune with 'real scientists' who Bull, Gilbert, et al. (2010) suggest, "design investigations to test their science ideas" (p. 5). While there was not a lot of 'student led' inquiry, students were encouraged to form questions and explore multiple perspectives to meet the demands of the main investigation question indented below.

> Re-examine the evidence [around the sinking of the Wahine], to see what contributed to the extreme event, what lessons can be learnt, and whether all possible care is being taken to avoid a repeat of the situation or mitigate damage if a similar event should occur again.

Figure 7.5 also shows student annotations of their questions about the sinking and what they need to find out to answer the commission.



Pat McLennon MP
Chair of Extreme Events Select Committee
Care of Distribution Services
Parliament Buildings
Wellington 6160

11th August, 2011

Seers
142 Oracle Place
Hamilton
3210

Dear Mr Robertson,

As part of the Government's Extreme Events Select Committee (EESC) I am writing to ask if you and your company would consider doing a historical scientific audit of the sinking of the Wahine. Due to the extreme weather and the spate of natural disaster that both New Zealand and Australia have been experiencing recently, the select committee has decided to commission a series of reports looking at historical events and re-examining the evidence to see what contributed to the extreme event, what lessons can be learnt and whether all possible care is being taken to avoid a repeat of the situation or to mitigate damage should a similar event occur again.

We have been talking to our counterparts at Christchurch City Council and upon hearing about your exceptional work for them and examining it ourselves; we have decided to ask you if you would be interested in submitting a proposal for the contract we shall describe below.

Please contact Pat McLennon on pclennon@eesc.govt.fnz if you require any further information. If you are interested, the closing date for submissions is the (date). Please reply in writing to the above address attention Pat McLennon MP.

Yours faithfully

Pat McLennon

Pat McLennon MP (Chair of EESC)

Figure 7.5 The Commission letter and investigatory questions

Figure 7.6 shows more examples of the questions raised by the students studying the commission.

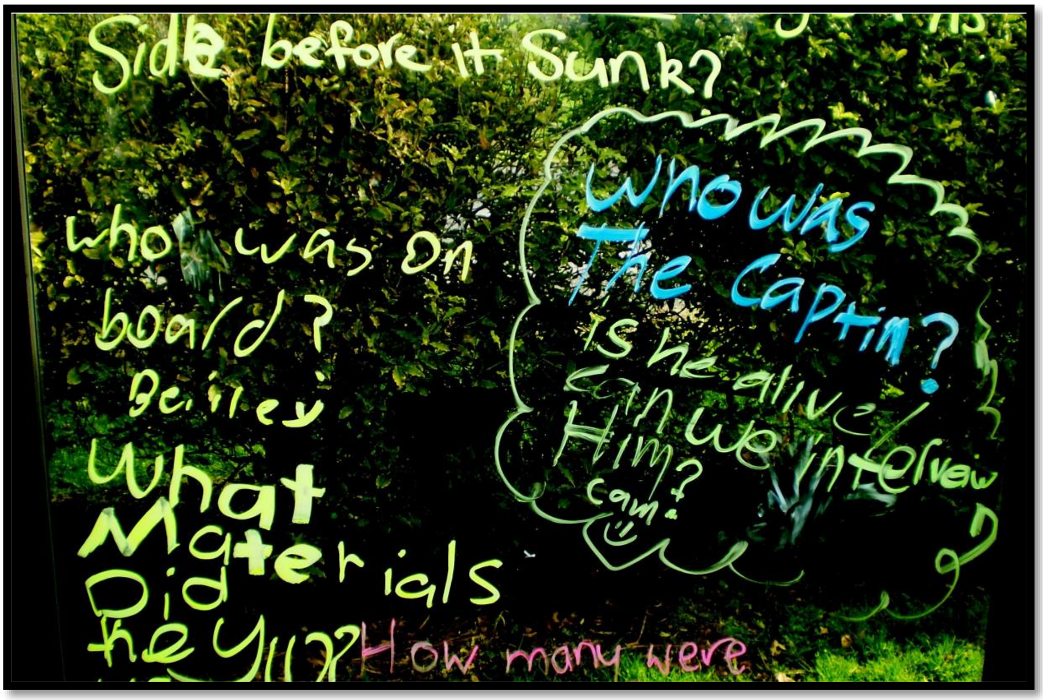


Figure 7.6 Example of students' investigative questions on the wall

Table 7.1 is a compilation of the investigation questions students generated. Some show students were operating in their company role as scientists as they asked, "What are you going to pay us?". Other questions were related to the sinking of the Wahine. The students asked, "Why did the Wahine sink?" They broke this question down to other questions like: "why did it take so long to sink?" and "why did it turn on its side?". The students queried the number of lifeboats, as that might have affected the survival of the people on board and wanted to talk to the captain to find out 'first hand' what happened. They asked questions relating to the construction of the boat by asking about the 'material used', the 'hull', whether its construction was similar to the 'Titanic' and wanted the blueprints and information about the builders. They also wanted to know the number of people and what freight was on the vessel as that might have affected its buoyancy.

It would appear from these questions, that the students had carefully considered what they needed to know to answer the commission.

Table 7.1 The questions derived from the commission written on the 'smart wall'

Questions for the client and science related questions
What are you going to pay us?
Why did the Wahine lie on its side before it sunk?
What materials did they use?
Who was on board?
Who was the captain – is he alive- can we interview him?
Objects that would be on the boat
Why did the boat go on its side?
How many lifeboats were their[18]?
Why did the Wahine sink?
Why did it take so long for it to sink?
How much do we get paid if we accept this offer?
Who built the boat?
What was the structure of the boat and was it similar to the Titanic?
Why did it turn on its side?
Was the hull thick enough?
How deep was the water?
Who designed the Wahine and was it designed to last through a big storm?
May I have the blueprints?
Were there any testing on the boat before the axident?
What was underneath the boat when it sank?
Was it preventable and predictable?
How did the water get in the boat?

Using experiments to help answer the investigation questions

The students carried out their investigation into the sinking of the Wahine using carefully designed experiments framed as research for the client. Although pre-planned by the teacher, these investigations were deliberately set up to encourage students to 'identify, seek patterns, explore and investigate models' (Ministry of

[18] The actual spelling the students used on the wall is given here.

Education, 2007c) to support the development of students' conceptual understanding.

Data from sections 5.4.2 and 5.4.4 indicated that the students believed that 'hands on' investigations were fun and enjoyable and helped them learn scientific concepts. The students I interviewed identified that investigating their question and exploring concepts in an accessible context related to 'real life' situations was useful. Lucy and Brooke explained:

Lucy: I kind of liked with the experiments we didn't just do things with the Wahine. We kind of did stuff with fruit how the Wahine sunk.

Brooke: It sort of showed us how the Wahine sunk (FG, 17/11/11).

TJayne echoed these student views. As already mentioned in section 5.4.3, TJayne considered that when the students were experimenting they were working in the manner of scientists; asking 'questions', making 'predictions' about what they might find, testing out what happened, and recording the results.

Jayne: When they were doing those experiments they were [acting like scientists], cause they were questioning, they were predicting and they were recording down their results (TI3, 15/10/11).

TJayne considered it important that the students had time to conduct their investigations and reflect on the learning they gained through these (section 5.2.2 and 5.4.4). Reflection through drama and writing a report helped to consolidate learning:

Jayne: The experiments were so valuable but alone they wouldn't have consolidated that understanding …. They had plenty of time to experiment …. And with the reflection ... we spent a lot of time on that, through the interviews and then another way that we were reflecting was through our report (I3, 13/10/11).

In summation, this section presented data related to students working in an investigative manner in science by asking questions, analysing and reflecting on data and reporting their findings, in a similar manner to scientists. Importantly, the students and the teacher thought the experiments were not only fun but also helped them understand the science concepts behind the Wahine sinking. They all recognised that using a 'hands on' investigative approach that combined drama and experimentation in a reflective ‘minds on’ manner, produced conditions conducive to effective science learning.

7.2.3 ‘Communicating in science’

The ‘Communicating in science’ section of the NZC online declares that students should learn how scientists communicate ideas and how to communicate their own science learning (Ministry of Education, 2007c). The importance of communication was a theme in the final student interviews where they emphasised that they talked to both get information (section 5.3.2), construct knowledge in group settings (section 5.4.1) and to explain to their parents what they had learned (section 6.4). Some additional features are described here to illustrate the ‘communicating in science’ NOS category. This section details student use of scientific vocabulary and being able to talk about scientific matters using the normative practices and patterns of science (Lemke, 1990; Yeo, 2009).Teacher and student impressions of the importance of communicating in science are also presented.

Use of scientific vocabulary

As detailed in Chapter 6.2, as the unit progressed and the students were introduced to more scientific words; the words used by students to describe the sinking of the Wahine changed to include more scientific vocabulary. In Table 7.2 examples taken from the four episodes described in section 6.2 are given to show the breadth of change in student use of terminology. For example, in the first episode - ‘sink’ was used; in the fourth - a student used ‘capsize’ and ‘heavy’ became ‘weight’ or ‘mass’.

Table 7.2 Examples of science vocabulary used in the signposted episodes

Examples of science vocabulary used over four episodes			
Episode One (ET, 04/08/11)	**Episode Two (ET, 25/08/11)**	**Episode Three (ET, 06/09/11)**	**Episode Four (ET, 15/09/11)**
Air	Air	Air	Air (light – air bubbles)
Heavy	Heavy	Weight/mass	Heavy/weight/mass (density)
Holes	-	-	Holes
Something down the middle	-	-	Centre of gravity
Tipped	-	“One side had weight”	Tip/stability More water one side
	Weight is more spaced out	Spread out wider	
	Drag	“went down more pressure”	
		Buoyancy	Buoyancy
		Water rises - Displacement	
Sink	Blow out air - sink		Capsize Density (Denser than air) (full of stuff) (weighs more than water) Weather contributed

In addition, I also asked TJayne in her midway interview about possible changes in vocabulary usage by the students. She confirmed that in her view the students had become more fluent in both the language of science and communicating ideas using it.

Jayne: When they were talking about density and buoyancy they say it - very roll off the tongue. So it was quite natural. So I know that would just mean they are quite confident with the vocab (TI2, 13/09/11).

When I asked the focus group of six if they were more able to talk and write about the weather and floating and sinking now, all agreed. When I asked them if they would have been able to write about floating and sinking before the unit, half dissented.

Children: No (about three voices) (FG, 17/11/11).

The students recognised they were not able to talk or write about the science concepts prior to the unit. I asked them whether framing the report in the context of the Wahine helped them communicate their findings in their writing, but they were unable to answer that question. I re-phrased the question, asking them if they could write a report about ‘floating and sinking’. Tom’s response was no, as you would have to ‘research’ first to make sure you were not ‘wrong’ about some of the facts. Brooke agreed.

Tom: I reckon probably not, cause you don’t really know much about it. You need to research it and then write the report. You can’t write straight off what you think you know cause you could be wrong.
Brooke: Yeah.
Tom: Cause like if you want to write a report you have to get the facts right (FG, 17/11/11).

Brooke realised that if she was to write without preparation; the language used and understanding demonstrated would be simple, for example, she would just mention vessels needing ‘air’ to float.

Brooke: Yes, if I was to do one of those I would probably just say something very simple (like if it doesn’t have very much) it would sink and if it’s got air in it will float (FG, 17/11/11).

I asked them what changed in the words they used initially and the more complicated scientific words they used later. Tom implied that initially he did not know the scientific words.

Tom: I think it was just cause we didn’t recognise the words (FG, 17/11/11).

Both Lucy and Cameron identified that it was not just recognising a word but understanding what the word meant that made the difference in their writing.

Lucy: Yeah, kind of the language … cause some of us didn’t know some of these words ... I think if we had a better understanding of the words.
Cameron: We kind of had to learn the big ones. Like some people didn’t know buoyancy (FG, 17/11/11).

Tom and Brooke identified that they didn’t know the meaning of density, with Tom confusing it with buoyant.

Tom: I didn’t know density.
Brooke: Me neither.
Tom: Yeah, I knew it had something to do with dense. I thought it was like dense meant buoyant (FG, 17/11/11).

They noted they had to be exposed to the vocabulary before they could use it with any degree of accuracy.

As well as developing an understanding of science vocabulary, students also needed to develop an understanding of the ‘conventions of science’ or the normative practices for communicating science as such, justifying their claims with evidence and having findings authenticated through peer review.

One way the students showed they were working in the normative practices of science communication was in their analysis of documents. In an early episode (ET, 23/08/11), the company analysed newspaper articles published just after the Wahine Disaster, looking for scientific reasons why the Wahine sank (see Figure 7.7 for an example of student analysis). By doing this they were building their knowledge of ‘vocabulary, numeric and symbol systems’ of science, as well as sorting the opinion of the writer from scientifically verified facts.

Another aspect of communicating in science is being able to disseminate and justify your findings orally before your peers. Conclusions derived from students’ work in role as expert scientists analysing the newspaper articles were shared with the ‘company’. The students were asked to share their findings in a collegial adult manner rather than by the teacher asking and students responding.

TJayne: Guys, I wonder if this could happen quite naturally. I don’t need to go, Mitchell you start up and do it. You just stand up and go (ET, 23/08/11).

In response, Belinda shared from her article that the vessels met industry standards, thus implying that the vessel was seaworthy.

Belinda: I read in an article, one of them and it said that the ship was up to the standards (ET, 23/08/11).

As already indicated in section 5.3.4, Mitchell noted that no one was found guilty of negligence.

Figure 7.7 Example of student analysis of newspaper articles

Students were seen to communicate their knowledge of science when they discussed science concepts in small groups and in whole class settings. Specific examples were given in sections 6.2 and 6.3. Other examples are given here to demonstrate the proposition.

An additional example of dialogue is taken from a small group investigating whether potatoes float and if they can be made to float. Girl A stated, “The potato sinks” (ET, 14/09/11). I then asked the class whether the result would be different with a small piece of potato. Upon testing they told me that a small piece of potato didn’t float. Alicia tried to work out how to make the potato float. Eventually she hollowed it out and it floated. Girl B offered the suggestion that it floated because it now had air in it, which while technically correct, does not mention the decreased density and increased volume.

Alicia: I’m trying to make this [the potato] float ... I think it will float. TJayne, it floats! We hollowed it out and it floats.

Girl B: It’s got air in it (ET, 14/09/11).

Another way the students communicated like scientists was through their written work. Publication in peer-reviewed journals is central in the legitimisation process of new scientific knowledge. As part of the commission, students were asked to write a report communicating their findings on the science behind the sinking of the Wahine. Clear guidance was given on this - all statements were to be backed up with experimental evidence, not just 'opinions'. As mentioned in chapter six, 15/25 (60%) of the students were able to back up their scientific claims by drawing on experimental evidence.

As already stated in section 6.3, Tom used the potato boat experiment mentioned above to link the vessel getting denser on one side when it took on water to a potato sinking because it was dense (see Appendix V for the full report). His understanding of the science behind the potato boat experiment was more advanced than Girl B on the previous page who considered the potato floated because it "got air in it".

Tom: We at S.E.E.Rs did experiments to test density using fruit. The potato sunk because it was dense but then we hollowed it out and it floated because it was less dense than before (WR).

Another example is from Brooke (see appendix V) who used the paper boat experiment to explain the sinking of the Wahine.

Brooke: The starboard side started to fill up with water making it more dense and causing it to roll on its starboard side. I found this out because we experimented with paper boats. We placed paper boats in the water and put a marble on one side. This showed that when mass is added to one side the boat will tip to one side (WR).

Student interview comments indicated that they were able to interpret the weather forecasts on TV suggesting that they transferred this practice to home. Detail was provided in section 6.4; a further example of Brooke communicating her understanding with her father is given here.

Brooke: I can tell most of it. I will be sitting there watching with Dad and I go, "I know what that means now" (B&J, 05/10/11).

However, data also suggested not all students were comfortable communicating orally. Ofa (L&K, 05/10/11), who has English as an additional language, wanted to explain her science knowledge but indicated she found talking in an interview situation stressful. She was, however, able to write down her ideas. This demonstrated a basic but correct understanding of why the Wahine sunk. As already mentioned in section 5.4.1, Jess did not want to talk in front of others.

Jess: Cause you don't want to muck up in front of everyone (B&J, 05/10/11).

In summary, students were able to work within the 'conventions of science' to communicate their ideas about science and their peers in oral and written formats. Students also realised that evidence was required to support claims with 15/25 students using evidence to substantiate their findings in their reports to the client.

7.2.4 Summary

Findings in this section have shown that working within the Mantle-of-the-Expert commission allowed and required students to engage with a number of science processes. Using the dramatic convention of 'Role-on-the-Wall' seems to enable students to dig deeper into the roles and characteristics of scientists, including the communicative aspect of being a scientist. The impression portrayed of scientists was largely positive and multi-faceted. However, their visual representations of scientists indicated the stereotypical 'mad scientist' rendition was still strong.

Findings showed that the careful framing of the Mantle-of-the-Expert approach seemed to help students decide what questions were important to investigate. It also gave them the opportunity to work in the manner of scientists as they investigated the sinking of the Wahine. The 'hands on' nature of the investigation was useful in embedding learning

Furthermore, students were communicating their science ideas in a more adult manner, and were more likely to use appropriate scientific words to describe science concepts by the end of the unit than at the beginning of the unit. They were also communicating their science ideas and the science ideas of others, through a variety of different modes, such as orally, dramatically and in written formats. Criticality was demonstrated through their substantiation of their claims with evidence.

7.3 Science Futures

This section presents findings on whether the students saw themselves having a future career in science (section 7.3.1). It explores their ideas of what constitutes a career in science and offers an example of what can occur by widening students ideas about careers that include science (section 7.3.2). It also looks at student perceptions of themselves as ‘good scientists’ (section 7.3.2). The findings in this section address research question 3:

3. How do year 7/8 students see themselves in science now and in the future?

7.3.1 A future career in science

Assessment data was examined to ascertain whether students (split into boys and girls) aspired to a science career. The International Standard Classification of Occupations, 1988 (ISCO-88) was used to identify the category of science the students mentioned in the assessments. Figure 7.10 graphs student science choices as: physical science, life science, health science and engineering[19]. Any career choice mentioned without a strong science aspect, based on ISCO categories, was placed in ‘other’. If science was mentioned in a general fashion it was placed in general science. For instance, a vet comes under ICOS-88 category 222 – Health professional, which I placed under health science, while a florist would be categorised ‘other’.

[19] Physical science was drawn from ICOS-88 categories: physicists, chemists, and related professions (211), mathematicians, statisticians and related professionals (212) and computing professionals (213). Life science professionals (221), engineering professionals (excluding electro technology) (214) and health professionals (222 and 223), were the other science related categories.

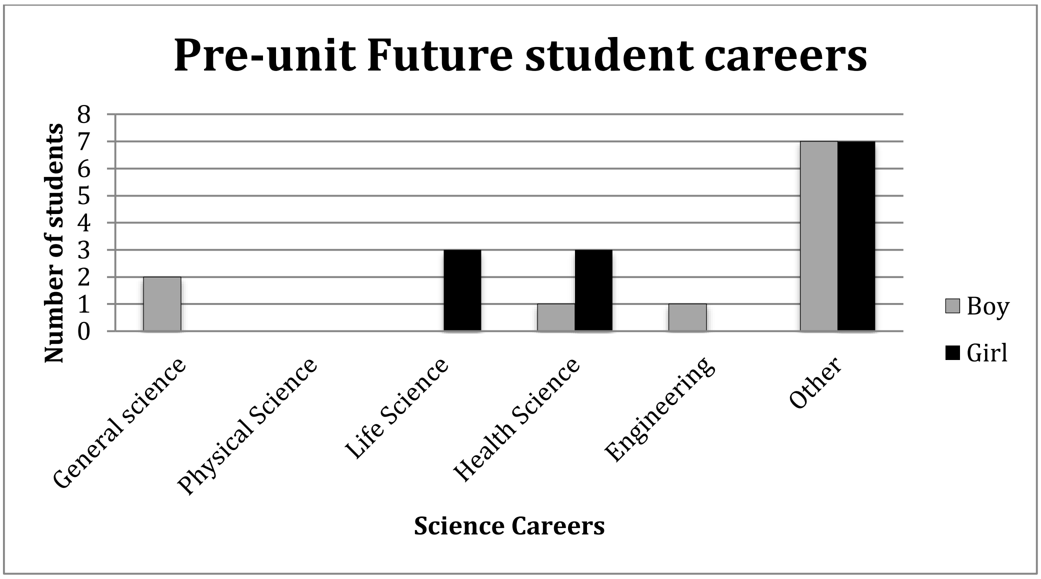


Figure 7.8 Differentiation of students' future science career choices pre-unit

42% (10/24) of the students in the pre-assessment (Figure 7.8) indicated there was a possibility of a science career in their future. The four boys who expressed an interest in science careers chose careers in three different categories – general, physical and life sciences. The six girls wanted to work in either life science or health science.

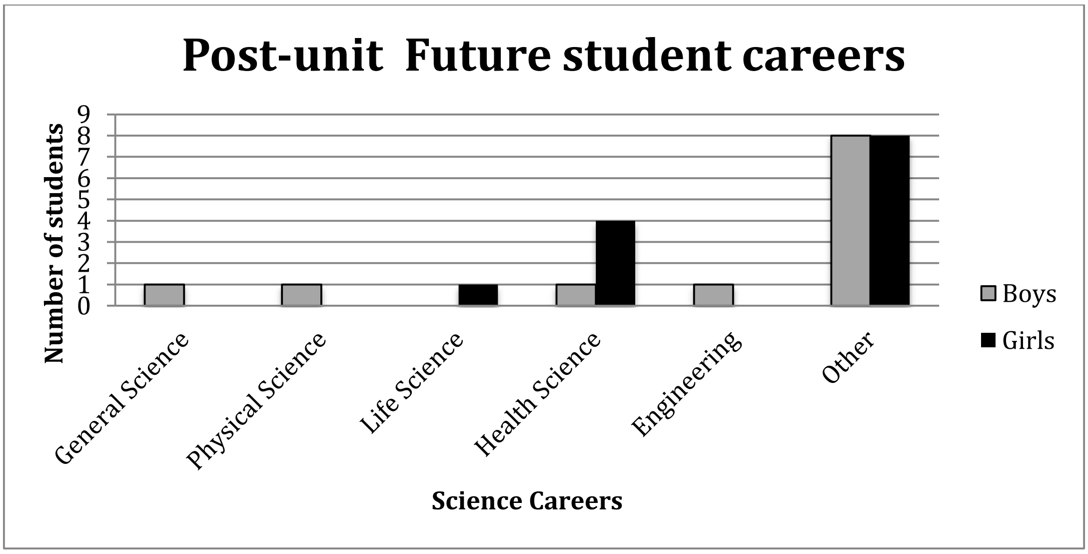


Figure 7.9 Differentiation of students' future science career choices post-unit

In the post-assessment (Figure 7.9) the boy who had previously indicated interest in a career in engineering retained his interest, as did the boy who wanted a career as a vet. One of the boys who previously indicated a general career in science became more specific, choosing a career in the physical sciences. The choices by the six girls remained clustered in the life and health sciences.

Interestingly, TJayne, in her initial interview, identified some students as likely to pursue science careers.

TJayne: Absolutely like that one child [Tom] that you got to know (TI1, 25/07/11).

All of the students whom I interviewed were asked about whether a science career would feature in their future. Tom, the child identified by the teacher as having a science identity and self-identifying as becoming a vet; also had strong science capital, as his parents were involved in science.

Tom: I've wanted to be a vet ever since … My parents both have something to do with science (FG, 15/11/11).

Four of the other students mentioned science-based careers in their post-unit interviews (05/10/11). Ofa wanted to be pre-school teacher who taught science; Taylor, a doctor; Cameron, a career in IT (Information Technology); while Josh wanted a career in sport, which certainly includes aspects of science.

Jess did not mention in her interview whether she wanted a career in science. However, in her post assessment (05/10/11) she mentioned wanting to be a "vet, teacher or dietician", all of which involve science.

Brooke was uncertain, as she had not made up her mind about her future career and whether science would feature in it. Lucy hedged as she had not done a great deal of science and wanted to explore more.

Brooke: I'm not sure. It would depend on what kind of science we are doing (B&J, 05/10/11).

Lucy: I think for me to decide I might need to do a bit more work on science because it is something new and I have never done science before (L&K, 05/10/11).

In summary, students' possible science careers appeared to be fairly stable over the duration of the unit but became slightly more specific. The gender based split was of interest with the girls clustered in health and life science whilst the boys career choice was more spread out. It must be noted this was a very small cohort.

Of interest was the identification by the teacher of students with clear science identities. Surprisingly six out of the eight students interviewed thought there was a possibility of career involving science in their future.

7.3.2 Knowledge of science based careers

Data presented in this section shows the types of science careers the students identified in their assessments. These were categorised according to the ISCO-88. In addition to the categories already given in Figure 7.10, the careers mentioned were divided into teaching (23) and a generic category entitled careers with science, to denote careers that include some science aspect. The data was also divided by gender, to see if there was a discernable gender preference for distinct categories of scientific careers. This section also presents data on what occurred when a simple science careers poster was introduced and discussed.

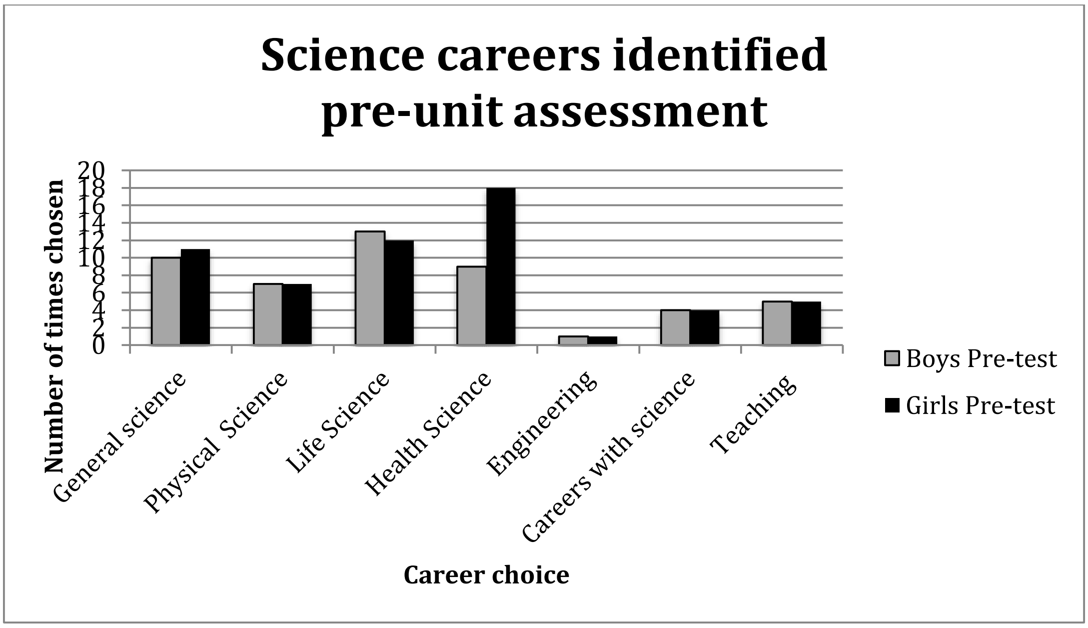


Figure 7.10 Pre-unit assessment of students' identification of science careers

In the pre-unit test girls mentioned a career from the health sciences category at double the frequency of boys. In all other categories, the numbers of girls and boys choosing a career from a given category were almost identical.

Literature suggests that students need to be explicitly introduced to possible science careers, as they are less likely to choose science as a possible career if they do not know of any, especially when they are forming a possible ‘career identity’ (Tytler et al., 2008). As one of my aims was to explore science career development, it was important students were introduced to a variety of science career choices. To do this a poster (see Figure 7.11) titled ‘Science careers” which showed 30 possible science careers was displayed on the classroom wall chosen to appeal to student interests.

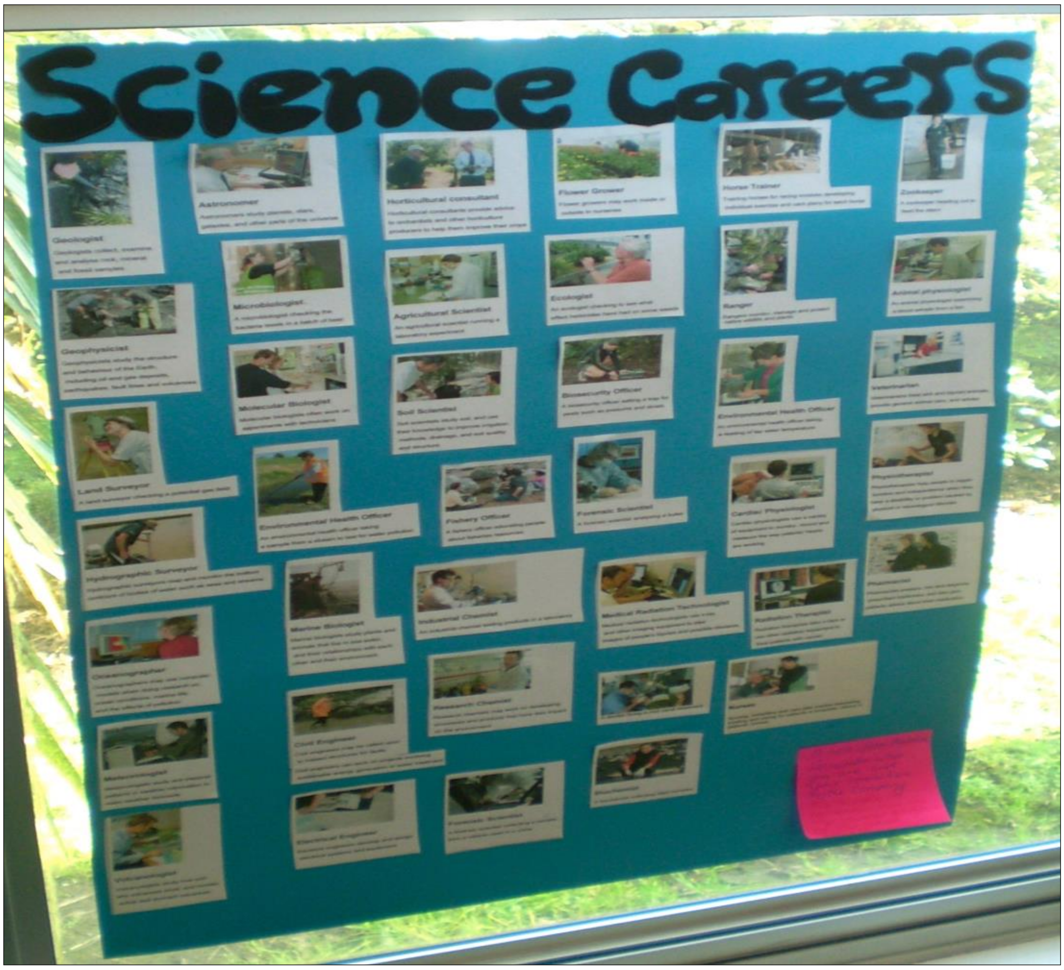


Figure 7.11 Poster showing science career choices

Student comments indicated that the variety of careers involving science on the poster was a surprise to them. Student A explained, ‘I’ve never seen some of these before.’ While Josh said, ‘I only knew like three (ET, 11/08/11).’

As part of a whole class discussion Student B and TJayne explored the link between hairdressing and science. TJayne mentioned that different chemicals that are used in colouring hair.

Student B: How does hairdressing involve science (ET, 11/08/11)?

TJayne: When your mum gets a hair dye you put different peroxides and chemicals onto her head so they have to test it out. If you put too much peroxide – your hair might fall out. They have to balance the chemicals (ET, 11/08/11).

This conversation about hairdressing involving science appeared to widen the students' understanding of careers that include science, as is seen in the post-unit assessment (Figure 7.12) where seven students mentioned hairdressing as a possible career.

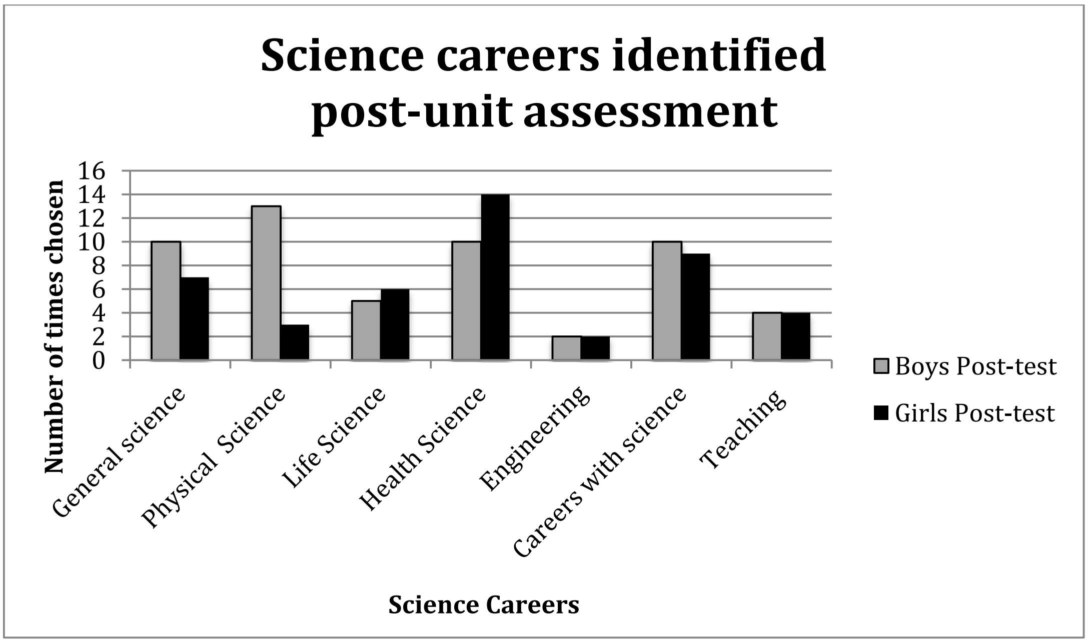


Figure 7.12 Post-unit assessment of students' identification of science careers

In the post-unit test, boys mentioning generic science careers stayed constant, while the girls dropped from 11 to 7. The number of boys choosing the physical science category was double the rate of the pre-test, while the number of girls choosing this category was reduced by half. Students mentioning the life sciences in the post assessment dropped by half in both genders. A similar number of boys mentioned health-based careers, while the girls' choice of this category was reduced from 18 to 14. In both genders, engineering as a career choice rose from one to two. The mention of other careers, which included science, was doubled for both genders. Science teaching remained at similar levels for both genders.

Teacher and student comment confirmed a greater awareness of the variety of science careers options by the end of the unit. For example, TJayne identified students were more aware about different careers that involve science, and that her awareness of science usage in everyday life was enlarged.

TJayne: I think they have. Definitely – they are so much more aware of what careers are out there that involve science. I think it has made even me as well more aware about how often we use it every day (TI3, 13/10/11).

This supposition was also acknowledged by Josh who commented that his understanding of what constitutes science had widened from his pre-unit ideas of 'blowing up stuff'.

Josh: Yeah I think it's opened up science more to me. Not just the blowing up stuff ... There's lots of different science and lots of things that are involved with science (T&J, 05/10/11).

However, this enhanced awareness of the variety of science careers available did not necessarily translate into students choosing to pursue science as a career. When asked if learning in this manner had opened up more career choices, Tom replied in the negative. It must be recognised that he already had a very strong science identity. Josh didn't consider it had opened up more career choices for him but identified that it had showed him how much science is involved in everyday life and how many different careers include science.

Tom: Not really

Josh: I don't think it's shown me more career types, it's just shown me what that how much science has got to do with jobs and just everyday stuff (T&J, 05/10/11).

It would appear from these findings that during the study, there were some changes in students' identification of science careers from the pre to the post assessment. Boys were more likely to chose a physical science based career than girls. Health sciences remained popular choices. Engineering as a career choice, whilst not a common choice became slightly more popular for both genders. What was interesting was the increased awareness of other careers, which included science as the students were exposed to these during the intervention through a careers poster.

7.3.3 Summary

This section described the findings about science futures. 42% (10/24) of the students identified an interest in a future career in science. It was apparent, even in this very small sample size that more girls than boys chose to work in the life and health sciences. The boys favoured the physical sciences and engineering. There were a few students who were perceived or identified themselves as having a ‘science identity’. Interestingly, six of the eight students interviewed mentioned a possible career that would involve science. The other two students were more ambivalent.

Student knowledge of careers that involve science appeared to mirror their gender based choices at the beginning of the unit, with girls being more likely to mention careers in the health or life sciences. Science careers were introduced to the students in an explicit but informal manner by providing a poster catering to the prior interests of the students on the classroom wall. Students were surprised at the variety of careers that included science and how much science impacts their everyday life. There were small shifts in student knowledge about science careers, with the additional knowledge about the types of careers that include science contributing to the expansion of knowledge at the end of the unit.

7.4 Chapter Summary

This chapter examined the data to ascertain whether working in Mantle-of-the-Expert supported students to learn about and through the aspects of the Nature of Science, as it is defined in the NZC. It has also examined students’ future science aspirations and knowledge of science careers.

In terms of ‘understanding in science’, the data presented shows that student ideas about the tasks scientists do diversified over the duration of the unit. There was no discernable difference between the view of the boys and the girls about the tasks scientists carry out. The dramatic technique of ‘Role-on-the-Wall’ appeared initially to perpetuate the stereotypical notion of a ‘mad’ scientist. The statements on the image and class discussion painted a different picture. In these, the image of a scientist was positive, someone who was courageous and working for the greater good of society. Additionally several of the interviewed students commented that their understandings about scientists had become more realistic and less sensational.

In the 'investigating in science' section, the inquiry focus of working in Mantle-of-the-Expert was highlighted. Deconstructing the commission provided space for the students to ask questions about science ideas, which then focused their investigation into the sinking of the Wahine. The investigative frame enabled the student to question, experiment, analyse the data and report their findings like 'real scientists'. Students and teachers considered that the experiments and drama helped them understand the science concepts behind the Wahine's sinking.

By the end of the unit, the vocabulary students used to describe science concepts had expanded to include more scientific terms alongside everyday words. Students used the conventions of science to analyse data and to communicate and defend their understanding of the science orally, in written formats and through drama. Most students also supported the claims in their written reports with evidence, thus demonstrating they were operating within the normative conventions of science.

Findings identified that students' ideas of science-based careers were not comprehensive at the beginning of the unit. Providing an opportunity to talk about science careers using a poster appeared to broaden their knowledge of the science-based careers available. In terms of career choices, the boys favoured a career in the physical sciences or engineering, while the girls were more likely to consider a career in the health or life sciences. However, the number of students considering a science-based career was very low.

This chapter is the last of three findings chapters. Chapter five presented findings on learning science through Mantle-of-the-Expert. It highlighted the importance of being 'positioned as experts to learn science', 'positioned as ethical scientists', and being 'engaged into learning through Mantle-of-the-Expert'. Chapter six used multiple sources of data to provide evidence of students learning about the science concepts of buoyancy, stability, cyclones and weather isobar map interpretation when the learning being framed dramatically through Mantle-of-the-Expert. This chapter has investigated student learning about aspects of the NOS. It also examined whether students' attitudes towards school science improved. In addition it explored the data for students future science aspirations and understanding of the breadth of science careers.

The results from the finding chapters are interpreted in Chapter eight, the discussion chapter.

Chapter Eight: Discussion

8.1 Introduction

In this chapter, findings from chapters five, six, and seven are interrogated against relevant literature in relation to the research questions.

1. How did Mantle-of-the-Expert support or constrain the learning of science concepts and the Nature of Science by a class of year 7/8 students?
2. What shifts in students' written and verbal use of science concepts, Nature of Science, and science language, occurred over the course of a nine-week Mantle-of-the-Expert unit?
3. How did the Year 7/8 students in this study come to perceive science now and in their future?

The chapter is divided into three main sections. Sections 8.2 and 8.3 relate to question 1. Section 8.2 provides findings on how the main structural components of Mantle-of-the-Expert - being positioned as expert and working within a company to fulfil a commission for a client - supported students' science learning by providing a participant structure and motivation for students to learn science. It also outlines how the introduction of 'fictional others' beyond the client, and the re-positioning of how the curricular content was taught to support student expert status, supported students' learning of science. In section 8.3 findings are presented regarding with learning within a fictional context; the merits of drama and of science-based curricular tasks; and the inclusion of an ethical imperative for action. This section also discusses the impact and implications of students operating in multiple figured worlds. Section 8.4 discusses findings relating to shifts/changes in student understanding of science concepts and Nature of Science as well as changes in student attitudes towards science and their knowledge of science careers, research questions 2 and 3 respectively.

8.2 Structural components examined through positioning theory

This section interrogates the findings related to what I term the structural components of Mantle-of-the-Expert: namely being positioned as 'experts' and working for the company[20] to fulfil the commission for a client. These findings are described and analysed through positioning theory. In addition, I present findings that indicate that re-positioning the how the curricular content was taught to support students in their expert scientist positioning was able to also support the students' science learning. The findings indicate that the company, client, and commission are interlinked with, proceed from, and contribute to the positioning of students as experts. The centrality of positioning students as experts and the various relationships of these components are illustrated in Figure 8.1. I begin by discussing findings to do with being positioned as expert because this was pivotal to the pedagogical approach and outcomes for the study.

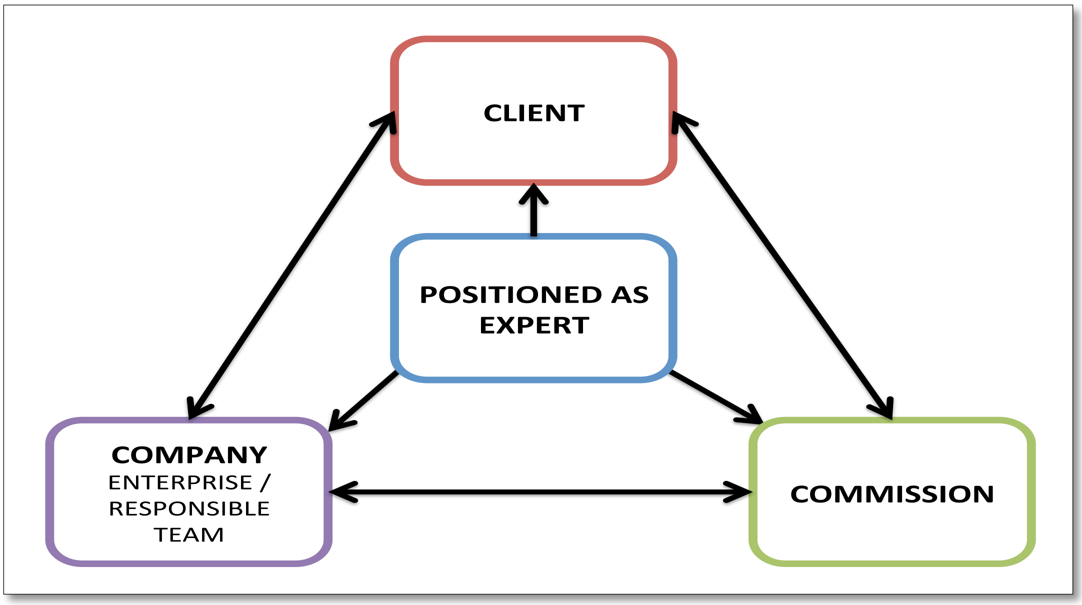


Figure 8.1 Interrelations between the main components of Mantle-of-the-expert

8.2.1 Positioned as experts

The depth and breadth of findings on students being 'positioned as experts' within the participant structure of Mantle-of-the-Expert set out in sections 5.2 and 5.3

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[20] This is also known as the enterprise or responsible team. Company is used in this thesis because that was the terminology familiar to the students who participated.

highlights the importance of this component. Students were intentionally positioned as expert scientists by the social force (Harré & van Langenhove, 1999c) of the teacher's explicit speech acts and the use of sign such as the company noticeboard. Together, the teachers and students built a shared storyline with a history, whereby they were in role as company members and scientists re-investigating the sinking of the Wahine (see section 5.2). While the social force of the teacher was behind the initial positioning of the students, student acquiescence to the positioning and agreement to take part in the drama was sought by the teachers and given by the students. The teachers used 'first order positioning' when they positioned the student as members of the company SEERS (section 5.2.1). Students' agreement to that positioning was seen through changes in their pronoun usage from talking about 'a' company to the collegial plural of 'our' company as illustrated in section 5.2.1. The students moved into second order positioning (see section 2.4.2) when they socially negotiated how their roles as members of the SEERS Company were 'played out' within the figured world of the drama. This happened when students were designing a floor plan of the company workplace (section 5.2.1) and when they chose a scientist identity when writing their CVs (see section 5.2.1). The students knew they were pretending, but their actions indicated that they agreed to believe the 'big lie' that they possessed the expertise implicit in their enacted role (Heathcote, 2008b, p. 10). These findings add to work that has used positioning theory to understand Mantle-of-the-Expert (Aitken, 2014b; Edmiston, 2003, 2007, n.d.-a), specifically they add ideas of first and second order positioning, and the examination of pronoun use as a way of understanding and enacting Mantle-of-the-Expert.

Being positioned as an adult expert changed how some students viewed their learning capabilities (section 5.2.3). These students stressed that when they were positioned as an expert scientist in role in Mantle-of-the-Expert they were still working as themselves, albeit an adult version of themselves. Cameron was the most eloquent of these students (section 5.2.3). He considered that the expert positioning changed his 'mindset' so he spoke and acted like 'an expert' with the confidence to explain what he knew. In Heathcote's terms, working in an adult positioning allowed students to act as a "self spectator" to the work they were doing (Heathcote, 2007, p. 9). It allowed students to analyse their learning (and actions) critically as illustrated by their comments on the quality of Roger's work (section 5.3.3). Overall, student acceptance of their positioning as experts enabled Cameron in particular to meta-cognitively 'act and communicate' in an expert role albeit supported by the teacher. Heathcote (1991c) asserts that walking in someone else's shoes and experiencing their life can extend students' thinking. This assertion aligns to Cameron's comment about changing his 'mindset' and 'acting' as if he was an expert scientist.

Findings presented in section 5.2.3 show that positioning students as fully functioning adult members of an company (Heathcote, 2008a) altered the power relationships between the teacher and students to one of "power with" rather than a "power on" relationship (Edmiston & Bigler-McCarthy, 2006, "Using power over", para.1., "Using power with", para. 1"). Instead of the teacher having a higher status than the students, the teacher and students were deliberately positioned as 'colleagues' (Heathcote, 2009) within the company. That all students were positioned as colleagues meant that no one was privileged over others. Students working in this way are in line with Heathcote's (2008a) description of how power operates in Mantle-of-the-Expert (see section 3.2.1). In addition, data in section 5.4.1 illustrates that working as colleagues fostered a supportive learning environment where students helped each other learn. Having a supportive classroom-learning environment has been identified as enhancing science learning (Darby, 2005; J. Osborne & Collins, 2001). Added to this Pike and Dunne (2011) assert that the appeal of science is enhanced if the teacher is positioned with less authority and ideas are discussed. In this study, focus group student commentary mentioned that the 'more equal' teacher - student relationship meant it was easier to 'learn more' (section 5.4.1). Certainly this was the impression Lucy gave. She felt that she learned more when the teacher was talking with her rather than at her (section 5.4.1).

For the study class, the position shift to being colleagues within the company rather than teacher and peers opened up a new and different space for discussion-based learning because the students felt their ideas were valued in this context. For example they decided whom the company should appoint to the new scientist position after assessing their science knowledge. To make this point another way, the change in the power relationships to be more equal and collegial enabled students to become “active meaning makers” (Gresalfi & Williams, 2009, p. 314). Others have found that being positioned into a knowledgeable role with responsibilities for their actions enhances students’ motivation and learning (Tan & Calabrese Barton, 2008). However, it is important to note that a few students were constrained from working collegially and overwhelmed by their positioning as experts because they were shy and/or worried about being incorrect (section 5.4.1). This finding is commensurate with that of Brickhouse (2012) who identified that not only students are not totally agentic in their authoring of their science identity but also some students may not be able or willing to take up the opportunities offered to them.

To sum up, the study provides evidence that being positioned as an expert as part of the Mantle-of-the-Expert participant structure afforded the students an opportunity to work in a more collegial role with the teacher and each other and made them feel valued. It changed some students’ ‘mindsets’ so that they felt they acted and spoke authoritatively and used their expertise to access learning opportunities. Some students considered that this helped their learning but others were more cautious in claiming a benefit. Overall, findings show that using this aspect of Mantle-of-the-Expert is possible and can be advantageous in a science setting.

8.2.2 The Company - working together

The company is another commonplace component of Mantle-of-the-Expert that was significant in this study. Findings show that working within the structure of a company supported students’ learning by cultivating an inclusive climate and providing opportunities for them to learn as part of a group process. All students and the teacher were included in the company and had a responsibility to contribute to the successful completion of the commission it had accepted. Student commentary indicated that everyone being ‘included’ as part of a company was an important component of their experience of learning within Mantle-of-the-Expert (section 5.4.1). This finding lends support to the Mantle-of-the-Expert literature (section 3.2.1), which iterates the importance of building an inclusive community, where all voices are heard and identities affirmed (Edmiston & Bigler-McCarthy, 2006). The importance of working in an inclusive collaborative manner has also been identified in the science education literature (section 2.5.1) where Sorenson (2007), for example, suggests that working collaboratively enhances students' ownership over their learning.

Findings presented identified that students liked learning with and from their peers as part of the Mantle-of-the-Expert approach (section 5.4.1). Students considered that working together aided their learning, as ideas could be amplified through 'bouncing off others' and clarified through discussing them (section 5.4.1). They stated friends could support them when they didn't know an answer. This way of working is a facet of Mantle-of-the-Expert facet that has been acknowledged in the literature as beneficial to learning (O'Neill, 1995b, p. viii). Learning socially has also been recognised to enhance learning in science (Duit & Treagust, 2012; Greeno & van de Sande, 2007; Mercer, 2008; Roth et al., 2008; Sainsbury & Walker, 2011; Vosniadou, 2012).

8.2.3 The Commission - providing a direction for learning

The commission from the client was identified as important in providing coherence and direction for student learning (sections 5.2.2, 5.3.2 and 7.2.2). As expected, the findings showed that the commission set the academic parameters for learning, with the students recognising they were required "to study science" and investigate such things as "why did the boat go on its side?" (section 7.2.2). Students were also clear that they had been commissioned to investigate the sinking so that such an event would 'never happen again' (section 5.3.2). They related to the humanitarian aspect of the commission, as highlighted in Eli's statement, "R.I.P. people are researching for the terrible truth behind the sinking of the Wahine" (section 5.3.2). This humanitarian connection has been identified as important to retaining student interest in science and science careers (Haste, 2004; Schreiner, 2006; Tytler et al., 2008). Having a humanitarian aspect is also seen as important in the Mantle-of-the-Expert literature where students work in an ethical manner in real life scenarios to explore what is to be human (Heathcote, 2009; Heathcote & Bolton, 1995).

Having a humanitarian purpose that provided an emotional connection (sections 5.3.2 and 5.4.3), and reason to study science (sections 5.2.2 and 7.2.2) was also identified as noteworthy in this study. The importance of students connecting emotionally to the learning topic is well recognised in the Mantle-of-the-Expert literature; learning in Mantle-of-the-Expert is never conducted in an emotional vacuum it “is always about something that matters to you” (Heathcote, 2009, appendix 17a). The value of students emotionally connecting to the need to understand science is in keeping with literature that identifies the role of ethics and values in science and science learning (Reiss, 2010; Roth & Tobin, 2007; Ryan & Buntting, 2012; Wong, Zeidler, et al., 2011).

8.2.4 The Client - an authentic external audience

In this study, as is common practice in Mantle-of-the-Expert (Heathcote & Bolton, 1995), the high status client acted as an audience for the students’ work rather than the teacher. The students worked with Malcolm as CEO of the company to complete the commission but their report was prepared for the fictional client - EESC (section 5.3.3). It was the client’s needs rather than the teachers’ that structured the unit and provided guidance on the science investigations. This was achieved through the detail of the commission and the resources provided to the company such as an archival box and newspaper articles (section 5.2.2). Providing an answer for the client was thought by the teacher to enhance students’ motivation to write a quality report (section 5.4.3). Cornelius and Herrenkohl (2004) identified the value and advantage of working for an audience (such as the client in this case) who demands excellence and accountability in shifting students from being passive listeners (or learners) to active creators of meaning. Enhanced quality in student work has been noted as a facet of working for an audience by Heathcote and Bolton (1995) and in the wider Mantle-of-the-Expert literature (Edmiston & McKibben, 2011; Kidd, 2011; Kidd & Millard, 2007; O'Brechain, 2006, 2012). This study adds to these findings, contributing that this aspect is important in a science-based Mantle-of-the-Expert unit.

8.2.5 'Fictional others' - an internal role model

The inclusion and impact of two 'fictional others' (Malcolm and Roger), aside from the client, is a distinctive feature of this study. Similar to the Mantle-of-the-Expert literature on the role of the client (section 3.2.1), these 'fictional others' provided students with an incentive to work and to develop their science ideas (section 5.3.3). As seen in Figure 8.2, the Client, Malcolm and Roger all functioned as an audience to the students' work in the company.

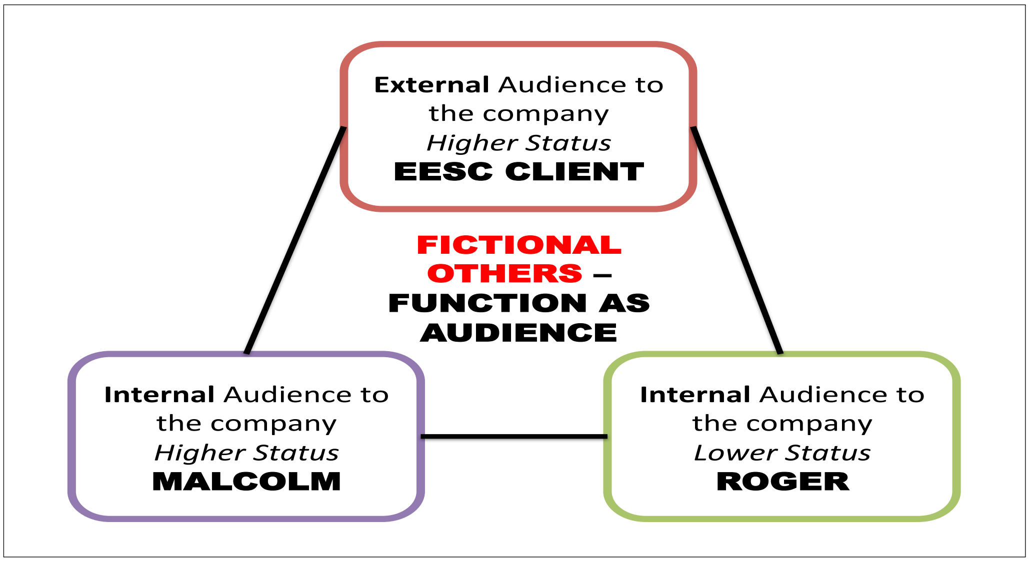

Figure 8.2 Expanded view of the three 'fictional others' who acted as audience in this study

Significant to their impact, the two fictional others also differed from a client in their positioning relative to the students and the authority engendered by their roles. Malcolm was a high status 'fictional other' who, through the positioning of the teachers in their respective roles of secretary and PA, inspired his staff (the students in role) to work ethically and produce work of a high standard (section 5.3.3). In addition, he was positioned by the teachers as someone for the students to emulate in their work as expert scientists, because his work was recognised to be of a high standard. Students wanted to meet Malcolm's expectations and rose to the challenge of producing work that was 'correct' in a timely manner (section 5.3.3). His recognised high status also served to position scientists and the work they do as valuable for society. The positioning of scientists as valued members of society has been deemed important by DeWitt et al. (2013) as useful in mitigating negative discourses of science as being useful but not for me. As a positive scientist role model, Malcolm played an important role in the MOTE although it is of interest that Malcolm's contribution was mentioned more by the class teacher than the students. Both teachers found him to be useful as a structural tool for shifting the focus from teachers demanding work. Malcolm acted as a valued internal audience before student work went to the client.

Roger, the second 'fictional other', occupied a lower status to the students in the company. He was positioned by the teachers, and recognised by the students as a likeable 'prankster'. Roger was introduced into the drama as a substitute for the students' flawed work and served as a representation of the consequences of not taking enough care with science processes (section 5.3.3). The students recognised that his science was 'basic' and that he took 'short cuts' and made 'mistakes' (section 5.3.3). While the students did not specifically note the parallels between Roger's actions and their own potential behaviour they talked about what to do to ensure they didn't 'get the heave-ho from [their] job' (section 5.3.3). Instead of the teacher censuring them the students were able to critique their actions in the light of his actions. The study found that the students' recognition of the consequences of Roger's actions created a desire in students to ensure their work for the client was of a high standard, which Heathcote and Bolton (1995) argue is one of the benefits of working for a client. This study indicates the value of different categories of fictional others as an audience. Students were adamant they did not want a science identity like Roger.

In addition, Roger as an incompetent 'fictional other' provided a way to acknowledge the impact of science on the lives of real people and society. In the drama, Roger's mistakes damaged the company's reputation, cost money and let down the 'people' who were waiting for his work (section 5.3.3). He served to show that science (in this case incompetent science) affects the lives of real people. Connecting science to the lives of real people is seen as crucial in guarding against science being seen as irrelevant and disconnected from society, which in turn is a risk factor for student disengagement (Cleaves, 2005; J. Osborne & Collins, 2001; Tytler et al., 2008).

8.2.6 Re-positioning the teaching of curricular content to support student expert status

As evidenced in findings from section 5.2.2, how the curriculum (defined as ‘the science knowledge and practices that the students need to know’) (section 2.2) was taught was repositioned to support the students in their positioning as ‘expert scientists’. In a conventional transmission model of teaching, the curriculum is positioned as knowledge to be delivered by the teachers and received by the novice learners. This was not the approach taken in this study, as it does not position students as experts. The following three practical activities illustrate how the teaching of the curriculum was repositioned to both support students’ fictional expertise and enable them to learn about buoyancy and meteorology through their positioned role as scientists.

In the first practical activity, the teacher provided many of the science conceptual and practical ideas that the students in role as expert scientists needed to productively explain to TRCarrie (who was positioned in this activity as one who did not know) about meteorology. The conceptual bridge between the students’ lack of expertise and their positioning as having expertise was achieved by providing them with the science information (section 5.2.2). This material enabled the students to operate on the stage of science (Szybek, 2002) with expertise in talking to TRCarrie, while in reality they were novices on the everyday stage. For this study this action is viewed as a repositioning of taught curriculum so the students were required to use science rather than simply receive information. The findings show when the curriculum knowledge was repositioned in this way the students were able to act ‘as if’ they were experts. Importantly, each of them had worthwhile knowledge to share which offered protection from having sharing ideas that were incorrect (Edmiston, 2000; Heathcote & Bolton, 1995). The students confidently worked through the activity (section 5.2.2).

In the second example from section 5.2.2, students were provided with artefacts from a fictional box from the Wahine inquiry. The conceptual bridge in this case was a water-damaged experiment sheet from an experiment modeling the sinking of the Wahine through using paper boats and marbles and a picture showing the Wahine lying on her side. The students in their positioning as expert scientists realised they needed to re-do the experiment so the results could add to the investigation data they were compiling. In this instance, they were provided with most of the information but had to investigate to discover why the vessel sank on her side. They worked mostly on the science stage (Szybek, 2002) but were supported by having the resources provided.

For the third example in week seven of the unit (section 5.2.2), the students, in their expert scientist roles, evaluated the science knowledge of four potential scientist employees through experimentation. The students generated and analysed data to test whether statements from the potential employees explained their experiment results. The prospective employee statements included a mix of correct ideas ranging in complexity and incorrect ideas. Again, this material acted as a conceptual bridge but in this case apparently ‘expert’ knowledge was open to challenge by the students working in their capacity as experts. As TJayne commented (section 5.2.2), this repositioning served to both consolidate student learning and to encourage criticality.

Looking more closely at these findings, it can be seen that repositioning how curricular knowledge was taught created a hybridised participant structure that had aspects of the transmission model in that knowledge about buoyancy, stability and meteorology was provided for the students in both activities. It also had aspects of the investigative model with students conducting the practical work as part of reinvestigating the sinking of the Wahine and hiring a scientist. The hybridised structure allowed the students to bridge the gaps in their understanding and to operate ‘as if’ they were scientists. Providing the students with information to cooperate in their learning has resonances with the cooperative logic model (Baldwin et al., 1995) and with Cornelius and Herrenkohl’s (2004) audience roles. In these studies, and in my own, students were supported conceptually by having information to help them bridge between the everyday and scientific stages, which Lundin (2007) acknowledges is difficult. This study finding adds to the Mantle-of-the-Expert literature by demonstrating how the teaching of curriculum can be repositioned in a domain such as science, to provide students with a conceptual bridge in support of their expert positioning and science learning.

8.3 Operationalisation of Mantle-of-the-Expert through figured worlds

This section examines the findings through the analytical lens of figured worlds (Holland et al., 1998) (section 2.4.1). The notion of figured worlds was chosen because of its synergies with the imagined worlds of drama and its capacity to illuminate what happened in the classroom (section 2.4.1). It assisted in highlighting the possibilities available for students to craft and operate within science identities. This section outlines these possibilities in relation to: the fictional context of the drama, the curricular tasks designed and used, and the ethical aspects of the unit. I then identity the specific figured worlds that were relevant in this study.

8.3.1 Operating within a Fictional Context

This section presents findings on the “fictional context” of the unit (Aitken, 2013, p. 42), which incorporated both imagined and actual aspects. Situating the fictional context in an actual event of national significance meant students could access authentic data such as newspaper articles (section 5.3.4) and YouTube news footage (section 5.3.2). This struck a chord with several students and their families (section 5.4.3), as they had experiences to relate about the event. Although based on student responses to one unit of work, the findings suggest that relevant events are able to hook students into and sustain their interest in science learning (Bolstad & Hipkins, 2008; Chetcuti & Kioko, 2012; Christensen, 2011; Education Review Office, 2010). The fact that the actual sinking occurred fifty years ago could be seen to be significant in providing a frame of distance and emotional safety for students when investigating the sinking of the Wahine (Heathcote, 1991a, p. 149; O'Neill, 1995a). Providing protection through distance in the dramatic frame was imperative because New Zealand had just had a major earthquake when this study took place in 2011. That adequate protection was provided was seen in the students being able to say they had helped in the Christchurch disaster (in their company role) in an empathetic and compassionate manner without anyone becoming upset (section 5.2.1). In fact the only person who was directly emotionally entangled with the Wahine disaster was the Principal who remembered the day clearly (section 5.4.3). The students empathised with those involved in the disaster (section 5.3.4) and connected with the unit learning emotionally (section 5.3.2) but were not overwhelmed by it. They were motivated and able to purposefully to find answers so an event like the Wahine ‘will never happen again’ (section 5.3.2).

Findings show that both the imagined and actual aspects of the fictional context were necessary to build the social and cultural constructs (Holland et al., 1998) the students needed when re-investigating the sinking of the Wahine. The imagined context was constructed through artefacts such as a letter from a satisfied client on the company noticeboard (section 5.2.1). The actual context was built through watching a YouTube recording of the TV news from the day the Wahine sank (sections 5.3.2 and 6.2) and surveying newspaper articles (section 5.3.4). Students were positioned as ‘expert scientists’ in the imagined fictional context and they actually worked as expert scientists as they experimented, debated and defended their science findings in the classroom setting. Working in this manner provided scope for them to see themselves as “insiders” to the world of science (Rahm, 2007, p. 543).

Time as a dramatic element also served to enhance student learning. Students worked in the fictional context in actual time, exploring the sinking of the Wahine carrying out experiments. When required, students stepped back in time to 1968 to explore the sinking through freeze frames and thought tapping (section 5.3.2) and talking to the captain of the vessel (sections 5.3.2 and 5.3.4). In all instances students worked in ‘immediate now time’ (Heathcote, 2009; Heston, 1994) to explore the action as if it were happening at that time. While working in actual time and fictional time is a common practice in drama and Mantle-of-the-Expert, it is not common in science education. However, *The treatment of Dr Lister* drama (Heathcote, 1984b; O'Connor, 2013) does shift time to explore the life of Dr Lister, the pioneer of antiseptic surgery with the students exploring the history of medicine and infection.

8.3.2 Operating through curricular tasks

Curricular task design is crucial for any unit but particularly important in a Mantle-of-the-Expert unit, for teachers not only have to deepen curricular learning but also deepen student commitment to the drama as well (Heathcote, 2010a). The unit tasks were designed to develop student expertise over time. In the early stages of the drama the role of Malcolm was used to remind the students of the company values when he 'sent' them a giant puzzle (section 5.3.1). In the middle of the unit, students mapped the harbour, stopping at key points to listen to what happened to the Wahine and make freeze frames (section 5.3.2). They also gained information about what happened by interviewing the captain (sections 5.3.2 and 5.3.4). By the end of the unit, the students were trusted, by virtue of their science expertise, to select and interview the most appropriate new employee for the company (section 5.2.2).

A wide variety of learning tasks, ranging from ‘traditional’ science experiments to dramatic conventions such as Role-on-the-Wall were used to deepen the students’ engagement and learning (Heathcote, 2009, Appendix 4d; 2010a). Student actions and comments indicated that they incorporated the meanings drawn from different tasks to co-construct classroom knowledge. For instance, they used information from mapping the sinking (section 5.3.2) and interviewing the Captain to gain a clearer picture of what had occurred to the Wahine (sections 5.3.2 and 5.3.4). The students responded positively to the variety in the tasks (section 5.4.3), a finding that is consistent with literature that highlights that students disengage when the same pedagogical strategies are used (Aschbacher et al., 2010; J. Osborne & Collins, 2001). The diversity of tasks offered scope for students to have fun while learning science through ‘hands on’ activities that also engaged students in critical thinking (see Abrahams & Reiss, 2012; Berry et al., 1999; Hofstein & Kind, 2012).

Not only did these tasks support the students’ expert positioning but they developed their curricular knowledge as they became “embodied over time through continued participation” (Holland et al., 1998, pp. 52, 53) in the drama. Also identified as important by the students was learning in role through ‘first hand experiences’ (section 5.4.2). For instance Josh said, “There was moments there that we remembered ‘cause our body remembered because we were doing it” (section 5.4.2). Put another way, the drama helped the students understand the scientific process as they experienced it in an embodied way when, in role as expert scientists, they conducted experiments (section 5.2.2), drew on evidence (section 5.3.4), and reported on their findings to the client (section 5.3.4). It can be seen that this helped clarify the abstract science concepts, supporting Wilhelm’s (1998) premise that role-play is useful for solidifying students understanding of abstract concepts. Experiencing the learning in an embodied lived way allowed the students to interrogate the learning from multiple perspectives, which O'Sullivan (2011) sees as an advantage of learning through role-play. Thus, working through Mantle-of-the-Expert and learning through both fictional and physical experiences enlarged the space for meaning making and provided an anchor for ideas. This idea resonates with Braund (2015) who found that drama can provide both “mental spaces and physical interactions” for students to engage with and reflect upon science (p. 16).

In summary, the findings related to curricular tasks are in line with the Mantle-of-the-Expert literature and reiterate the importance of carefully choosing tasks that both extend and support students’ expertise and sequentially deepen students’ curricular learning. It was also identified that using physical interactive tasks was enjoyable, helped them anchor ideas and gave them space to interrogate science.

8.3.3 Operating ethically

Mantle-of-the-Expert’s strong culture of ethicality (section 3.3.1) was evident in the findings. Students positioned themselves as ethical in their CVs (section 5.4.1) and were respectful and compassionate in their interactions with the captain (in role) (section 5.3.4). They used evidence from their experiments to substantiate any claims of negligence (see sections 5.3.4 and 7.2.3) and wrote their findings in a neutral, non-inflammatory manner to not upset the families affected by the Wahine (section 5.3.4). The students did not accept statements at face value, but sought evidence to base their conclusions on and worked to do this within the normative conventions of science. This suggests that working through this approach is useful in enhancing students’ scientific literacy: students in this study were able to discern the scientific reasons for the vessel sinking and back these up with evidence and to communicate their findings in a manner that mirrored ethical scientific practice (M. Braun & Reiss, 2006; Preczewski et al., 2009). At the same time, students’ actions were consistent with the cultural norms of Mantle-of-the-Expert. This was evident in students’ actions towards people (both actual and imagined) (Heathcote, 2008b).

The students explored complex ethical issues as they worked within their expert scientist identities in the fictional frame of the Mantle-of-the-Expert unit. As the findings show, the major issue was re-investigating the Wahine disaster to ascertain the scientific reasons for the sinking. Other issues explored were: the implications caused by an incompetent scientist and inaccurate science (see discussion on 'fictional others' in section 8.2.5) and whether the captain of the Wahine was liable for the sinking (section 5.3.4). Having to not only analyse the science, but also grapple with the ethical issues of incompetence, timeliness, accuracy and culpability added an extra dimension to the science. The students had to think critically about the science and consider the human ramifications. The benefit of exploring complex issues, according to Sadler (2004) and Wong, Zeidler, et al. (2011), is that it can enhance students' understanding of both science concepts and the NOS, and also augment students' skills in argumentation, critical thinking and group work. The students demonstrated most, if not all of these attributes over the duration of the unit as they interacted with the science ethically.

Findings show that ethical tension (see section 3.2.1) can provide the students with a reason to learn about floating and sinking. Student understanding of these science concepts was framed within the ethical imperative of finding out the 'truth behind the sinking of the Wahine' for the families of those who died on the Wahine (section 5.3.2). This ethical tension was heightened through the use of a commission letter, which provided an additional reason to prevent the tragedy from occurring again (section 5.3.2). Student comments indicated they were empathetic to those affected by the disaster, which included the families of those who lost their lives and the captain of the vessel (section 5.3.4). For this reason they considered it vital they had 'the right facts' in their report to the client (section 5.3.4). These findings suggest that using ethical tension was both engaging and served to focus students on ensuring their science was accurate. This finding is similar to that of other studies where an ethical hook proved to be effective in engaging students into science (Ryan & Buntting, 2012; Sorenson, 2007; Wong, Zeidler, et al., 2011).

A point of difference in this study was how ethical tension was constructed between two ‘fictional others’ (section 8.2.5). Positioning Malcolm as ethical and Roger as unethical provided a way for the students to see the consequences of poor science practice both in the fiction of the drama and in the classroom. The findings in section 5.3.3 show students were able to link Roger’s actions and the consequences for the company and their own actions in the company and classroom. This was seen in their desire to do the science ‘correctly’ to fulfil their commission in a timely and accurate way (section 5.3.3). The ethical tensions around Roger’s actions provided a way for the students to glimpse the practice and impact of science on society. In this way, students were led to display what Ødegaard (2002, pp. 9, 10) terms “ethical competence”.

8.3.4 Operating in multiple figured worlds

This section discusses the findings in terms of figured worlds. These show that the students operated in four figured worlds, each with their own cultural conventions, social norms, rights and obligations and ways of acting (Holland et al., 1998). Two figured worlds were actual - ‘school science’ and the world of the ‘classroom’. Two were imagined - ‘science and scientists’ and the figured world of Mantle-of-the-Expert company. Figure 8.3 illustrates the interconnections of these figured worlds.

Both students and teachers (solid shapes) are part of the actual figured world of the classroom as denoted by the dotted background rectangle. Students and teachers also agreed to operate in the imagined figured Mantle-of-the-Expert world, represented by the dashed line triangle. The two ‘fictional others’ within the company triangle are Roger and Malcolm, with the fictional client located outside the company. The dashes represent that they are imagined. The placement of the teachers, students, Malcolm, Roger and the client relative to the status line show the status they occupy. Note the teachers have a sliding status that can be adjusted to meet the needs of the drama. Nonetheless, they are lower in status than the company CEO Malcolm.

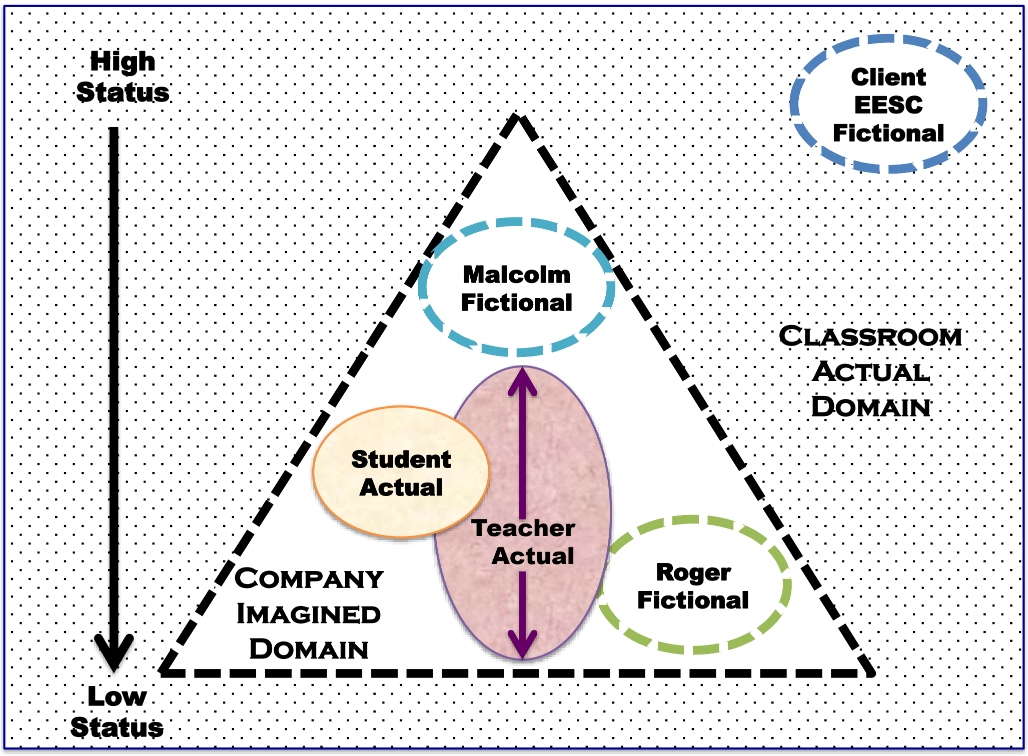

Figure 8.3 Graphic of the actual and imagined figured contexts of the drama

The findings highlighted here show that operating in actual and imagined figured contexts, in actual and imagined time and in multiple figured contexts and positions can increase the 'space' for the students to both explore the curriculum, and possible identities in science. This resonates with Holland et al.' (1998) premise that working in 'as if' figured worlds allows the players to make meaning about who they are, what they can become, and the actions necessary for it to occur.

In the imagined figured context of science and scientists, students were positioned as expert scientists in a company that was re-investigating the sinking of the Wahine (section 5.3.2). They moved back and forth between the imagined "as if" and actual "as is" figured contexts of the Mantle-of-the-Expert and classroom to deepen their curricular learning as described by Edmiston (2003) and Heathcote and Bolton (1995).

Findings show that students used the imagined contexts to view learning in different times and from different perspectives. For instance, they surveyed events on the day the Wahine sank (April 10th, 1968) using freeze frames to explore the important locations of the sinking, and speak to the captain depicted in an effigy (section 5.3.2). They also operated dramatically in real time when they spoke to Linda whose fictional husband had been on the Wahine (section 5.3.2). TJayne commented that working in this imagined context was important because it connected the students emotionally to the science learning (section 5.3.2). Evidence from the students' final reports and interview data, where several students referred back to the re-enactment of the sinking, showed how this cemented their science learning (section 5.4.2).

Findings also showed the importance of students' working in the actual figured world of school science to learn about floating and sinking by carrying out experiments and discussing what had occurred in the experiments (see sections 5.2.2 and 7.2.2 for examples). The iterative and synergistic moving between the figured worlds of the Mantle-of-the-Expert drama and school science supported and deepened student learning as evidenced by their test scores (section 6.5). This stepping in and out of drama to either learn more skills or to reflect on the learning is a common component of Mantle-of-the-Expert and was described in a science lesson in the seminal text (Heathcote et al., 1995).

In addition, the findings also showed that the students, as required by the drama, moved between their fictional positioning and actual roles. For example, in the drama, students either worked in their positioning as expert scientists, or took on different roles such as the meteorologist Albert (section 5.2.2). Other times they worked as normal students in the class such as when some boys prepared a PowerPoint presentation for the client (section 5.4.2).

8.3.5 Summary

To this point, I have illustrated and argued that the positioning of students as experts, verbally and through sign, and the students' acquiescence to that positioning and their self-positioning as expert was a key aspect of their learning within this Mantle-of-the-Expert unit. Accepting an expert positioning enabled the students to act and speak as adult members of a company while still operating within their own personality. Being positioned in a status equal with the teacher(s) provided opportunities for collaborative learning and created a sense of being valued.

Within this study, re-positioning how the curriculum was taught sustained the students' fictional expertise in the Mantle-of-the-Expert unit as well as creating a productive environment to learning science through. A hybridised model, which included both investigative and transmissive aspects, was created. It used artefacts to provide a conceptual bridge between the everyday world of the students and the science world they fictionally inhabited in their expert scientist role. As the unit progressed and they grew into their expertise, the conceptual bridge used to support their expertise became less prescriptive/defined and the students moved into investigative mode as they challenged the information contained on the artefacts in the manner of scientists. The study findings indicate that working in this manner was engaging, helped students maintain their focus and supported their learning. In addition, this approach demanded a high level of thinking as students had to actively evaluate knowledge, test claims, and debate and justify their findings.

The commission focused student inquiry over time. It helped students to connect emotionally with the unit tasks, providing a purpose for learning the science of floating and sinking so that they could help the people affected by the tragedy. Having a fictional client rather than a teacher managing the learning agenda disrupted the normal power relationships between the teacher and the students. Students were highly motivated to produce work for the client and this work was noted by the teacher to be of a higher than normal standard.

One point of difference in this study is the significance to student learning of 'fictional others' beyond the client. In this study, students prepared work for more than one audience. Moderating the work carried out for the client were interactions the students had with two internal audiences, one who modelled excellence and the other who modelled ineptitude. These insider-outsider audiences provided students with the impetus to strive for excellence as well as allowing them to explore the realities of working as scientists and the implications of not doing work well without the risk of actually 'failing'.

The figured context of the drama, which in this case was a historical event of national significance, provided space for students to actively connect with, explore and interpret the science from multiple perspectives as they worked as expert scientists reinvestigating the Wahine's sinking. The variety of curricular tasks used in this Mantle-of-the-Expert unit supported and extended the learning of science content. Using physical interactive tasks was not only enjoyable for the students but helped anchor memory and gave them space to interrogate science.

Findings show working ethically was a key aspect of this study. Ethical behaviour is considered important in Mantle-of-the-Expert and in this study it was explicitly built through positioning the students into ethical scientist identities through sign, the use of ethical tension and dramatic conventions. The use of an ethical hook provided students with an incentive to engage in the drama, learn science and to find answers. An ethical tension between the two 'fictional others' highlighted the interconnections between science and society. In addition, working ethically encouraged empathy and enhanced the students' scientific literacy by prompting them to seek evidence for their claims.

Another distinction in this study was the situating of the drama in multiple figured worlds, both actual and imagined figured contexts, in actual and imagined time and the use of multiple imagined positions. All of these facets increased the 'space' for the students to explore the curriculum and deepen learning.

8.4 Student Science Learning

This section addresses the question of if/how Mantle-of-the-Expert influenced student understanding of science concepts and the nature of the science. It also looks at shifts in student attitudes towards science and science careers.

8.4.1 Shifts in student understanding of science concepts

Data compiled from the students' assessments, classroom dialogue, student and teacher interviews and other classroom artefacts show that the students improved in their conceptual understanding of the key science ideas for the unit: buoyancy, stability, cyclone formation and weather isobar map interpretation. Comparison of overall scores from the pre and the post-unit assessments (section 6.5) show that the changes in student knowledge of the science concepts tested were statistically significant. The weight of this finding on student learning is increased when one considers the central concepts of buoyancy and stability are known to be challenging for Year 7/8 students (Flockton & Crooks, 2000). These results add to the literature that reports that using drama can enhance the learning of science concepts (section 3.3). They consolidate the findings from the limited science and Mantle-of-the-Expert literature that the approach supports the learning of science concepts (section 3.4).

Findings show that all students deepened and consolidated their understandings of why objects float (see sections 6.2 and 6.3). While all students improved their understandings about buoyancy, their understandings were not necessarily complete. This is in line with research on students' understanding of buoyancy concepts (Flockton & Crooks, 2000), and the common finding that it takes considerable time for students' conceptions to change to the scientific norm (Vosniadou, 2012).

The finding that some students possess incomplete understandings of science concepts was typified by the data on density (see section 6.2). The teacher identified that while most students recognised when the vessel became denser on one side it would tip, few comprehensively understood density. This supposition was confirmed in the post-unit assessment where more students chose the incorrect answer containing 'density' than in the beginning (section 6.3). One explanation for this finding could be that they were operating in a transitory (Lundin, 2007; Szybek, 2002) or immediate stage Vosniadou (2013a) of knowledge acquisition, drawing on newly learned terms to make meaning of the question, without having science understandings fully embedded. Some of the students interviewed (section 6.3), commented that they knew 'density' was an important component in buoyancy but acknowledged they didn't understand the concept fully. Taken another way, the students had added the word 'density' into their buoyancy conception but had not filled the gap (Chi and Roscoe, 2002) with an adequate explanation to be secure in their understanding. Their metacognitive awareness of the inadequacy of their density conceptions, created a sense of dissonance, which opened up the possiblity for them to add new knowledge in the future and mend their incomplete conception.

Even the misconceptions apparent in the discourse show the students were attempting to synthesise cohesive arguments for physical phenomena. This type of synthesis conception (Vosniadou, 2012, p. 123; 2013b) was seen in section 6.2 when one student claimed boats float because they are filled with air and because air rises. In this instance the child added a concept about convention to the conception of buoyancy. While muddled, the synthesised conception enabled the child to make sense of floating based on his prior knowledge and the teaching that had occurred.

The shifts in the language used by the students to explain science concepts over the duration of the unit also demonstrated that conceptual growth in understanding the science concepts of buoyancy and stability had occurred. For example, four of the six focus group students commented they had no knowledge of and/or an incomplete understanding of the term 'density' before the unit began (section 7.2.3). They also explained they could not have written the report as well without 'recognising' and 'understanding' the science terms associated with buoyancy (section 7.2.3). This changing use of buoyancy vocabulary is confirmed by data from sections 6.2 and 6.3, which shows that by the end of the unit, more students in the class were using scientific words such as density, weight/mass, volume and air in their conversations to explain why the Wahine sank. The development of the science vocabulary provides clear evidence of students growing fluency in the genre of science (Lemke, 1990; Yeo, 2009; Yore, 2004) and in the processes of science (Vosniadou, 2012). Additionally, the way students meaningfully communicated their understandings (Sainsbury & Walker, 2011) and the closeness of their discourse to the normative meanings of the conception (Greeno & van de Sande, 2007) also demonstrated that conceptual growth had occurred.

As well as demonstrating conceptual change in buoyancy, students' understanding of cyclones improved over the unit. This change was seen in the doubling of the number of students able to write an explanation about cyclone formation (section 6.4). Corresponding increases in conceptual understanding about cyclones were also seen in the students' written reports where they used appropriate terminology. Interestingly, the students could describe the characteristics of Cyclone Giselle in detail but were less competent at outlining key aspects of tropical cyclones. Being able to articulate a understanding of cyclones in one context and not another could indicate that the students were operating in a intermediate stage of knowledge acquisition (Vosniadou (2013a), with the concept not embedded to the extent they could apply it across a range of contexts.

Student also became more competent in interpreting weather isobar maps over the unit (section 6.4). Seven of the eight students interviewed identified that they now could understand isobar maps and had demonstrated their knowledge to their parents during the TV weather forecasts (section 6.4). This linking to their home life suggests the students were genuinely interested in the ideas and saw them as relevant to their lives, which Barmby et al. (2008) assert is optimal for learning and enjoyment. Other evidence of this linking came when students used their experiences in spa pools to construct a class understanding of displacement (section 6.2). Connecting prior knowledge to the concept being explored is an important step in fostering conceptual change (for example, Duit & Treagust, 2012; Schauble, Glaser, Duschl, Schulze, & John, 1995; Vosniadou, 2012).

When one considers the broader aim of the drama unit – reinvestigating the sinking of the Wahine, findings show that all students were able to integrate what they had learned and give scientific reasons for the Wahine sinking (section 7.2.3). Sainsbury and Walker (2011) argue that conceptual change is about more than being able to write an explanation or answer an assessment question; it is about being able to apply and communicate meaningfully about a concept. The way the students were able to meaningfully communicate and give scientific reasons for the Wahine's sinking in their report to the client indicates they were demonstrating conceptual change in the fullness of its derivation. Being able to both test and defend one's findings is operating within the genre specific characteristics of science (Vosniadou, 2012), and thus demonstrates a deeper embodiment of conceptual change than being able to define a science concept.

The students in this study not only deepened their understandings about the science concepts taught (see chapter 6), the NOS (chapter 7) but also the processes of science as they worked in role as expert scientists. They gained knowledge of science concepts through 'doing stuff' (section 5.4.2) both dramatically (for example interviewing the captain in role about the day the Wahine sank in section 5.3.2, and more conventionally through experimentation (sections 6.2, 6.3 and 6.4). The students formulated questions about the sinking of the Wahine to investigate (section 7.2.2), and tested their hypotheses when they replicated the sinking of the paper boat models with marbles (section 6.2). They communicated in the manner of scientists as they commented on the science components of the newspaper articles (section 5.3.4) and wrote scientific reports defending their findings (see 7.2.3). These examples meet Vosniadou's (2012) criteria that conceptual change requires evidence of changes in conceptual understanding, scientific processes (NOS) and genre specific aspects, and add weight to the claim that Mantle-of-the-Expert supports the development of conceptual change.

The question of why Mantle-of-the-Expert supports conceptual change might be explained by its similarities with pedagogical practices described as optimising conceptual change. For instance, the students learned science concepts within a sustained investigation (nine-weeks), which Vosnisdou (2010) and Zhou (2010) consider helpful in changing students' preconceptions. This study was framed within a relevant historical setting (Duit & Treagust, 2012; Vosniadou, 2012), the sinking of the Wahine. In Mantle-of-the-Expert students learn collegially through social interaction (section 5.4.1) as is recommended by Brock (2015) and Vosniadou (2012). The structure of Mantle-of-the-Expert encourages dialogue (section 7.2.3), which is recognised as vital in conceptual change (Duit & Treagust, 2013; Mercer, 2008; Vosniadou). Fulfilling the commission from the client meant students had to experiment, critique the data, and defend their findings in their written report, all of which demonstrates they are working within the genre of science (Vosniadou, 2012; Zhou, 2010). In addition, working in their expert scientists positioning mirrored how scientists work and scientific communities function (Zhou, 2010).

To recapitulate, students' knowledge of science concepts significantly increased. All students deepened their knowledge of buoyancy and stability. All students recognised the effect of the weather on the disaster. Students also gained expertise at interpreting weather isobar maps. All students gave scientific reasons for the Wahine sinking with most providing supporting experimental evidence. Evidence of the students' deepening conceptual understanding was seen in their assessments, class discussion and the increasing complexity of the scientific vocabulary used. It can also be seen in their ability to work within the processes of science, and communicate their understandings in the manner of a scientist.

A significant contribution of this study is that it adds to the small pool of studies that provide detailed evidence to back Heathcote’s (Heathcote, 2009; Heathcote & Bolton; 1995), claim that Mantle-of-the-Expert can support curriculum learning. It provides evidence in support of Bolton’s (2003) assertion that Mantle-of-the-Expert is particularly suited to science. They consolidate the findings from the limited science and Mantle-of-the-Expert literature that the approach supports the learning of science concepts (section 3.4). These results add to the literature that reports that using drama can enhance the learning of science concepts (section 3.3).

The findings also add to the conceptual change literature. Namely, that Mantle-of-the-Expert is a valid approach that those working in Conceptual Change could add to their repertoire of tools to enhance conceptual change.

To conclude, the findings show that drama (in particular Mantle-of-the-Expert) supports students to make sense of and negotiate meaning about science concepts (Nersessian, 2008; Wells, 2008) and progress their conceptual understanding closer to the scientific norm (Vosniadou, 2012).

8.4.2 Shifts in student understandings about the Nature of Science

For the study I was concerned, in line with current research and policy (Department for Education, 2014; Duschl, 2008; Lederman et al., 2002; Ministry of Education, 2007b; National Research Council, 2007) that the students develop their understanding of NOS as is defined by the NZC (Ministry of Education, 2007b). Here the categories of ‘understanding in science’, ‘investigating in science’ and ‘communicating in science’ are discussed; the NOS category of ‘participating and contributing’ was discussed in section 8.3.3 under operating ethically.

Shifts in understanding in science

Findings related to understanding in science come from changes in student knowledge about scientists and the tasks scientists do as evidenced in students’ pictorial impressions of scientists (see Figures 7.3 and 7.4) and the linked class discussion (section 7.2.1). Several factors appear to have contributed to the changes in student ideas. First, their engagement in Role-on-the-Wall (see Figure 7.3 and section 7.2.1) gave the students space to interrogate their ideas about scientists. Rather than the nutty professor stereotype (see Cakmakci et al., 2011; Finson, 2002; Narayan et al., 2013; Schibeci, 2006) illustrated in the Role-on-the-Wall outlines, the student statements about scientists went beyond the scientists are “weird” and “unfeeling” labels of Bennett and Hogarth (2009, p. 1990). The students suggested that scientists were ‘interesting, fun to be with, creative, and imaginative’ (section 7.2.1). This changing understanding about scientists and their work was corroborated in the student interviews where the students commented that scientists were not as they were portrayed on the television with ‘a lab coat and clipboards’ but worked more like they had on the commission (section 7.2.1). This finding lends support to studies (Boujaoude et al., 2005; Cakici & Bayir, 2012; Duveen & Solomon, 1994; McGregor et al., 2014; Pongsophon, 2010) suggesting drama can be a useful way to broaden students’ perceptions of scientists and NOS (section 3.3).

Student appreciation of the creative aspect of science is important because the perception that science lacks creativity is noted as a disengagement factor (Land, 2013; Lyons, 2006; J. Osborne & Collins, 2001). Within the study there was evidence that students understood that scientists ‘imagine things that aren’t possible’ and ‘think beyond the first thing’ (section 7.2.1). Some students also portrayed scientists as ‘heroic’ and ‘courageous risk takers’. Students’ broader understanding was reflected in the post-assessment data, where students considered scientists find cures, save lives and make life easier (section 7.2.1). The portrayal of scientists as heroic in the sense of contributing to their community, is identified by Schreiner and Sjøberg (2007) as a reason why some students (mainly in developing countries) want to study science. I hope that in this instance, students coming to see scientists as ‘heroic’ will encourage them to consider being a scientist.

Student demonstration of "investigating in science"

Investigation was a crucial facet of this Mantle-of-the-Expert unit. In accordance with the understanding that it takes time to build the culture of the Mantle-of-the-Expert drama (Heathcote & Bolton, 1995) and fulfil a commission, the investigation took nine weeks. This is in contrast to the simple inquiries or experiments commonly used in school science (Chinn & Malhotra, 2002) but in line with the type of in depth extended investigation viewed by Vosniadou (2012) as useful in enhancing conceptual understanding. The long-term investigation was framed by the commission and guided and motivated by the inquiry questions from the students (see section 7.2.2 for examples). Although, the investigation was not open-ended, it did provide the students with a glimpse of what life might be like in a real science laboratory. The students used a variety of approaches to answer the investigative questions they developed and thus to fulfil the commission. These included: interviewing people in role (sections 5.3.2 and 5.3.4.), researching in books (sections 5.4.2), conducting experiments (sections 5.4.3 and 7.2.2), and using models such as the paper boat model (section 5.2.2) and the soft-drink model of the cyclone (section 5.4.3). Thus, the students could be said to be working in the manner of 'real scientists' exploring a problem, observing a phenomenon, and attempting to understand why it occurred. Indeed, TJayne came to that conclusion commenting that the students acted like scientists when they were questioning, predicting and recording their science results (section 7.2.2). The students' actions within the drama showed that they were emulating the practice of scientists and bringing a scientific perspective to their decisions and actions (Barab & Hay, 2000; Duschl & Osborne, 2002), which also in an indication of conceptual change (Vosniadou, 2012).

The study findings confirm Allern's (2008) hypothesis that Mantle-of-the-Expert provides a way for science concepts to be learned through a combination of performance and investigation (p. 331). In the study the experiments and other practical activities were linked together through the dramatic frame. An example of this is where the students both conducted science experiments to test the science knowledge of potential employees but also performed the interview of the applicant whom they considered showed the most complete understanding of the science concepts (section 5.2.2). Half of the students interviewed considered that the drama and the experiments were useful in helping them learn and make sense of their investigation questions (sections 5.4.3 and 5.4.4). This was exemplified in Lucy's response from section 5.4.4, "I like experiments and I like finding out the answers by using drama". Working in someone else's shoes (Heathcote, 1991c), in role as scientist in Mantle-of-the-Expert led to a more realistic understanding of scientists and helped the students investigate the science.

As other studies have reported (Abrahams & Reiss, 2012; Chetcuti & Kioko, 2012; Durling et al., 2010; J. Osborne & Collins, 2001), the findings from this study concur that students enjoy experimental work (see section 5.4.3). In addition, both the students (section 5.4.2) and their teacher (section 5.2.2) deemed experiments as vital in 'consolidating' student understanding of the science concepts and helping them answer the research questions for they 'showed us how the Wahine sunk'. In fact, Josh and Tom (section 5.4.3) stated that using the experiments helped them understand the science concepts. It appears that the practical activities used in this study addressed most of Hofstein and Lunetta's (2004) aims of practical work, for students were motivated to learn and used scientific processes to solve problems by investigating in the manner of a scientist**.**

Shifts in communicating in science

Somewhat surprisingly, students did not identify that scientists need to communicate when they described the tasks scientist do in the pre-unit assessment (section 7.2.1). However, the communicative facet of being a scientist was developed during the unit, particularly within the Role-on-the-Wall exercise, where students identified eight forms of communication such as debate and share ideas (see Figure 7.4). The findings revealed that the students' abilities to communicate their understanding of science concepts using the genre of science. By the end of the unit, most students were more fluent in using the language of science (Yore, 2004) as seen by them using scientific words as well as everyday words to describe science concepts and explain physical phenomena (section 6.2). Students operated within the 'conventions of science' (Ministry of Education, 2007c) when they defended their scientific claims with evidence in their report to the client. Josh, for example, used the paper boat experiment to illustrate why the

Wahine tipped (section 7.2.3). Both students and teachers recognised that they were more confident and able to communicate their science knowledge orally and in written format (section 7.2.3). In section 7.2.3 findings are presented that show that rather than waiting for the teacher to call upon them, students shared their learning as a scientist would by standing up and speaking. In Mantle-of-the-Expert terms, most students were operating within the embodiment of their expert role with "conviction" (see section 3.3.1 (O'Neill, 1995b, p. viii). In addition they were demonstrating conceptual change as they communicated in the manner of scientists (Sainsbury and Walker, 2011). However, as I have already noted not all students were comfortable in communicating their ideas orally or dramatically (section 5.2.2) and required additional support to share their ideas such as one-on-one or in small groups. As language is used to construct meaning (Yore, 2004) and has been identified as crucial in fostering conceptual change (Duit & Treagust, 2012; Mercer, 2008; Vosniadou, 2012), it is important that multiple opportunities are given for students to articulate their understandings.

In light of a few of the students not being confident to communicate their science findings it is useful to ponder the reason why the students did not consider scientists communicate in their assessments (section 7.2.1). Possible reasons for students not recognising that scientists communicate, might be that students perceive scientists as doers rather than communicators or that they feel scientists lack interpersonal skills. Alternatively, students may consider communication is part of everyday life and not a unique characteristic of scientists.

Summary

In summation, the findings show that students' knowledge of scientists and their work deepened over the course of the Mantle-of-the-Expert-based unit. While they initially depicted scientists in a stereotypical manner, their depictions became both more positive and multi-faceted, especially after the Role-on-the-Wall activity. Students also demonstrated that they were able to conduct a long-term science investigation and demonstrated that they were using similar scientific processes to 'real' scientists. They enjoyed the practical aspect such as the experiments. Students were more able to communicate their understandings of science in a manner typical of the genre by the end of the unit.

8.4.3 Attitudes towards science

I was interested to see whether the students in my study changed their attitudes towards science given evidence that student attitudes towards science decline throughout their education (Alexander et al., 2012; Barmby et al., 2008; Bolstad & Hipkins, 2008; George, 2006; Hendriksen, 2015; Colette Murphy & Beggs, 2003; Rosberg & Lindahl, 2009; Schibeci, 1984; Turner & Ireson, 2010). Others have reported that Mantle-of-the-Expert fosters positive engagement or attitudes towards learning (Bromley & Labrow, 2006/7; Finneghan, 2012; O'Brechain, 2006, 2012; Towler-Evans & Law, 2007), including the few studies that have focused on science (Aitken & Townsend, 2013; Kolovou, 2011; Stevenson, 2009, n.d).

Findings from the science attitudinal question, which asked students whether they perceived themselves to be "good at science", showed that the students' perceptions of their abilities were largely unchanged from the pre to the post-unit assessment. However, in contrast, student responses to the attitudinal question "How much do you like doing science at school" showed a general decrease from pre to post unit assessment (section 6.5). This finding is similar to the findings of Hendrix et al. (2012) who noted a similar decrease in student attitudes towards science in their investigation into the use of creative drama to teach science. They attributed this to students already being strongly positive towards science; two thirds of the students in this study liked doing science 'heaps' or 'quite a lot' indicating that they started with positive attitudes, which is a similar finding to the 10-14 year-old students who took part in the *ASPIRE* study (Archer, Osborne, et al., 2013).

Other factors that might shed light on this attitudinal shift include the class teacher's view (section 5.5) that although the students were happy to work within the positioning of expert scientists and were engaged in the drama they were not obsessed (Heathcote & Bolton, 1995). Aitken and Townsend (2013) identified the probable cause of the non-engagement of a child in their study as being due to their lack of continuity in the fiction, as they were absent for some of the drama. This may have been the case here because I was only in the classroom two days a week (section 4.3) and the classroom teacher was unable to sustain the fiction outside of those hours (section 5.5). The importance of sustained learning has been emphasised by Heathcote and Bolton (1995) and is something that needs to be investigated further.

8.4.4 Students' knowledge of science careers

Both assessment data and classroom dialogue from early in the unit (sections 7.3.1 and 7.3.2) showed that the students and class teacher lacked extensive knowledge about the variety of science careers available. The limited knowledge of science careers identified by the teacher and students reverberates with work by Cleaves (2005) who assert that limited knowledge of science-based careers could limit career choice (see also DeWitt & Archer, 2015; DeWitt et al., 2014; Hendriksen et al., 2015). The teacher lacking knowledge about science careers is concerning because teachers have a crucial role educating students about science based careers (Archer et al., 2012b). However, by the end of the unit, student knowledge about the types of science careers available had shifted slightly (section 7.3.2), with the choices moving from general science to physical science careers like meteorologist. The science career categories identified varied slightly between genders (see section 7.3.2) with the girls' choices centring more strongly on life or health sciences and the boys identifying more physical science based careers. This pattern is similar to that described in the literature (Bennett & Hogarth, 2009; Bybee & McCrae, 2011; George, 2006; Lindahl, 2003; J. Osborne & Collins, 2001; Schibeci, 1984; Sikora & Pokropek, 2012; Spall & Stanisstreet, 2004). It must be noted that the sample size in this study is very small and so no conclusions can be drawn about the impact of the Mantle-of-the-Expert-based unit in this instance.

Findings also show that by the end of the unit, students' awareness of "how much science has got to do with jobs and just everyday stuff" (section 7.3.2) was heightened. Consequently, students were introduced to a range of science careers (see Figure 7.11) and the teacher discussed the science in hairdressing (section 7.3.2). There was an increase in the numbers of students identifying other careers that include science (such as hairdressing) in their post-unit assessment (section 7.3.1). This finding adds to the literature that identifies that there is merit in teachers providing diverse and specific information on science careers (Archer et al., 2012b; Hendriksen et al., 2015). Despite these shifts, data presented in section 7.3.1 showed that no more students thought they might chose a science career at the end of the unit. The percentage of students indicating they may chose a science career remained around 40% which is similar to findings by Bennett and Hogarth (2009) and double that in *Aspires* studies data (Archer et al., 2012b, p. 10; DeWitt et al., 2011), which was undertaken with similar aged students.

In sum, findings presented show that at the end of the unit, a third of the students in this study were contemplating a science-based career, and this remained relatively constant over the unit. There were slight variations noted in career choices between genders, with life and health sciences more favoured with girls. A key finding was the increase in students' awareness of 'careers with science' and the notion that science is present in many aspects of everyday life. It also highlights the importance of providing science career resources.

8.5 Chapter Summary

The essence of this thesis was determining whether Mantle-of-the-Expert could be used to teach science. The answer to that question was yes. The complexities of determining how the learning occurred and what aspects of Mantle-of-the-Expert (as used in this thesis) enhanced student learning required more thought. Situating myself in the research as a complete participant observer allowed me to experience what the students and teachers were experiencing (emotionally, physically and intellectually) and helped me to theorise the intricacies of the approach. The use of mixed methods also provided me with a rich tapestry of data to corroborate the findings through thematic and statistical analysis and viewing through the interconnected lenses of positioning theory and figured worlds.

This research has allowed me to break down one science-based unit taught using the Mantle-of-the-Expert participant structure into its constituent parts to see how it affected student learning and draw out nuances of the themes. Crucial to student learning was positioning the students as experts. Agreeing to the positioning and working in role as expert scientists changed how some students viewed their learning and capabilities in science and appeared to enhance their self-efficacy. Working as expert scientists necessitated changes in how the teachers positioned themselves and the configured the teaching of the curriculum. Being positioned as colleagues in a company rather than novice learners disrupted the normal power relationships, raising students' status in the classroom. The expert positioning, enabled some students to act and speak in the manifestation of their positioning, and to use that expertise to not only access the learning but also heighten their thinking. The collegial structure of working together as part of the company encouraged an inclusive atmosphere, in which everyone was included and worked together as part of a group process, which provided opportunities for collective construction of knowledge.

The commission delineated the scope of the project and provided an emotional purpose for learning. Working for an audience – the client rather than a teacher, changed the power dynamics in the classroom to a more equalized relationship, which allowed some of the students to be more agentic in learning and communicating science. The use of 'fictional others' internal to the company provided impetus for the students to investigate science and enhanced excellence. It also broadened their understandings of the value of science to society.

In addition, repositioning how the curriculum was structured and taught to produce a hybridised model was advantageous for it worked as a conceptual bridge allowing the fiction of the students' expert positioning to be maintained but yet still enable science concepts to be taught. The gradual removal of scaffolding as the students became more proficient in their fictionalised expertise, enabled them to work in an investigative manner.

Working within the figured context of the drama, in actual and imagined domains, time, positions and storylines helped students to learn science by providing both physical and dramatic space to learn science through. Additionally, the varied tasks (both dramatical and experimental) used in the episodic structure of Mantle-of-the-Expert provided multiple ways for students to connect with and consolidate their learning. The ethical framing of the Mantle-of-the-Expert unit helped students engage with the drama, gave them an incentive to investigate the problem, find scientific answers supported with evidence and aim for high standards. The embodied aspect of the drama appeared to also enlarge the space the students had to make meaning within.

What was clearly shown through multiple data sources was that the students understanding of the science concepts taught significantly improved, and conceptual change was demonstrated. Students were able to use that knowledge to craft a report that showed their expertise in operating in the genre of science in the strength of their science understanding, their usage of science vocabulary and through their use of supporting evidence. This proficiency was also seen in the way they used the components in the Nature of Science as delineated in the NZC (Ministry of Education, 2007b) to learn and communicate through. However, the findings showed that students' attitudes towards school science did not, in the main, improve and in some cases decreased. Their self-efficacy in science remained the same.

Students' knowledge about scientists deepened throughout the study. Their knowledge of science careers and how much science is involved in everyday life appeared enhanced after being given a small amount of information about science careers in the form of a poster. The number of students indicating a possible science based career did not change.

Chapter Nine: Conclusion

9.1 Introduction

This study was driven by my concern about students ruling out science as a subject and a career for themselves. It took place at the level deemed most at risk of disengaging from science – year 7/8 – (11 to 13 year olds). I posited that the collaborative drama-based pedagogical approach Mantle-of-the-Expert might have potential in helping students learn science and enhance their conception of themselves in science in the future.

Answers were sought for the following research questions:

1. How do the Year 7/8 students in this study and their teacher consider Mantle-of-the-Expert supports or constrains learning of scientific concepts and the nature of science?
2. What shifts in students' written and verbal use of science concepts, nature of science and science vocabulary, occurred over the course of a nine-week Mantle-of-the-Expert unit?
3. How do Year 7/8 students in this study see themselves in science now, and in their future?

A précis of the research findings is detailed in this chapter. The contributions that this study has made to research in the area of drama, science and the curriculum are outlined. It also identifies the limitations, under the headings of policy and practice. Finally, recommendations for further research are given.

9.2 Summary of research findings

The main findings from this study are addressed in brief under three headings which relate to the three research questions.

9.2.1 Mantle-of-the-Expert Approach

The students and their teacher identified that the participant structure of Mantle-of-the-Expert was effective for learning science concepts and the nature of science. The main factor highlighted as important in helping students learn through Mantle-of-the-Expert was the positioning of the students as experts. This expert positioning was supported by re-positioning how the curricular content was taught to maintain the expertise of the students. Using a hybridised model, where the students were provided with science knowledge through artefacts that operated as a conceptual bridge until the students gained enough legitimate expertise to act in their positioning with authority was vital. This model not only provided conceptual support but in time as student proficieny grew, challenged their thinking and led into an investigative mode.

The students' agreement to act within positioning changed their mindset towards learning, because they acted in the embodiment of the authority of their positioning as expert scientists. Within their positioning as expert scientists, the students had to formulate research questions; investigate problems; evaluate and test knowledge claims; and report and defend their findings in science. This meant that through their positioning as expert scientists, the students were demonstrating many of the characteristics and skills of scientists.

The students and their teacher considered that the company and the commission helped them learn. Students and teacher alike claimed that being positioned collegially in a company of experts disrupted the power dynamics in the classroom towards a more equal relationship, where students and teacher worked together to fulfil the commission for the client. The commission framed the learning by providing relevancy and an emotional/ethical purpose to explore the science.

Another major component that supported student learning was working for an authentic audience – the fictional client – rather than the teacher. The value of students interacting with ‘fictional others’, internal to the company, was a particular feature of this study. One ‘other’ demonstrated excellence in science and the ‘other’ incompetence. Using ‘fictional others’ provided the students with the opportunity to explore the implications of not working in an accurate and timely manner. The ‘others’ also helped connect science ideas to real world issues. These interactions helped enhance the quality of student work and provided them with a glimpse of why science is important.

The figured context of the drama allowed the students to actively connect with, explore, and interpret the science from multiple perspectives. Using varied curricular tasks - both dramatic and experimental - engaged students in the learning and embedded the science concepts. Structuring the drama ethically hooked the students into learning, creating an incentive to investigate the science and to produce high quality answers backed with evidence. The ethical tensions between the fictional others - Roger and Malcolm - were also found to be pivotal in heightening the quality of the students’ learning. It can also be seen that being positioned as an expert, using both actual and imagined fictional contexts, working in actual and imagined time, and operating within multiple figured worlds provided the ‘space’ for students to explore both science and what it is “to be human” (Heathcote, 2009, pp. 2, 20).

9.2.2 Learning of science concepts and Nature of Science

The second research question focused on student learning of science concepts, understanding the nature of science and learning and use of scientific vocabulary. Data was presented that showed that students’ knowledge of the science concepts taught improved significantly over the course of the nine-week Mantle-of-the-Expert unit. Changes were confirmed through analysis of student classroom dialogue and written reports. By the end of the unit, students were using more scientific words in conjunction with everyday words in their conversations and written work. In addition, the way they worked emulated the processes of science. The findings also showed that students were readily able to access the science concepts when they were contextualised within a relevant frame such as Cyclone

Giselle. However, it must be acknowledged that from the study design and findings it is not possible to say whether Mantle-of-the-Expert is more effective than any other teaching approach.

The way the unit was structured, and the dramatic conventions used (such as Role-on-the-Wall), were also found to influence the development of student understandings about science and scientists. Being positioned as expert scientists to investigate a problem, create inquiry questions, and explore the problem in a multi-modal way helped the students to learn science concepts and experience science through investigation, which is a recommended pedagogical approach. Also apparent was that students were becoming more fluent in communicating their knowledge in the genre of science and were demonstrating criticality in substantiating their work with evidence. They were also bringing scientific perspectives to their thinking and demonstrating ethicality.

9.2.3 Science Identity

The third question focused on students' impression of themselves in science now and in the future. The students in this study were largely positive about science at school, with most enjoying it, especially when it involved practical work. Most students did not see a future for themselves in science but the percentage that did was higher than some other literature has indicated.

Using Mantle-of-the-Expert for a term and working in the role of expert scientist did not noticeably evoke more interest in science careers; what it did do was extend students' knowledge of science in everyday careers. They also showed growth in their knowledge about the skills scientists possess and the tasks they undertake.

9.3 Contribution of this study

This study explored the use of Mantle-of-the-Expert to teach science concepts and NOS to a class of Year 7/8 students and as such it contributes to knowledge about the curricular learning that Mantle-of-the-Expert can produce. As indicated in Chapter 3, there are very few research-based studies of Mantle-of-the-Expert in science classrooms. This study provides evidence that Mantle-of-the-Expert as a participant structure can support student science learning. It extends the commonplace Mantle-of-the-Expert notion of the external client and audience to include ‘fictional others’ who are internal to the company. In this study these ‘fictional others’, positioned with different authority and competency, served as an audience to student learning and as role models of what to do and not to do in the figured world of the drama and the classroom. Working in a way that hyridised transmissive and inquiry teaching and learning was shown to help students to bridge the conceptual gap. The hybrid approach was realised by developing tasks that supported student expertise, and gradually withdrawing the level of this support as the students’ proficiency with ideas and their capacity to challenge them through investigation increased. It also reiterates the importance of ethics in hooking students into science, sustaining their interest and enhancing criticality in both their interaction with school science and science in society.

The literature on the use of the arts to teach an integrated curriculum is extended in this study. It contributes specifically to literature on learning science through drama, in particular process drama and/or role-play and specifically Mantle-of-the-Expert. It provides evidence of the merits of dramatic conventions such as the Role-on-the-Wall to teach NOS. The study did not however produce a change in student attitudes towards school science. In noting this it needs to be acknowledged that these were high to start with. In addition student impressions of their abilities in science remained constant for just over half of the class, with the other half of the class equally divided between perceiving an improvement in their abilities and students considering they were less proficient.

This study adds to the literature that explores how students develop productive science/scientist identities and/or trajectories. Specifically, the research highlights the value of students exploring a scientist identity through being positioned into an expert scientist role as part of working to fulfill a commission for the client in the drama. This provided students with opportunities and incentive to investigate and communicate science ideas in the manner of a ‘real’ scientist. Hence, the findings extends literature that asserts that learning in situated contexts is valuable in terms of student engagement and perceptions of relevancy by indicating that the context can be an imagined context. Focussing on ethics and values as part of learning and doing science engaged students in learning, enhanced their empathy for others and created a desire to produce high quality work.

This study adds to the conceptual change literature. It demonstrates how working in drama and specifically in Mantle-of-the-Expert can support conceptual change, something that has received very little attention the literature. A dramatic investigative approach can help students to change their conceptual understanding to closer to the scientific norm thereby offering new and novel approach to STEAM.

9.4 Limitations of the research design

There are several limiting factors in this study that may have impacted upon the findings, which shall be outlined.

This study was an action research project carried out in one classroom. While initially there was scope for another class to use the unit, this class took another track. Thus said, Mantle-of-the-Expert has a strong inquiry component and even if two classes worked through the same unit, teacher response to student ideas would mean that the pathway and end products would likely be dissimilar. Working with one class did mean that the small number of participants was often too small for substantive statistical analysis. Nonetheless, data illustrates a trend that could be pursued in other studies.

A volume of data was collected from multiple sources. This allowed for triangulation. However, one limitation was that I could not identify all the students in the class discussions on the audio, due to lack of familiarity with their voices and classroom noise. Video recording and/or individual microphones may have alleviated some of the identification issues but this was not practically possible with the resources I had.

As a researcher who was a co-teacher, I could not observe the action from a distance. However, through the audiotapes, the photographs, and reflective blogging, I was able to create personal distance and review what was happening. In addition, I did have the advantage of learning with the students and experiencing what they were experiencing. On the other hand, a major limitation of this study was that it was non-continuous. I was in the classroom only two afternoons a week and the teacher was not able to maintain the continuity in my absence which disrupted the flow of the drama. As well, the term was busy with lots of other interuptions to the school programme, however school life is frequently chaotic, with continual interruptions.

9.5 Implications for policy, practice and future research

This section indicates implications of this research for policy and practice.

9.5.1 Implications for policy

The first implication speaks to the current focus internationally, and in New Zealand, for students to be scientifically literate (Gluckman, 2011; Lindsay, 2011; Loughran, 2011; Ministry of Business Innovation & Employment Hīkina Whakatutuki, Ministry of Education, & Office of the Prime Minister's chief science advisor, 2014; J. Osborne, 2007), where this includes a focus on “exploration, critical thinking and discussion of socio-scientific issues” at school in years 7-10 (Gluckman, 2011, p. 48). A Mantle-of-the-Expert unit was able to meet these criteria. The use of the arts to support curricular learning has been widely recognised as valuable (Ewing, 2010). While less common, the literature highlighted has also shown that drama can enhance the learning of science (see section 3.3). Interestingly only a few nations like South Korea have specific policy mandating the use of the arts to teach science (Marginson et al., 2013). One implication from this study is that Mantle-of-the-Expert could usefully be endorsed within policy as an approach that supports student science learning while also enhancing their ability to “participate as critical, informed, and responsible citizens in a society in which science plays a significant role” (Ministry of Education, 2007b, p. 17). On the other hand, both science and the arts are ways of exploring the world. Therefore, science could be used to enhance the role of the arts within the taught curriculum.

A second implication for policy relates to the governmental focus on students achievement in science and progress into science careers (Ministry of Business Innovation & Employment Hīkina Whakatutuki, Ministry of Education, & Office of the Prime Minister's chief science advisor, 2014). Working in drama (specifically Mantle-of-the-Expert), opened up opportunities for students to enhance their conceptual understanding (see chapter 6, and section 8.4.1), and explore the possibility of science careers (sections 7.3 and 8.4.4). Mantle-of-the-

Expert is under-utilised in the science classroom. Priority should be given to providing professional development for science facilitators and/or teachers about the approach and how to implement it in the classroom. This would meet the goals of action point 1 in the Science and Society science challenge, specifically enhancing teacher education and providing professional development in approaches that enhance conceptual change in science (Ministry of Business Innovation & Employment Hīkina Whakatutuki, Ministry of Education, & Office of the Prime Minister's chief science advisor, 2014, p. 7).

A further implication for policy makers relates to the value of providing resources that inform students and teachers about scientists and science careers. As shown in this study, providing and discussing even a small resource on science careers can broaden student knowledge about possible science careers and the amount of science in everyday life. While no more students in this study indicated that they wanted a science-based career; more were open to learning science and realised the value of science and the amount of science in everyday life. These outcomes are a worthwhile goal in themselves with the potential to extend student engagement in science learning and to encourage to students to use science in students' leisure and work activities (Economic and Social Research Council, 2006; Kjærnsli & Lie, 2011; Organisation for Economic Co-operation and Development, 2008; Tytler et al., 2008).

9.5.2 Implications for practice

The study has implications for teacher educators, for practicing generalist primary teachers, and for drama teachers. If teachers are to develop competence in using Mantle-of-the-Expert, then teacher educators need to ensure student teachers are aware that drama is not only a component of the arts curricular strand (Ministry of Education, 2007b), it can support learning in other curricula learning areas. Student teachers will need to be guided to critically explore the benefits and constraints of using Mantle-of-the-Expert (or other sorts of drama) to teach curricular subjects (Ewing, 2010). Aitken (2014c, pp. 5, 14) recommends that beginners in Mantle-of-the-Expert start with dramatic conventions such as freeze frames, before undertaking a complete Mantle-of-the-Expert unit. This thinking aligns with Braund et al. (2015) who advise that student teachers of science need to be introduced to drama early in their training and practice to become proficient.

Practicing teachers being able to support student learning through Mantle-of-the-Expert would be a valuable adjunct to conventional science teaching practices. However, some general implications need to be considered before embarking on a Mantle-of-the-Expert unit in science. These include: the time required to plan a Mantle-of-the-Expert unit, the necessity to develop knowledge of and artistry in the approach, as well as having knowledge of the science concepts, the NOS ideas and science processes involved. As identified in this study it is important to spend time building belief in the company and set the scene carefully so that students are hooked into the learning and want to fulfil the commission. It is also important to ensure that sufficient time is allotted to maintain the continuity of the drama and sustain student interests.

As the findings show, Mantle-of-the-Expert supported changes in the students' conceptual understanding. However, to optimise learning, as well as having knowledge of the dramatic approach, teachers should also have knowledge of common misconceptions for phenomena as well as the scientific explanations. Braund et al. (2015) considered this important, for while drama is useful in highlighting student misconceptions, it may also create additional misconceptions if care is not taken when designing the drama. Ensuring that adequate time is given in the drama to investigate the science concepts, discuss and debate the science findings, as well as using dramatic conventions and dramatic tension to deepen motivation is also vital.

Foremost amongst the implications for the practicing teacher is the need to think through how they will support students in their positioning as expert scientists in the drama. Some strategies include teachers repositioning themselves with less authority in discussions and/or positioning themselves as physically equal to the students. Providing the students with artefacts that bridge the conceptual gap between their actual knowledge and their fictional expertise was seen to be essential. As was detailed in this unit, using statements about scientific concepts and misconceptions and requiring students to analyse the data and defend their choices as to which answer best explained the science experiment is a useful strategy for achieving this. Students liked the security this approach offered, as it provided them with the common reasons for the concepts. It also gave them somewhere to move to, which is recommended by Chi and Roscoe (2002). Structuring the learning this way may both support students who are not strong in science and challenge students to defend their reasons for choosing the answer they think the most accurate. This approach would necessitate the teachers finding out the common misconceptions for the concept being tested.

The value of incorporating an ethical element in a science unit was highlighted in this study. Adding an ethical component appeared to heighten the tension in the drama and assist in making the context three dimensional and life-like. It provided a context to learn and use science within, which reflected the “real world” (Reiss, 2010, p. 16). The ethical imperative to find a justifiable answer and problem solve catalysed student interest in science as it provided a purpose for learning and doing excellent science. The inclusion of an ethical aspect is worthy of consideration by teachers when they are planning a unit of work.

There are implications for drama teachers as well as generalist teachers that arise from the use of ‘fictional others’. Similar to the use of the client in classical Mantle-of-the-Expert dramas, ‘fictional others’ can serve as a distancing device, to mitigate the effects of public scrutiny, something Heathcote (2009) considers vital. Rather than the teacher needing to chide students for poor science, a ‘fictional other’ was able to highlight and link the importance of science and good science practices to society (Schreiner & Sjøberg, 2007; Tytler et al., 2008). This realisation has been identified as crucial in encouraging students into science careers (Tytler et al., 2008) and in enhancing students’ motivation to be critical in their interaction with science-based issues (Lindsay, 2011; Loughran, 2011). Introducing ‘fictional others’ and ethical conflict as part of the company dynamics meant that students had to deal with the reality and impact of scientific inquiry as it affected their company’s integrity directly. This assisted them in moving beyond ‘performing’ a task for a distant client to thinking of broader issues. Using ‘fictional others’ to moderate classroom behaviour and to extend students’ notion of the effect of science on society should be considered as a valuable tool for teachers to add to their pedagogical repertoire.

Another implication for teachers from this study is the impact of the different figured worlds the students interact within in the classroom. Looking closely at the figured worlds in operation, and their affordances and constraints, may help teachers choose a dramatic frame (or use a participant structure to teach within) that extends students' access into learning rather than shutting it down. Teachers would be advised to take into account the wider figured worlds the students operate within when selecting a science issue/science ideas when designing a Mantle-of-the-Expert unit. This way they would cater for their students' interests as well as their educational needs.

9.5.3 Implications for future research

This study took place in one classroom, over one term in New Zealand. Although the results were favourable, it would be advantageous to expand the scope of this study. Possible options would be: to use the same unit with other classes, and to examine the impact of different units. It would be interesting to explore the responses of student from different countries to a Mantle-of-the-Expert unit that used a frame similar to that provided by the Wahine disaster.

Results regarding student attitudes towards science were not as favourable in this study as expected from the literature. The teacher speculated that a lack of continuity and constant interruptions may have contributed to less than hoped for enthusiasm for the unit and science. It would be worthwhile exploring this phenomenon in more detail. A possible extension would be to design a unit with more flexibility and continue the unit focus across the school day and week to ascertain whether the students' attitudes to science were enhanced by being more responsive to the requirements of the drama and the needs of the students.

The field would benefit from seeing whether students develop a different understanding of the science concepts and the NOS through doing the same experiments conventionally or as part of a Mantle-of-the-Expert drama. More work needs to be done on analysing the impact of post-experimental discussion and/or dramatic reflection on the strengthening of students' conceptual understandings when science is taught through Mantle-of-the-Expert.

This study showed that providing the students with information about science careers broadened their knowledge of the impact of science in society and science careers. A further longitudinal study to see whether offering information about science careers earlier and throughout students' schooling, as recommended by Archer et al. (2012), would result in more students continuing in science would be worth persuing. It would also be useful to gain more detailed insight into the effect of drama-based pedagogies on students' perceptions of scientists and science careers compared with resources like posters and interacting with real scientists.

Looking at ethical issues is recognised as useful in engaging students in science (Reiss, 2010; Roth & Tobin, 2007; Ryan & Buntting, 2012; Wong, Zeidler, et al., 2011), and is important in Mantle-of-the-Expert (Edmiston, n.d.-b; Heathcote, 2010a), however, it is under researched. Examining the intersection of Mantle-of-the-Expert and ethics to see how it supports students' science comprehension (or other curricular learning) would be useful.

Further work could be done on theorising the interaction of 'fictional others' in Mantle-of-the-Expert units and/or in drama units. This could include: looking into the benefit of interactions with multiple audiences other than the teacher, and/or the influence of 'fictional others' of different statuses. Huxtable (2009) claimed that Mantle-of-the-Expert could be used to support the development of key competencies. Researching the impact of both Mantle-of-the-Expert and 'fictional others' on enhancing students' acquisition of key competency skills would be worthwhile. One caveat may be that a dramatic frame would have to be established before 'fictional others' are introduced.

This study did not focus on differences in responses from boys and girls. It may be of value to explore whether gender plays a role in learning science through drama, or if certain types of drama suit boys more than girls or vice-versa. Particularly pertinent to New Zealand, it would be useful to ascertain whether drama may enhance science learning or student retention in the STEM pathway for Māori and Pasifika students.

9.6 Final Comments/ Epilogue

Like Dorion (2011a), when I was contemplating this research, I had to choose whether the focus of my study was looking at science taught through drama, or using drama to teach science. I chose to angle my research towards teaching science, and to explore if and how using the Mantle-of-the-Expert approach in science teaching could help students learn about floating and sinking. I have discovered that science and drama aspects are not easily untangled within a Mantle-of-the-Expert approach and that the sum of the whole is greater than the parts. I have been fascinated to learn how the structure of Mantle-of-the-Expert, which is both simple and complex, works to support learning.

There is convincing evidence from this study that Mantle-of-the-Expert supported conceptional change. This was seen in the improvement of students' understanding of science concepts, their actualisation of the NOS and their ability to work within genre specific aspects. Ethical tension and an audience other than the class teacher (whether it be the client or the 'fictional others' of my study) played a vital role in drawing students into learning, maintaining their impetus and producing an incentive to produce work of a high standard. Being positioned as expert scientists allowed the students to explore science and examine the implications of accurate science for the wider community rather than just learning science concepts in a classroom. Through their positioning as expert scientists, students were able to experience something of what it might be like to be a scientist as they investigated a socio-historical issue and reported on their findings. Repositioning how the curriculum was taught to sustain the fiction of the students' scientific expertise allowed students to explore science ideas and practices from a position of authority. Working in this hyridised way offered students both security and challenge.

I hope that others will benefit from the findings of my study and be encouraged to use Mantle-of-the-Expert in their teaching and research.

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List of Appendices

Appendix A. Core elements in Mantle-of-the-Expert

Core elements of Mantle-of-the-Expert as described in Literature

As described in Drama for learning (Heathcote & Bolton, 1995) by Heathcote (n.d.)	**Heathcote (2007, pp. 8-10)**	**(Heathcote, 2009, pp. 3, 4)**	**(Aitken, 2013, taken from fig 1)**
Enterprise	Enterprise Language shift summons the enterprise culture; creating culture and inclusivity ****	All enterprises exist to serve needs of the client *****	Company / Enterprise / Responsible team
			Commission
Client	Serve the client, fulfilling his demands	All enterprises exist to serve needs of the client *****	Client
Positioning as experts			Powerful repositioning
Fictional world	Language shift summons the enterprise culture; creating culture and inclusivity **** Students work in role as themselves but explore different contexts and places.	Agree to work within a fictional context.	Fictional context
			Frame
Curricular task	Enterprise chosen to support the curriculum All behaviour springs from the tasks	Curricular tasks carry the learning and dictate behaviour	Curriculum framed as professional tasks
Reflection		All work is from perceptive of the artist – “active reflection”	Reflections
	Sign is used to denote purpose		
		Operates in immediate ‘now’ time.	
		Teacher has responsibility for sustaining action.	
		Protection is provided by shifting contexts to that of making - not imposition	
			Tension
			Drama for learning/ conventions

Appendix B. Brief outline of unit

25/07/11: Teacher Interview One.

02/08/11: Introduced myself to the class. Students did pre-assessments A and B.

04/08/11: Whole class discussion was held about New Zealand having a national identity and events that impact us as a nation. We watched a YouTube clip of the television news on the night the Wahine sank. The class discussed the YouTube clip, focussing on scientific reasons for the sinking. Pictures of the tragedy from the newspaper were reproduced through Freeze Frames and explored through thought tapping. Teacher in Role was used to give the students more information about the tragedy. Linda, the wife of someone who had been on the Wahine visited the class and spoke about the disaster.

09/08/11: The whole class analysed the noticeboard of the Scientific Extreme Events Reconstructive Services (SEERS) company to find out what the company was like. We discussed the skills the people who worked in SEERS would need. We constructed floor plans for building that would house SEERS and made nametags for our personal roles within the company.

11/08/11: This session built belief in the company. Malcolm the CEO had sent us some items, an award for ethical science, a puzzle and a chart on science careers. We analysed what ethical meant. We solved the giant jigsaw puzzle to unpack what our name meant and what scientists to do. We rang Malcolm (the company CEO) in role to find out why he had sent the puzzle. He told us that he thought we had forgotten what it was like to be a scientist. As part of professional development we used the dramatic convention ‘Role-on-the-Wall’ to help us think and see what scientists are. Our findings were then discussed.

16/08/11: Malcolm emailed the company and asked us to write a CV, which included our memories about when we joined the company, our qualifications, the positions we have worked in and favourite memories of working for the company. We shared these with the company.

18/08/11: The episode started with a reflection about learning in science and Mantle-of-the-Expert. We received the commission from the client and analysed the letter in small groups and then as a class. We wrote our questions for the client and research questions on the wall to be compiled by our company secretary and sent to the Client beginning negotiations for accepting their offer.

23/08/11: We received an email from the client, which asked us to analyse authentic newspaper articles (Newspapers in education, 1983) to find out the scientific reasons why the Wahine sank. Our findings were shared with the rest of the company in role as scientists. We also tried to piece together a map of Wellington harbour with pieces of text to geographically and chronologically order the series of events that had led to the sinking.

24/08/11: An outline of Wellington Harbour was placed on the floor of the classroom in masking tape. The students physically mapped the disaster, moving to each location and listening to commentary about what had occurred there. We then dramatically explored what had happened at each point through the viewpoint of a person who had been on the boat, when for example; it hit the rocks and the vessel was abandoned. Finally, the class spoke to an effigy of the Captain represented by his photograph and voiced by a student and I, about the sinking and his impressions of the sinking.

25/08/11: In this episode I was in role as the company PA who did not have a clue about weather science and needed to consult an expert named Albert. The students were in collective role as Albert the science expert. To help them ‘be’ expert they were provided with one fact each about weather maps and meteorology on a strip of paper. I asked Albert (the students) questions about meteorology, which they answered from their strips of paper. We also looked at an isobar map and talked about aspects of buoyancy. After the conversation, the students played weather dominos (Ministry of Education, 1999, p. 87) to consolidate the learning.

30/08/11: Extreme Event Select Committee (EESC), the Client asked us to explore how cyclones work and asked us to make a model of a cyclone from two soft-drink bottles. After carrying out the experiment, the students described what had happened and related it to cyclones. Albert (TIR) visited and talked about cyclones in general and Cyclone Giselle.

01/09/11: The students translated a Morse code message about the weather when the Wahine entered the harbour. The company received a parcel from the client containing items from the inquiry into the sinking. Amongst the items was a weather-damaged experiment to reproduce the sinking of the Wahine using marbles and paper boats.

06/09/11: In this session we used ethical tension level 12: Loss of faith in companions to drive the learning and heighten excellence. The dramatic convention of overheard conversations; some scattered emails and a newspaper article were used to introduce the students to another member of the company – Roger, who was positioned as likable but incompetent and unethical. This led in to us talking about what we needed to do to ensure our science was accurate.

We conducted the paper boat experiment and discussed the science behind the sinking.

13/09/11: The students were asked to choose a replacement for Roger from four potential employees. Six stations were set up with a science experiment and comments from the potential employees describing their understandings of the science concept being tested. The students conducted the experiment and chose the statement that described the science the most accurately. Then they acted out an interview between the potential employee they chose and Malcolm the CEO, where the potential employee had to justify their knowledge about the science tested.

Experiment 1: Predicting which objects would float and sink
(Modified from activity 1, Ministry of Education, 2003, p. 8).

Experiment 2: Weighing similarly sized shaped of different densities and placing into a container of water – looking at density and displacement
(Modified from activities 2 and 3, Ministry of Education, 2003, pp. 10-11).

Experiment 3: Free surface effect (own experiment)
4 small containers are placed inside a large plastic container. The containers should not move in the large container. The small containers are filled with water and closed, mimicking buoyancy chambers. The large container is placed in a tub of water representing a boat in the ocean. The lid of the large container is placed on top of the large container upside down and water added so it moves freely. Students experiment with totally filling the small containers, half filling the containers and non-equally filling the containers. This experiment allows them to look at the vessels' centre of gravity and free surface effect.

Experiment 4: Looking at impact of trapped air on floating and sinking objects.
E.g. a sponge, apple, lemon, potato
(Modified from activities 1 and 3, Ministry of Education, 2003, pp. 12-14).

Experiment 5: Changing shape to increase volume
Using tinfoil and modelling clay and experimenting with different shapes to make the material sink or float
(Modified from activity 3, Ministry of Education, p. 14).

Experiment 6: Potato chip experiment
Objects with air inside normally float. Boats need ballast to be stable.
(Modified from http://www.workman.com/blog/wp-content/uploads/2013/04/CW_Potato_Chip_Science.pdf

13/09/11: Teacher Interview Two.

14/09/11: The students rotated through the other experiments.

15/09/11: Students worked in small groups to come up with scientific reasons for the Wahine sinking, which were collated on a white board after a group discussion.

20/09/11: We revisited the reasons why the Wahine sank. We talked about how to write a report to the client, stressing the need to include evidence from the experiments. The students started drafting their report using books, the Internet, the newspaper articles and evidence from the experiments.

21/09/11: Students worked on their reports.

26/09/11: Students continued writing their reports.

27/09/11: Final classroom session on writing the reports to the client.

28/09/11: A 30-minute unproductive group discussion was held on how to present the report to the client. Following the session, TJayne and I devised the basic structure of the presentation.

29/09/11: A large boat was taped in masking tape on the hall floor on the day of the disaster. We presented our work to the client (my supervisor in role). She probed our thinking about the science and the human factor. We presented our tributes to those who had died on the Wahine written on paper boats. This was done to provide closure and dissipate tension.

05/10/11: Students re-sat assessments A and B and did an anonymous assessment. We had a shared lunch.

13/10/11: Teacher Interview Three. I drew on statements taken from our discussion after each session and my research questions. The class book was used as a memory aid.

17/11/11: A focus group was held with six of the interviewed students to get a group perspective of key statements taken from their interviews. They also reviewed their summarised transcripts.

Appendix C. Detailed planning of episode

Task 2	*Aims of episode*	*Preparations*	*Artefacts and dramatic conventions used*	*Questions*
Episode Four 09/08/11	To start to build belief in a company, giving a purpose for the work. To engage with the idea of forming a company and having history.	Create a noticeboard and the artefacts needed Set up class as a company Set up the desks for a meeting A3 paper and felt pens Have a minute book and name tags	**Noticeboard** (DH 15-objects to represent a person's interest or in this case to introduce an entity –company)** Company Name- Seers√ Long range weather forecast Sea maps of wellington √ Map of New Zealand Old Conference notice for Extreme weather conference with note on bottom – Conference reports due date. Recycling notice√ Notice of Malcolm's party√ Letter from Christchurch City Council. √ Map of NZ with fault lines√ **Meeting notice** DH 15 (notice board) DH10 physical modelling company DH1 T-I-R name tags Time line Ritualise Company attributes DH (21)	As you come into this room, you will notice that some extra items have been added to the classroom. Explore touch, read. Please do this quietly. What are the items? Who might own these items? What type of people are they? When you have finished exploring please come and sit down. What have you noticed about the room? What type of company do you think this company is? What is the purpose of the company? What type of jobs do you think the firm would do? What resources would they need? (Physical model of company – DH 10) You have used MOTE – invite you to become part of a company – discover and grow our company (starting in T-in-R (DH1)– yet not fully engaged into MOTE) Take minutes – Introduce self – Name tags (DH1) Reunion Timeline – Ritualise positive special things about firm (DH 21).

*Planning headings modified from "Internal coherence - a factor for consideration in teaching to learn. A paper to explain the interior planning and outer praxis when a drama element is used in working in "Mantle of the Expert" mode with students in a middle school in Victoria Canada May 2009," by D. Heathcote, 2010, *Drama in Education, 26*(1), 24 - 66. Retrieved from http://www.mantleoftheexpert.com/wp-content/uploads/2010/03/Jan-101.pdf

** DH 15 refers to Dorothy Heathcote's Drama Conventions, which can be retrieved from http://www.mantleoftheexpert.com/wp-content/uploads/2009/08/DRAMA-CONVENTIONS.pdf (A. Taylor, 2006b). In this instance I have identified which convention I am using in my classroom teaching.

- At the beginning not in role- allow time to explore silently. Have a class discussion about company and notice board etc. (? On mat/ or at desks configured into boardroom without explicitly stating.
- Lead into thinking about the company. **What type of company do you think this company is?** (Big/small, caring/not caring, ethical/non ethical → must set up ethical etc on notice board – pictures etc/ recycling data).
- What type of jobs do you think the firm would do? What resources would they need? – Lead into Physical modelling of company – groups – justify whole class draw big group. (closest DH 10 Stylised depiction of someone- company as a physical entity)
- Lead into Meeting (TIR)
- Ask someone to take minutes
- Apologies – Introduce self -Carrie PA to Malcolm who is in the Pacific on a 60th Birthday cruise. He will be back in time for his birthday celebration-hopefully (? Caught in cyclone).
- New staff present – Name tags – security issue – name and role/ department as part of our company (take time to do that – can be continued later in colour)
- Sharing –chose one – get someone in the class to make it up during the week and add it to the notice board

Appendix D. Assessment A: Attitudes

1. Have you learnt using Mantle of the Expert before?

   Yes No

2. How much do you like learning using Mantle of the Expert?

Heaps *Quite a lot* *Some* *Little*

3. How much do you like doing science at school?

Heaps *Quite a lot* *Some* *Little*

4. How good do you think you are at doing science?

Excellent *Good* *OK* *Not very good*

5. What science have you done before at school and at home?
6. Do you want to keep learning about science when you grow up?

   Yes No Maybe

7. What do you want to do when you grow up?
8. Do you think it involves science? If you do think it involves science, please explain how?
9. Name five jobs that use science
10. What sort of things do scientists do?
11. Do you think you would make a good scientist?

    Yes No Maybe

12. To you, what is science about?

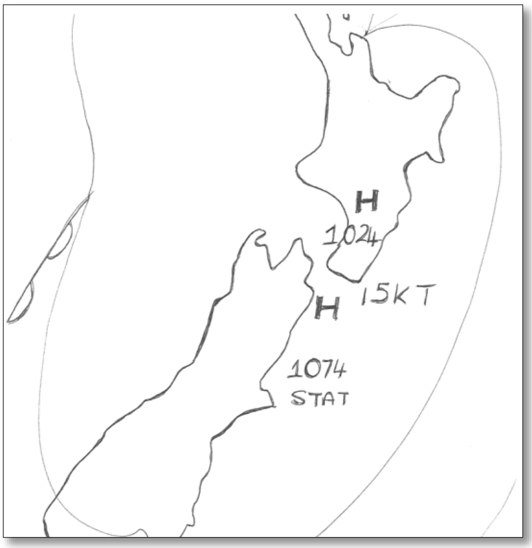
Questions 3, 4, 5,6, and 11 are adapted from the NEMP attitudinal survey (Crooks et al., 2008, pp. 62, 63), which is used with permission.

Appendix E. Assessment B: Science concepts

Kaitaki. From *Our ships and services: Interislander: Ngā waka - New Zealand ferries*. Photograph by L. Keats, 2006. Retrieved from https://www.interislander.co.nz/Kaitaki.aspx Reprinted with permission.

This is a picture of the Interislander ship Kaitaki. It is one of the three ferry ships that travel between Wellington and Picton each day. The journey takes three hours and is 92 km.

It is very important for the captain to find out what the weather for the crossing will be like. The captains generally listen to marine forecasts and look at weather maps. Here are two weather maps for two days the Kaitaki travelled across Cook Strait. Study the maps and answer the questions.



Weather Map One [Adapted from] *National education monitoring project New Zealand: Science assessment results 2007*. (p. 52), by T Crooks, J Smith and L Flockton, 2008, Dunedin, New Zealand: Ministry of Education. Used with permission.

1. What do you think the weather will be like on this day for going on the ferry?

(a) calm
(b) calm and warm
(c) hot
(d) a good day
(e) I don't know

2. How does the map tell you that the weather will be like that?

Weather Map Two [Adapted from] *National education monitoring project New Zealand: Science assessment results 2007*. (p. 52), by T Crooks, J Smith and L Flockton, 2008, Dunedin, New Zealand: Ministry of Education. Used with permission.

3. What symbol is used on weather maps for a warm front?

4. L on the weather map stands for

a) cold
b) low pressure
c) windy
d) I don't know

5. The lines on the weather map (isobars) mean that the weather crossing the strait will be?

a) calm
b) windy
c) cold
d) I don't know

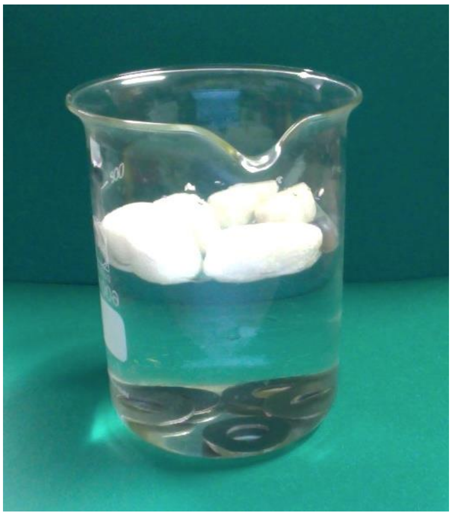
Question 1-5 are adapted from Crooks et al. (2008, p. 52) and used with permission.

6. A cyclone may be known by other names in different parts of the world.

Name two

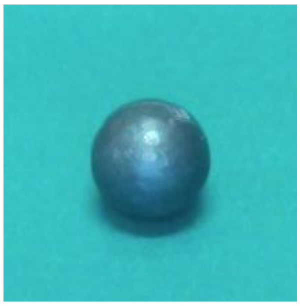
7. Can you tell me how a cyclone is formed? Words which may help you are:

Eye, depression, spiral, thunderstorm, sea, wind, warmth, rain, tropics, low pressure, rising air



8. Why do the pieces of polystyrene float and the steel nuts sink in a beaker of water?

a. The polystyrene pieces are light for their size and the steel nuts are heavy for their size.
b. They polystyrene pieces are smaller than the steel nuts.
c. The polystyrene pieces are denser than the steel nuts.
d. I don't know



Kaitaki. From *Our ships and services: Interislander: Ngā waka - New Zealand ferries*. Photograph by L. Keats, 2006. Retrieved from https://www.interislander.co.nz/Kaitaki.aspx Reprinted with permission

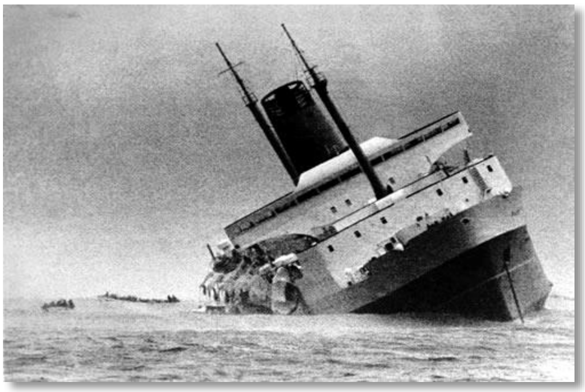
9. Both of these objects are heavy. Why does a boat float and a steel ball not float?

a) Boats have engines which keep them afloat
b) The shape of boats displaces enough water to hold its weight
c) The boat shape is more spread out than the ball so it floats.
d) The boat floats because there is air inside it.

The idea for question 9 is adapted from Flockton and Crooks (2000, p. 39) and used with permission.

10. What factors affect buoyancy or the ability of an object to float?

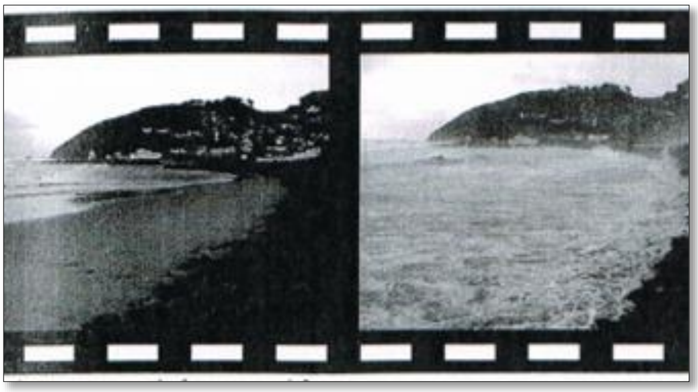
a) The forces acting on an object and the density and volume of the object.
b) The forces acting on an object
c) The volume and density of the object
d) The forces acting on an object and the density of the object



Ship Wahine sinking in Wellington Harbour, (unidentified Evening Post staff photographer, 10 April 1968). Ref: 35mm-01149-29-F. Wellington, New Zealand. Alexander Turnball Library. Used with permission.

11. The Wahine floated in Wellington harbour for a while before sinking.

Why did she eventually sink?



Moving Water video Screenshot from *National Education Monitoring Project New Zealand: Science assessment results 2003* [p. 49], by T Crooks and l Flockton, 2004, Dunedin, New Zealand, Ministry of Education. Reprinted with permission.

Question modified from Crooks and Flockton (2004, p. 49) and used with permission.

Appendix F. Anonymous Reflection

1. How does Mantle-of-the-Expert's way of learning help you get interested in the topic? Why? Why not?

2. Do you feel Mantle-of-the-Expert helped you learn science?

3. What was your favourite moment and why?

4. What were the disadvantages of doing Mantle-of-the-Expert? (What didn't you enjoy?)

5. What were the advantages of doing Mantle-of-the-Expert?

6. How does this way of learning compare to an ordinary day at school? Would you want to do Mantle-of-the-Expert more?

	Example of students answers - Question 3
1	My favourite moment was when we were acting out the scene when the Wahine hit the rocks as it was going up Cook Strait.
2	My favourite moment was going into role and becoming a scientist and learning new things about science.
3	I liked the part when we made the reports.
4	Experiments
5	Experiments
6	Testing density using everyday objects.
7	Paper boats because we got to play around with them.
8	The report
9	My favourite bit is the fun learning
10	The experiments
11	Creating skits
12	I liked the potato experiment.
13	Making the cyclone in the bottles because it was interesting.
14	I liked the freeze frames in the beginning because they didn't drag on.
15	Doing the experiments because it was fun to learn like that.
16	My favourite moment was the experiments.
17	Doing the report and doing the presentation was really great as well.
18	The tests we did because we got to come up with and test our own theory.
19	Making paper boats because we got to see how much marballs we could put in the boat until it sunk in the water
20	Making the paper boats
21	The Wahine because I didn't know much about the Wahine
22	It was fun doing the experiments.
23	Doing hands on activitys
24	Experimenting with the cyclone in a bottle. It looked cool.
25	Writing the report, as I enjoy writing.
26	The experiments
27	Making a hurricane.

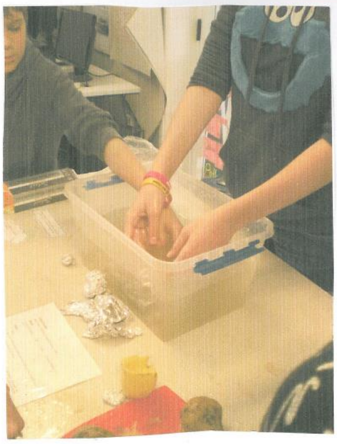
Appendix G. Sample of Class Book

Episode Thirteen: Being and becoming Expert

A nine am start. I arrived at eight am to set up the stations. I was able to interact with not only the students I had been working with but also the students from the other class. I gathered a crowd around one of the stations where I was checking an experiment to simplify it. Questions flowed and we talked and experimented together. Why do you think this piece of pumice floats? Will this stone displace more water or the pumice?

Before starting the science rotation, we talked about predicting and good questioning. We should be using how, why and that we try and ask open ended questions rather than closed questions.

We then explained to the students that we were regrouping them and they would rotate through each of the experiments. The original groups were numbered off and all the ones went together etc. One person in each group would be an expert at each station because they had already carried out the experiment.



As the groups passed through each station the expert with varying degrees of success explained to the other group members how to carry out the experiments. Jane had to stop the class and mention that some group members were so excited that they were not giving the leader a chance to lead.

As I wandered around the groups I noticed a buzz of excitement. Everyone wanted to try out all the experiments. A mother wandered into the classroom. "What's going on?" she asked, noticing her son knife in hand hollowing out a potato. I explained that I was visiting the class to do science and this was the research that we had sent a consent form home for last term. Her comments, "He'd love that." Her son loves science and has a very good understanding of science concepts.

I asked the students as I moved around what they knew about the science behind the experiment. What I found was they had a greater understanding of the science than before and were using the vocabulary. Situating them as experts the day before had given them a good handle on the science.

At the predicting station the reasons given for an object to float or sink generally mentioned that it had something to do with air. Some mentioned that the item was light for its weight. When we compared two different candles one tiny and one enormous some thought that the big candle would sink. Why did it float? The answer given was it was light for its size. Any other reasons I asked. One of the students mentioned that it was made of wax and oil and water do not mix.

Appendix H. Questions for the teacher first and second interviews

Interview One

- Describe your educational background.
- Can you describe your science background? At school, uni
- Have you taught science much in your classroom? How would you describe your confidence at teaching science?
- What is your background in drama, Mantle-of-the-Expert?
- How supportive is your school of Mantle-of-the-Expert?
- Can you describe your use of Mantle-of-the-Expert in the classroom?
- What do you consider the benefits of using Mantle-of-the-Expert in your teaching?
- What are your impressions about student learning using Mantle-of-the-Expert? Do the children enjoy it and why?
- What science have you used recently in your classroom?
- Do you feel that the students were engaged?
- Are there any children in your class who you think may want a career in science?
- What do you expect to get out of the study?

Interview Two

- What evidence have you seen of student engagement into this Mantle-of-the-Expert?
- Have you noticed any changes in the way students think about science over the course of this unit?
- How do you think learning through Mantle-of-the-Expert supports learning in general? And in science?
- Do you consider that using dramatic conventions such as role on the wall help students to learn generally and in science?
- What changes have you seen in student behaviour over the course of this unit (if any)?
- Have you noticed any changes in student’s use of language about science i.e. getting more complex or a deepening of understanding?
- From your notes what unusual or unique occurrences have you seen during this unit?
- What stands out for you about student learning this time?
- What challenges have you faced over the course of the unit?
- We have team taught together. Do you feel that this has been successful? If so why? What areas could be improved?
- What areas of the unit have disappointed you and why?
- The unit has mainly occurred on two afternoons a week with limited time outside of me being in the classroom. Do you feel this has been ideal? What would have been your ideal configuration?

Appendix I. Example of student transcript summary

CM summary of Interview October 5th 2011

Learning Style

You consider you best learn by Mantle of the Expert. Reading is great but too much reading is not good.

You like ‘hands on’ stuff.

Mantle-of-the-Expert

You described Mantle of the Expert as , **“It is to do with getting into role and the beginning you telling us that’s what you said that we were told that we were experts and to talk about it.”**

You said that, **“some people might feel more confident in what they are saying because of the mind-set. The mind believes they are an expert so they say stuff like they are an expert. By the end of that they were.”**

Learning through Mantle of the Expert is, **“It’s more hands on. It’s not boring or dull.”**

You considered that writing reports, **“was easier after doing hand on work because we knew what we were talking about.”**

You like to have a balance of learning through drama and researching by yourself, **“so you don’t get sick of it and drying your eyes out through hundreds of books.”**

You told me, **“that with Mantle of the Expert it’s better because you don’t know what’s happening because you’ve got the teachers are planning it,”** not just books or the computer.

You were able to pick when the teachers were in role.

When asked if having a purpose for your learning like in Mantle of the Expert makes a difference to how much you want to learn you replied, **“You are always given a direction in school on where to go with your learning. I guess the only way that it is different is that you are acting.”**

“you get given a purpose in MOTE basically by putting you in a position where you know nothing about the topic unless you have read a book or something to do with it and um (I forgot what I was going to say). You get given a direction to go to where you are in a position where you don’t know

anything and if it's something interesting you want to find out more so you do all that you can to find out about it and basically show it off in front of all your mates."

When asked about being positioned as an expert you said, **"If you say that we are an expert it is like a confidence boost and we feel more confident in yourself so you can stand up and say what you know."**

Talking about power you said, **"In MOTE we are kind of more equal because the teacher isn't sitting up on the chair and we aren't all sitting on the mat. You guys would sit down on the mat next to us and ask us questions and we were all equals."**

When asked whether you were passionate about Mantle of the Expert you replied, **"Yes because it's more fun. (definite tone). Umm sports if you are passionate about sports then you learn more about it and you get better at it. It's the same with learning. If you enjoy the topic then you learn about it and you get more confident about what you are saying about it."**

You agreed that Mantle of the Expert was **"fun."**

<u>Science</u>

About science you told me that you've always liked science mainly so you can sort out people in an argument.

Your views on scientists when you were younger

> **when you are younger you always think of scientists as nutty professors creating dinosaurs in their dungeon (OK) When you grow up. It seems like when you get to five, six years old you start discovering that they do not make dinosaurs. It seems to get dull because you are not making stuff. But them we grow to 11, 12,13 and you start to realise that when you do stuff like this it is more than just walking around with a lab coat and clipboards and taking notes and things.**

You haven't decided on a career but think it may have something to do with IT.

You didn't know much about weather before you started this unit.

You found the cyclone section **"kinda hard."**

You noted that knowing how to read weather maps, **"is useful because if you were lost in a desert somewhere and you got somehow managed to get weather maps of the next few days (which is probably very unlikely) you**

could read the weather and see if it is going to be hot. You could make shelter. If it is going to be like windy and rainy you could make a stronger shelter or move to higher ground."

You told me that boats float because, **"They have air inside them and the water displaced around them to keep them afloat."**

You said that the Wahine sunk because, **"I guess when the rocks punctured the hull on the starboard side all of the weight. It was side on to the waves and the wind and it was pushed out over onto its side and more water was coming in and it's buoyancy couldn't float it back up to straight position so it just kept pushing it over and over. All of the vehicles in the vehicle deck added with the weight of the water slowly it went onto the side and sort of dragged it down."**

When asked about whether learning science through Mantle of Expert was easier you told me that, **"To boys destruction is always fun so when I discovered I was doing how the Wahine sunk I was quite happy because something got destroyed.**

Appendix J. Example of document log

Episode Date	*Name*	*Resources*	*Data collected, Collated & Transcribed*	*Research Question*
All		Class book	All episodes modified from blog with pictures	
All		Planning general document	---	
All		Planning science folder	Thinking re science and science resources	
		Additional Wahine resources/books/pc	---	
25/07/11		Audio interview with Jayne (teacher)	Transcribed	
One 2/8/11	Personal Identity and Assessment	Blog	Yes	3
		Assessment A	Analysed	1 and 2
		Assessment B	Analysed.	1 and 2
		Transcript – minimal listen prob no transcript	To listen, transcribe if required	
Two 4/8/11	The Hook	Plan	Yes	--
		Blog	Yes	3
		Photographs	Yes	1
		Audio		

Appendix K. Matrix detailing data set to answer specific research questions

Data gathered	*What Shifts occur in written and verbal use of concepts, language and skills in science*	*How do Students see themselves in science now and in the future?*	*How do students and teachers consider the MOTE supports and constrains the learning in science?*
Pre test	X	X	
Post test	X	X	
Audio of Carrie (12 lessons)			
Audio of children (12 lessons)	X		X reflection sessions
Student end Interviews (6)		X	X
Teacher interviews (3)			X
Co-constructive Reflective Journal including headnotes straight after class			X
Unobtrusive data	X		
Writing in role, reports, experiments – student work during the intervention			
Photos (12) lessons worth	X from whiteboard discussions	X (Used as prompts in interview)	
Photos – teacher photos with comments		Only as part of the journal and reflection process, to add to the thick rich description	

Appendix L. University of Waikato Ethics Approval

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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

MEMORANDUM

To: **Carolyn Swanson**
cc: Associate Professor Bronwen Cowie

From: **Associate Professor Linda Mitchell**
Chairperson, Research Ethics Committee

Date: 19 May 2011

Subject: Supervised Postgraduate Research – Application for Ethical Approval (EDU014/11)

Thank you for submitting the amendments to your application for ethical approval for the research project:

> **Refocusing, refracting, and reflecting student learning of and in science in years 7 and 8, through the prism of Mantle of the Expert**

The Committee noted that the consent forms look very good, and the questions have now been refined.

I am pleased to advise that your application has received ethical approval.

Please note that researchers are asked to consult with the Faculty's Research Ethics Committee in the first instance if any changes to the approved research design are proposed.

The Committee wishes you all the best with your research.

Linda Mitchell

Associate Professor Linda Mitchell
Chairperson
Faculty of Education Research Ethics Committee

Appendix M. Précis of Research Project at Research School 2011

Research Questions and framework

How does using the Mantle of the Expert drama based pedagogy to teach science in a Year 7/8 class, support students to think scientifically and 'see' themselves in science?

This unit will be supported by the socio-historical occasional of the sinking of the Wahine and explore the science behind the sinking supported by the framework of the Mantle of the Expert. In this instance we (the students, I and their teacher) are a company of Scientific Extreme Event Re-constructive Services (Seers) and are fulfilling a commission for an Extreme Event Selective Committee of the Government to do a historical scientific audit of the Wahine sinking.

I am interested in seeing if there is a change in the way students perceive their scientific identity. Hopefully I will see growth in their ability to think scientific and enhanced scientific knowledge. In particular I will be looking at any evidence of deepening conceptual knowledge and understanding through their language. I will also be listening to their voice and analysis of their learning and physical embodiment of their journey. I will also collect their writing and look at how it demonstrates understanding.

School Commitments

- Work with a Year 7/8 classroom over the third term and the teacher of the classroom in a science based Mantle of the Expert experience.
- Perhaps be involved in the classroom for one to two days per week over six to eight week duration (or as is convenient to the school)
- Two hours in the class
- Students participants will be voice recorded and collection of student work and still photography
- Pre-test and post-test children re ideas about identity and weather/science facts relating to the Wahine.
- Interview six students post-test.
- Use Mantle of the Expert to teach unit.

- Present our research to the parents and staff in a pseudo court setting.

Curricular Grounding

- Set at level 3/4 with scope for extension and support as required by individual students.
- Science – Interacting systems in Planet earth and beyond, focusing on weather, climate, weather forecasts and cyclones
- Science – Aspects of the physical world and the material world as we consider other scientific reasons that contributed to the sinking of the Wahine.
- Social Science – how events have causes and effects
- Arts – using drama techniques and conventions to help us as we work in the fictitious and world of the classroom as we learn through and in the process of our drama and be, present and respond to the demands of our client.
- English – Listening, reading, speaking writing and presenting in and out of role using authentic artefacts to drive learning.
- Mathematics and Statistics – data collection methods and depending on the inquiry focus may include graphing, gathering sorting and displaying data and detecting patterns and trends.
- Key Competences- include most aspects, in particular using language, symbols and text and participating and contributing
- Learning Languages – use of a small portion of te reo and linking to relevant student’s cultures and identity.

Appendix N. Letter to parents/guardians

(Address)

Date

Dear (insert name of Parent/Guardian),

I am writing to ask your permission for your child to be involved in some educational research. I, Carrie Swanson, am a PhD student at Waikato University under the supervision of Associate Professor Dr. Bronwen Cowie and Dr. Viv Aitken from the Faculty of Education. The research I am undertaking is part of my Doctoral thesis, entitled *Refocusing, refracting, and reflecting student learning of and in science in Years 7 & 8, through the prism of Mantle of the Expert.*

Recent national and international research has noted that New Zealand students are disengaging from science and this appears to start from Year 8. The researchers propose that more students will be engaged into science when science is taught using a broader range of pedagogies and learning is embedded in contemporary issues and encompasses problem solving in a collaborative learning community.

The purpose of this project is to investigate whether an innovative drama-based teaching approach known as Mantle of the Expert has the potential to support students at Years 7 & 8 to think scientifically and 'see' themselves in science. I would be interested to know how the students in this study feel about science, whether they can see a future for themselves in science, and whether their science thinking changes over the project. I also want to know if teaching science within the Mantle of the Expert approach has been engaging, fun and a useful way to learn science. I have included an article written by Dr. Viv Aitken explaining more about Mantle of the Expert for your information.

If you are agreeable, the format of the project is as follows. The students and I would be learning about weather linked to the sinking of the Wahine by working in and out of role as part of a fictitious company fulfilling a commission for a client. The commission provides the impetus to the study and a framework to carry out set tasks linked to the curriculum. Students would be supported to become experts in their learning, taking on responsibility both for learning and deepening knowledge of the study.

The children would be required to sit a pre and post test and answer questions about the topic and their views about science and science careers. I would then interview a small proportion of the students about their answers. The unit would consist of 10 lessons of approximately 1 and a half hour in duration. The sessions would be audio and video taped. I would take digital copies of class work with the student's permission. At the end of the sessions the students would be invited to become 'researchers in role' and analysis their learning like researchers, ensuring their voices are heard.

It is anticipated that the research project would occur during term three. The children will not be participating in the normal classroom routine but will be learning science, social sciences, drama, English and using a small amount of Te reo. Your child's participation in the project will help to advance the teaching of science and validate a cross-curricular collaborative way of teaching. I do not anticipate any adverse affects.

I would ensure that the children's anonymity was protected by referring to them by self-chosen pseudonyms in my research. I would cover up any signage that would identify the school. I would ensure that your identity and that of your child's school remain confidential and that all documents and transcripts are kept in a secure location.

Although I am carrying out the research in your child's class there is no obligation for your child to be involved. Your child's participation in this project is voluntary and he or she may chose to not answer any of the questions posed during the project or may opt out of part of the study. If you and your child chose to be involved you can withdraw your consent at any time up until .... There will be no penalties for withdrawing from the project and your child may take any previously gathered data. The results of the research may be published but your child's name will not be used. I will endeavour not to use any footage of your child in presentations. However, if the fluidity of a presentation is such that I must use a picture I will ensure that your child's image is obscured. I will leave withdrawal forms in the classroom during the sessions and your child or you can formally withdraw from the project if desired. I will provide alternate work for your child to do, or they may be able to move to another class if they want to.

The data obtained will be used in writing my thesis and may also be used at conferences, seminars or in academic papers. Although I am filming the unit and may use part of the footage or still shots in presentations, I am not planning on releasing visual data onto the internet. If I obtain some exemplary data I may contact you and your child to ask for additional permission to release the visual footage for teaching or learning purposes. Your child's name would be not released in that instance. The footage taken and the data gathered will be stored securely by me during the project and by the University for up to five years after the research is completed for ensure veracity. After this the images will be destroyed.

Your child will be involved in validating their learning during the project in our reflection sessions. I will provide a summary of any interviews to the child concerned so they can add, delete or amend the points raised in the interview. When I have written up the data I will provide the participants and their families with a summary of my findings and conclusions and may call a general meeting if there is enough interest to talk in more detail about what we (the students and I) did and found out about science learning in and through the Mantle of the Expert.

Please feel free to contact me with any questions relating to my proposal.

If you are happy with this proposal I have provided a written consent form that can be filled in and an envelope to return the form to me via your classroom teacher. If you wish to talk with me about the proposal I am more than happy to come in and talk with you at a time that suits you. If you are not interested at this time to take part in this research, can you also please return the form with the "I/we do not give permission for our child to participate" section filled in or email me to let me know.

Thank you for your consideration and assistance.

Yours faithfully

Carrie Swanson.

……………………………………………………………………………………

I, _________________________________, parent/guardian of __________________________
have read the information pertaining to the proposed research project entitled, *Refocusing, refracting, and reflecting student learning of and in science in Years 7 & 8, through the prism of Mantle of the Expert.*

At this stage I am not willing for my child ___________________ to participate in this study.

- He/she can stay in the classroom but I would prefer that he or she did alternate work.
- I would prefer if he/she went to another classroom during this research.
- He/she can be involved in the work but I would prefer if you did not include any data pertaining to them in your research.

(Please cross out those which do not apply).

I, ____________________ am willing for my child _____________________ to be involved in this project. I am aware that their participation in this study is voluntary and that my consent may be withdrawn at any time up until ....

I understand that the researcher Carrie Swanson is not planning to release any visual photographs or video footage of my child. However, I am willing to be contacted in the future if there is any exemplary footage that may benefit student learning, to show me and my child the photograph or video segment and obtain consent for that item to be released.

Additional comments about your child that you wish me to know.

____(Name)
____(Relationship to child)
____(Date)

Appendix O. Letter to student participants

<u>Letter to student participants</u>

(Address)

Date

Dear (insert name of student),

My name is Carrie Swanson and I am a PhD student at Waikato University. I really like science and drama. At about Year 8 many students who previously liked science start to dislike science. I want to use a drama based way of teaching, known as Mantle of the Expert to teach a unit of science to see if learning science in this way makes a difference in how you (the students) think and learn science and whether you can see yourself doing more science in the future.

I would like to invite you to join with me as I teach this unit. At times we will be teacher and students, at other times we will take on different roles as we explore the learning. In a Mantle of the Expert unit, students and teachers work together as part of an imaginary company, taking on the role of experts, and working together to fulfil a project for a client. The drama will connect with a piece of New Zealand history and we will become experts in our roles and learning as we experiment, write, draw, act and discuss the tasks that have been set to help us learn about science and accomplish our commission for our client.

To find out what you already know about this science topic and how you feel about science you will need to sit a test. Some of you (six) will be chosen to have an interview and tell me more about the answers you gave in your test. The unit will be for 10 weeks in term and will last about 1 to 1.5 hours at a time. In the last twenty minutes of each session, we will become 'researchers in role'. During this time, you can put on your researcher eyes and tell me what you thought about the learning today. I will bring my thoughts from the previous week and you can tell me if I understood what you were saying and doing last week.

At the end of the unit, I will give you another test to see if you know more about the science taught and whether your thinking about science has changed. I will interview about six students again.

I will videotape the session from a fixed camera. Sometimes a student might like to operate a camera and show what is important to them during the session. I will also have a digital recording devise operating. I will take digital pictures of the experiments, dramas we create and our work. I will provide a weekly journal for us to comment about the sessions. If you agree I would like to take copies of your written and visual work.

This project will disrupt your normal learning but we will be learning science, social science, English, drama and a small portion of Te reo and I would value your help in trying to make science fun.

Your participation in the project is not compulsory and you will not be punished for not taking part. If you do not want to be involved, you can have different work to do in the class or go to another room during the session times. If at any time during the unit, you feel that you no longer want to be involved, you can take home a withdrawal form and discuss it with your parents and opt out of the project and take any previously gathered data with you if you wish.

To make sure that your identity is anonymous, we will chose pseudonyms (fake names) when we go into role as participants in our company. I will not identify the school and I will keep the information gathered about you confidential. I will store the videos and information in a secure place.
If you have taken part in an interview I will show you the key points raised during our discussion. I will also provide a written summary of my findings and conclusions after I have studied the information.

The information that we have collected and made during the unit will be used by me as part of my thesis. I may also use it at conferences or in articles. I will not release any pictures or video footage to the internet without asking for additional permission from your parents and yourself.

If you have any questions about the research please contact me on (email and phone number given). I am happy to talk with you or your parents at school or visit you at home.

You could also contact my chief supervisor or second supervisor (emails and phone numbers given).

If you feel that you have been given enough information to decide that you want to participate in this research and am happy to be involved please fill in the following informed consent form and bring it back to school to your teacher and I will collect it from there.

If you or your parents don't want to take part there is a part to fill in as well and I would appreciate you returning the form as well to school in the envelope provided.

Thank you for reading this and your time,

Carrie Swanson

I, ____________________________ have read or had read to me the information about the planned research by Carrie Swanson into science and drama. I have understood what is involved and give my informed consent and I am willing to take part in the research. I understand that this is not compulsory and I can withdraw my consent at any time up until the final.....

______________________________ (Name)______________________________

(Date)

Or

I, ____________________________ am not willing to take part in the research at this time.

Cross out the ones that do not apply.

I would be happy to join in with the work in the class but please do not use my information.

Please provide other work for me to do in the class.

Please may I work in another classroom?

Appendix P: Consent form for photographs

Address

December 13, 2011

To the students who took part in my PhD research and their parents,

I wish to thank you so much for allowing me to come into the classroom and work with you (your child) looking into the science behind the sinking of the Wahine through Mantle of the Expert. I really enjoyed my time in the classroom and was made to feel very welcome. The experience was valuable to me both as a teacher and as a researcher. I was very impressed by the quality of the reports written about the sinking of Wahine. You were able to explain to me reasons why the Wahine sunk. You linked these reasons to scientific theory and the experiments we did in class. I enjoyed watching you explain the science by using role play, and show your understanding of the event through freeze frames. Thank you for your generosity and hard work.

I have also included with this letter, two pages of photographs, which were taken during the unit, which I feel are representative of our learning. To avoid having to contact you again I am wondering whether you can have a look at the photographs and check that you are happy for me to use these images of you (your child) in my work and sign the form underneath. If you are not happy with me using these images can you also return the form and I will not use the images, which have you (or your child) in? If you are not happy with me using a certain image can you please circle it and I will not use the specific image?

The instances in which I am envisaging using the images are for are in my thesis, presentations, and conferences. I would also like to make a photo-book of our experience and give a copy to the school library and the Faculty of Education library showing our journey. If you are happy with the photographs I would also like to release the images to the Mantle of the Expert website www.mantleoftheexpert.co.nz. showing the students working using Mantle of the Expert and science.

For further information please contact me

Thank you

Carrie Swanson

I_____________________________(parent) and _________________________________

(child) have looked at the pictures supplied of me taken during Term three, 2011.

I give Carrie Swanson permission to use these images in her thesis, presentations and at conferences. □

I give Carrie Swanson permission to use these images in a photo book.□

I give Carrie Swanson permission to use these images on the Mantle of the Expert website. □

I do not give Carrie Swanson permission to use these images in her research. □

(**Please place a tick beside the statements you are happy with)**

Additional comments or restrictions on image use

_______________________________________ (Name of participant)

_______________________________________ (Date)

_______________________________________ (Name of parent/guardian)

_______________________________________ (Date)

**** Photographs included with the letter

Appendix Q. An example of my reflective blog

Episode Seven B: Walking the tragedy

Today we were using drama for learning. We decided that we would set up the outline of Wellington harbour in the classroom just as it was on last piece of work that the students had worked on. We closed the doors in the classroom and wrote Cook Strait on the fold back doors. The sign situated our learning. We had music playing to provide a more sombre atmosphere.

Jayne told us that we were to follow the path of the last voyage of the Wahine stopping at the signposts we had attempted to map yesterday. I read out the text. We stopped at the mouth of the harbour, moved from side to side as the Captain attempted to get the vessel under control when the cyclone hit, then went heart-brokenly over Barrett reef. We drifted up the harbour, miraculously upright and passed perilously close to Dorset point. We bumped the bottom near Steeple Rock and went bow end towards Eastbourne and slowed went over to starboard to the bottom. At the end of the harbour I drew the class down quietly to a sitting position. Although it was a sober exercise, I felt that additional depth was needed. We had physically mapped the Wahine's path, now to remind everybody that this was a human tragedy. I spoke of the fact that people were drifting in the harbour, with broken limbs and people died. I did break the tension though.

Jayne drew us back again, "Do you know that after the boat struck the reef, everyone gathered in the cafeteria and they sang songs?" I asked the students, "What do you think they sang?" Someone suggested Amazing Grace. They also sang songs that were humorous about water. They guessed "there's a hole in my bucket". So I sang them two verses. We also talked about the fact that they handed out coke and other food. I offered a child an ice-cream. He refused saying he would be sick. This episode enabled us to think of the individual cost of the tragedy and wonder what happened to the passengers at the different stages of the Wahine's final voyage.

Jayne took the class back to the entrance to the harbour in the terrible weather. How would it feel? How would it look? When we hit the reef? When the boat lost the battle to remain upright? As individuals the class depicted what was happening to them at each of those stations. Some wonderful work here. I could see a baby in someone’s arms, emotion etched on faces, wide expansive arms, wry grins, confusion, crumpled people, shattered lives.

We asked them if they wished to meet the Captain. We explained that he was dead but would be represented by his photograph and I would with permission be his voice. I also said that if someone wanted I would be happy hand over the “voice” and let them speak for the Captain.

I got asked lots of questions. “How did I feel the next day?” “Why did I say starboard and not right?” Eventually I handed over to one of the students and she was amazing! Marvellous poise and depth of understanding. As a class we passed through a tumultuous storm and survived, gaining more insight.

Appendix R. Permissions log

Page number in thesis	*Details of in-copyright material*	*Date permission requested*	*Permission granted for print thesis*	*Permission granted for digital thesis*	*Conditions*
pp. 366	Image of the Wahine sinking (Ref: 35mm-01149-28-F) in your thesis and online journal article.	20/03/2014 –Granted 23/03/2014 Mary Skarott Research Librarian Alexander Turnbull Library	You are welcome to use this image. 13/03/2014	You are welcome to use this image. 13/03/2014	Please be sure to include the citation given with the image in both instances.
pp. 189, 390	Adapted image from big ideas and glossary	Lynne Smith Ministry of Education 27/05/15	Granted 27/05/15	27/05/15	Nil
pp. 363-366	Tasks taken from NEMP assessments	Allison Gilmore 27/11/14	Granted 15/12/14	15/12/11	They said I must get permissions for Interislander image
pp. 363, 365	Image of the Interislander Kaitaki	Greg Smith 28/11/14	Granted 05/12/14	15/12/14	Changed image to one they had the rights for
p. 142	Open Access Journal	06/08/15 Margaret Drummond	Permission granted 06/08/15	Permission granted 06/08/15	Acknowledge source WJE As an open access journal

Appendix S: Glossary of Buoyancy Terms

Figure [Adapted from] *Building science concepts 38: Understanding buoyancy: Why objects float and sink* (p.16) by Ministry of Education, 2003, Wellington, New Zealand: Learning Media. Reprinted with permission.

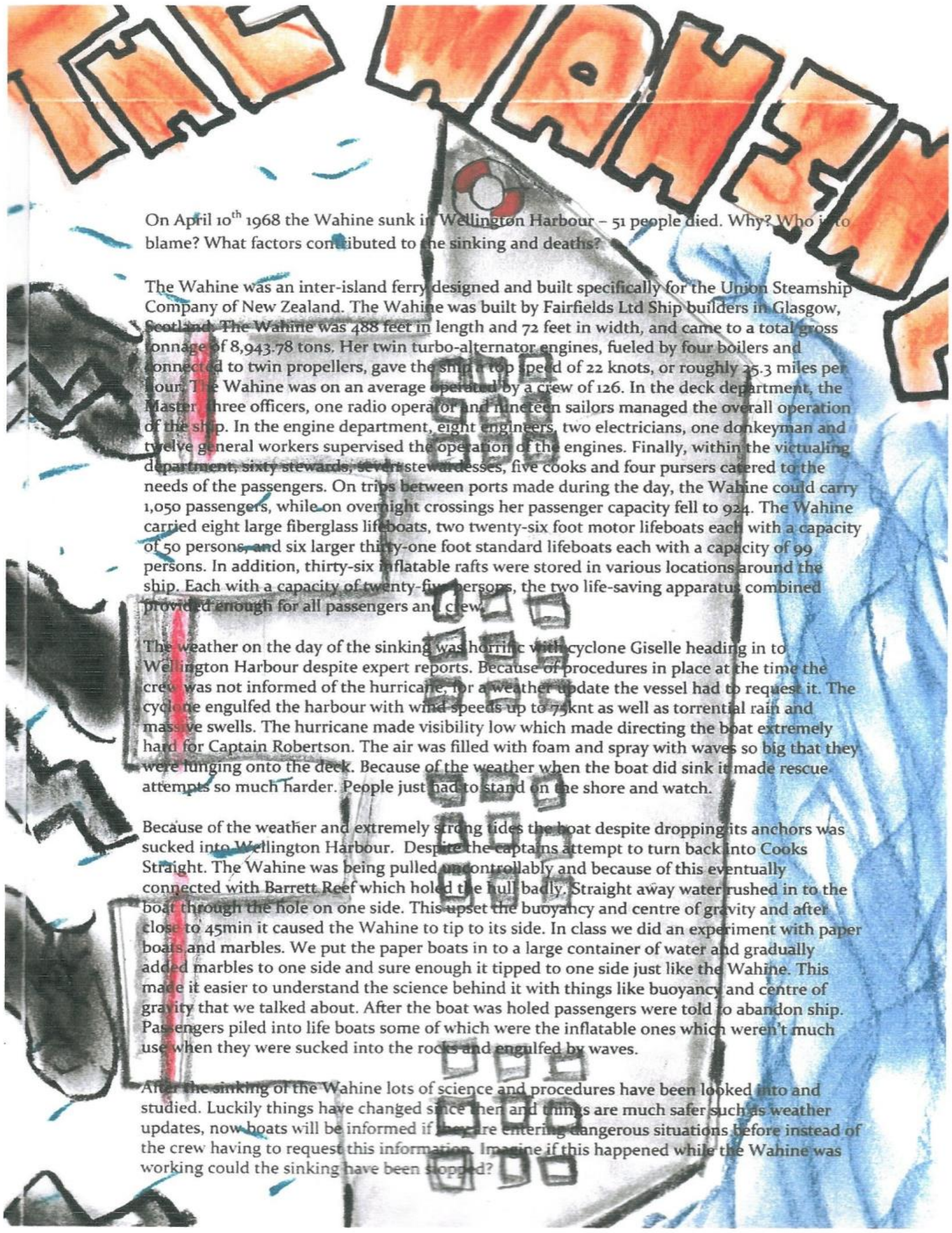
Buoyancy Glossary	
Buoyancy	The ability of an object to float. *
Centre of gravity	The centre of gravity is the force that pulls the boat down toward the water. Generally the lower the centre of gravity, the more stable a vessel is. **
Density	The relationship of an object's heaviness (mass) to its size (volume). Density = mass/volume *
Displacement:	The process whereby an object pushes out a volume of liquid. When an object enters the water, the part of the object that is actually under the water occupies the space that was previously occupied by the same volume of water. The 'water' that was there before is thus pushed out or "displaced". *
Floating Object	"An object or material may be considered to be floating in water if it is at the surface and partly immersed (e.g. a ship), if it is on top of the surface and does not break the surface tension (e.g. a spider) or if it is entirely submerged but freely suspended (e.g. a fish swimming)" (Biddulph, 1983, p. 3).
Free surface effect	Free surface effect is when unconfined liquid (or any other material) moves freely on vessel. The water tends to roll back and forth, moving to the lowest point, thus raising the centre of gravity and lessening a vessel's ability to right itself. **
Mass	The amount of matter in an object (kg). *
Sinking object	"A sinking object can be defined as something that is denser than water" (Allen, 2010, p. 147)
Stability	The stability of a vessel refers to its ability to stay upright in the water. **
Upthrust	A force that pushes upwards, such as when water pushes up on or supports an object that is floating in it. *
Volume	The amount of space an object occupies. We sometimes use the word size. Volume is more correct. Volume is used in determining density. *
Waterline	It refers to the line where the hull of a ship meets the water surface. **

Appendix T. Student group work detailing the reasons why the Wahine sank

	General sinking	*Weather related*	*Density*	*Stability*	*Free surface effect*	*Other*
Group One	Because it got a hole in its hull.	To ruff to get off the ship Crazy weather, really big waves 60 -75 Knot winds The wind blew the Wahine into the rocks. If the wind was going in a different direction, the Wahine wouldn't have sunk		Too much weight on one side	Wher the water got inside the hull, it went into the vechile deck causing it to sink	If they abandoned the Wahine earlier less people would have died **
Group Two	The Wahine sunk because the boat got blowen by the winded and waves to get scrapped across the bottom of the sea and got holes in the boat so the water started flowing in and tipped on its right side and then sank.	The weather came from a cyclone It was a veary stormy day and knight. "Got blowen by the winded and waves"	Made the boat denser	tipped on its right side and then sank (duplicate)	All the water went to the viecal deck	

Group Three	It hit a rock and was punct It hit the bottom making a hole letting water in It hit a rock on Barrett reef which caused water to rush in. Lost air - Why it sink! It hit the bottom making a hole letting water in, increasing the density suddenly it tip and sank	Currents Bad visibility Really big waves Stormy, Gail 60-75 knots winds Cyclone Giselle	Incresing density increasing the density (duplicate)	I think it sunk because all of the water went to one side of the boat and started to tip and then sunk**.** Leaned to her starboard side More weight was on one side, which caused it to take longer to sink and lean to one side. (duplicate it tip and sank (duplicate)		Sea sick Trauma, Intence emotions Captain making a simple mistake Captain refused to turn around ** Food ad drink served Singing 'Hole in my bucket' Everyone was told everything was all right. Dragged anchor for ages
Group Four	The Wahine hit the bottom of the wharf (**) making holes and letting water in the vhiecle deck Wahine Sunk It had a hole in its hull	Choppy sea, Waves Cyclone Giselle Killer rocks			Letting water in the vhiecle deck (duplicate)	The Wahine's life boats were NOT good because they were inflatable and could float towards the rocks
Group Five		The weather blew and helped the boat crash onto the rocks The weather also contributed to the disaster making it crash in the first place.	When the Wahine became full of water which ment the inside was more dense. When the Wahine hit the rocks the boat filled with water creating more density	The water and weight was on one side causing it to tip on one side		
Group Six	Gaping hole sunk	Stormy weather Waves	Weight, Density, Boyince Density	Balance Half capsize		Captain

Appendix U. An example of a student report



On April 10th 1968 the Wahine sunk in Wellington Harbour – 51 people died. Why? Who is to blame? What factors contributed to the sinking and deaths?

The Wahine was an inter-island ferry designed and built specifically for the Union Steamship Company of New Zealand. The Wahine was built by Fairfields Ltd Ship builders in Glasgow, Scotland. The Wahine was 488 feet in length and 72 feet in width, and came to a total gross tonnage of 8,943.78 tons. Her twin turbo-alternator engines, fueled by four boilers and connected to twin propellers, gave the ship a top speed of 22 knots, or roughly 25.3 miles per hour. The Wahine was on an average operated by a crew of 126. In the deck department, the Master, three officers, one radio operator and nineteen sailors managed the overall operation of the ship. In the engine department, eight engineers, two electricians, one donkeyman and twelve general workers supervised the operation of the engines. Finally, within the victualing department, sixty stewards, seven stewardesses, five cooks and four pursers catered to the needs of the passengers. On trips between ports made during the day, the Wahine could carry 1,050 passengers, while on overnight crossings her passenger capacity fell to 924. The Wahine carried eight large fiberglass lifeboats, two twenty-six foot motor lifeboats each with a capacity of 50 persons, and six larger thirty-one foot standard lifeboats each with a capacity of 99 persons. In addition, thirty-six inflatable rafts were stored in various locations around the ship. Each with a capacity of twenty-five persons, the two life-saving apparatus combined provided enough for all passengers and crew.

The weather on the day of the sinking was horrific with cyclone Giselle heading in to Wellington Harbour despite expert reports. Because of procedures in place at the time the crew was not informed of the hurricane, for a weather update the vessel had to request it. The cyclone engulfed the harbour with wind speeds up to 75knt as well as torrential rain and massive swells. The hurricane made visibility low which made directing the boat extremely hard for Captain Robertson. The air was filled with foam and spray with waves so big that they were lunging onto the deck. Because of the weather when the boat did sink it made rescue attempts so much harder. People just had to stand on the shore and watch.

Because of the weather and extremely strong tides the boat despite dropping its anchors was sucked into Wellington Harbour. Despite the captains attempt to turn back into Cooks Straight. The Wahine was being pulled uncontrollably and because of this eventually connected with Barrett Reef which holed the hull badly. Straight away water rushed in to the boat through the hole on one side. This upset the buoyancy and centre of gravity and after close to 45min it caused the Wahine to tip to its side. In class we did an experiment with paper boats and marbles. We put the paper boats in to a large container of water and gradually added marbles to one side and sure enough it tipped to one side just like the Wahine. This made it easier to understand the science behind it with things like buoyancy and centre of gravity that we talked about. After the boat was holed passengers were told to abandon ship. Passengers piled into life boats some of which were the inflatable ones which weren't much use when they were sucked into the rocks and engulfed by waves.

After the sinking of the Wahine lots of science and procedures have been looked into and studied. Luckily things have changed since then and things are much safer such as weather updates, now boats will be informed if they are entering dangerous situations before instead of the crew having to request this information. Imagine if this happened while the Wahine was working could the sinking have been stopped?

Appendix V. Data about buoyancy from the students' reports to the client

Name	*Why sunk*	*Science terms*	*Linkage to experiments*	*Connectives*	*Recommendations*
Brooke	Cyclone Giselle	Force Dense Mass unbalanced	"The winds got up to 60-75 knots and the cyclone was called Giselle. Cyclone Giselle pulled the boat off course and because the Wahine hit Barrett reef with such force, it created a hole on the starboard side. The starboard side started to fill up with water making it more dense and causing it to roll on its starboard side. I found this out because we experimented with paper boats. We placed paper boats in the water and put marble on one side. This showed that when mass is added to one side the boat will tip to one side."	and Because Cause/effect "I found this out because " – illustrating "This showed"	"Better communication with the weather man and a new design idea for lifeboats"
Josh	Great attention to detail – described boat – noted sufficient life-boats Cyclone Giselle Current reporting of weather Weather impacted on rescue	Buoyancy Centre of gravity	"Despite the captains attempt to turn back into Cook Straight. The Wahine was being pulled uncontrollably and because of this eventually connected with Barrett reef which holed the boat badly. Straight away the water rushed into the boat through the hole on one side. This upset the buoyancy and centre of gravity and after close to 45 minutes it caused the Wahine to tip to its side. In class we did an experiment with water and marbles. We put the paper boats in to a large container of water and gradually added marbles to one side and sure enough it tipped to one side just like the Wahine. This made it easier to understand the science behind things like buoyancy and centre of gravity that we talked about."	Despite – qualifying Because –cause and effect After –sequencing Caused – cause and effect And "sure enough" emphasizing "just like" – comparing This –referring to the experiment – illustrating	Weather updates Life boats were not adequate- inflatable – "sucked into the rocks and engulfed by the waves."
Tom	Giselle and large storm combining	Density Air	"The Wahine was a 900 ton ferry heading from liytletown to wellington when she hit barrit reef making a small hole letting water in increasing the density on one side making it tip on its right side we at s.e.e.rs know that only things with air in them float because water and air are like opposite magnets. Unfortunately while this was happening one of the most sever storms in NZ was	because - Talked about cause and effect While – sequencing Because & while Illustrating a point	"This disaster was preventable by the captain double checking the weather and docking at the nearest dock"

			happing…. We at S.E.E.Rs did experiments to test density using fruit. The potato sunk because it was dense but then we hollowed it out and it floated because it was less dense than before.” Mentioned that the boat sank because of increased density and then described an experiment about density.		
Jess	Cyclone Giselle & Storm	Free surface effect Centre of gravity - unbalanced	“Cyclone Giselle pulled the Wahine to Barrett reef at 6:40am, causing the Wahine to hit rocks…During my research we found that there were 13 compartments on the Wahine. 9 of the compartments got flooded with water. So in my opinion, when the Wahine had one side full and the other side empty, it caused the Wahine to get unbalanced. But if all 13 of the compartments had been flooded at the same height then the Wahine might not have sunk.” Didn’t link to experiment but referred to discussion and related to free surface/centre of gravity experiment.	“During my research” illustrating “In my opinion” – qualifying “caused”- cause & effect If – qualifying Comparing with what happened..	“More lifeboats, Better communication with the weather man so we know what the forecast is”
Lucy	Cyclone Giselle Insufficient weather report “I think the Wahine sunk because of bad weather and the boat had a hole in it.”	Water coming in Centre of gravity changed More weight changes the stability	“The structure of the boat was nice and strong. It was going fine until the wind flew wildly and the boat hit an outer rock of Barret Reef. The boat hit the rock and made a hole so the water came in, moved the passenger’s vehicles on to one side. The boat had trouble getting into Wellington harbour. It eventually sunk killing 51 people. The way our company found out was by doing experiments. One experiment was if we put marbles on the side of the paper boat and it would sit to that side. More weight change the stability of a floating object. The strength of the boat depends upon its ability to stay upright in	And – adding So- cause & effect Eventually – cause & effect “The way our company found out was by” – illustrating if – Qualifying and – adding	Floating devices Ask for weather forecasts Life boats like mini-passenger boats

			the water. When the Wahine got its hole, more weight was added and the water was allowed to move freely around the vehicle deck. This caused the boat to list and her centre of gravity moved and the boat was unable to stay upright. "		
Cameron	Cyclone Giselle Captain's decision to enter harbour	Centre of gravity. Buoyancy Weight Unbalanced Eluded to free surface effect	"While turning the wind and water current changed, now the Wahine was side-on to the entire force of the storm. The wind & waves shoved the boat onto rocks –penetrating the starboard hull. . On the inside of the ship there was water flooding the vehicle deck, air tight doors had been locked closed. Trapping water on one side (which was already weighed down with the weight of loose cars and rapidly growing water levels). The merciless onslaught of nature would not let the Wahines natural buoyancy roll her back into an upright position. Water was continually entering the ferry through open doors (incorrect). That left the Wahine slowly filling up with more and more water, so even when the storm was over she couldn't have righted herself.	So – cause and effect. Didn't join many sentence together, used comma to some effect. Illustrated	No recommendations
Ofa	It was too rough to get off the boat during the storm. There were very high winds and the current was strong.	Weight Alluded to centre of gravity and unevenness	"When the Wahine hit the killer rock on Barrett Reef it made a big ugly hole in the bottom of the Wahine boat. Water got trapped in the boat. It went on one side because water was filling it up. All the objects on the boat might have weighed a lot like the marbles. "	Because – cause & effect Like - comparing	"To stop this happening again you should check the weather forecast to see if it is stormy or not."
Taylor			Nothing received		