An exploration of the concepts of force and motion in the upper primary context

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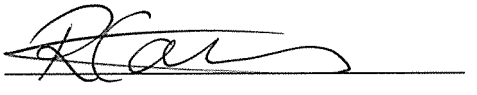
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Statement of Originality

I, Rebecca Carruthers, hereby declare that this thesis is my own work. All persons consulted, and all assistance rendered, are fully acknowledged. All references used are indicated in the text and accurately reported in the list of references. I have not presented the substance of this thesis, in whole or part thereof, to this or any other institution for a degree.

Signed:  Date: 21-11-2006

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Dedication

To my beautiful Nan, for all of your love and support. Thank you for believing in me when I didn't, and doing all you could, and more, to help me succeed. I could never have done this without you!

Abstract

Students enter the science classroom having already constructed ideas about the world around them and how it functions based on their interactions with it. They do not enter the classroom as 'empty vessels'. In this study, twenty one grade six students participated in focus group interviews and individual interviews based around simple demonstrations and scenarios posed on flashcards in relation to the concepts of force and motion. Seven of these students also participated in practical activity sessions centred on the inclined plane apparatus. The findings of this study suggest that the students share a number, but not all, of the conceptions about force and motion outlined in the literature, which was largely focused on secondary and tertiary-aged students. Demonstrations involving magnetism and static electricity were found to be useful for introducing the idea of a force as a *push* or a *pull*. This study suggests that the concepts of contact and non-contact forces are suitable for introduction at this stage. However, the concepts of net force and momentum were found to be too complex for students in this study. A thorough examination of the transcripts uncovered points of high productivity in the dialogue which could act as 'signatures for cognitive growth'. These episodes included analogical reasoning, in-depth questioning, hypothesis generation and experimentation by the students. From the results of this study, a series of six lesson plans has been created to more effectively introduce the concepts of force and motion to upper primary school children.

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Chapter 1 – Introduction

Science and Technology is included amongst the Key Learning areas (KLAs) in all states of Australia (NSW BOS, 1993; VCAA, 2005) and also in the Seventh-day Adventist school system (AUC, 2001). The research reported here focuses on the Science and Technology syllabus, and in particular the section of the syllabus dealing with the concepts of force and motion.

1.1 Background of the study

Anecdotal evidence suggests that the teaching and learning of science and technology has traditionally been a cause of stress for many primary teachers. A number of primary teachers do not have an adequate understanding of the scientific concepts required of the syllabus documents, and to make matters worse, these requirements are usually sketchy at best. By the time students reach the upper primary school, the situation becomes rather critical with teachers tending to ignore the more complex scientific concepts in the syllabus or electing to spend as little time as possible on the teaching and learning of these concepts. Rice (2005) also demonstrates that primary teachers lack a basic knowledge of the core scientific areas within the primary curriculum.

This study focuses specifically on the teaching and learning of the concepts of force and motion in the upper primary school. These concepts are particularly complex, and can often cause difficulty even for university physics students (Champagne, Klopfer & Anderson, 1980). The modern physics view of the concepts of force and motion, as outlined in Newton's three laws, is carefully defined in contrast to the common sense view of these concepts which often equates force with power, energy, motion or momentum. The common sense view of scientific concepts has been the topic of much research over the last twenty years.

1.2 Significance of the study

Although there is a significant body of research into student conceptions and learning in the areas of force and motion at the secondary and tertiary levels, there is minimal literature which includes the upper primary age group. The literature which does include a study of the ideas of students at the upper primary level also incorporates a study of the ideas of students in the secondary or tertiary age brackets and tends to focus on the older students (Gunstone & Watts, 1985; Watts, 1983). This study not only investigates the ideas held by one group of students who are exclusively within the upper primary age group, but also applies the results of this investigation to create a series of lesson plans which take into account the prior ideas of students and attempts to use these ideas as building blocks to assist students in developing a view of force and motion which is more consistent with current scientific thinking. Given the lack of materials supporting teachers in primary school science, these lesson plans will provide a useful start to supplying such support.

1.3 Structure of the study

This study uses focus group interviews, individual interviews, and practical inclined plane activity sessions to gather data on student interactions with force and motion concepts. This variety of techniques was chosen in order to present a variety of contexts for student responses and also allow for triangulation of the results. The structure of this thesis is now outlined.

Chapter two provides a detailed summary of previous research into student ideas relating to force and motion, and also outlines research methods previously used. Syllabus requirements for the upper primary school and the current scientific view of the concepts of force and motion are also included in this chapter. From the literature surveyed, a series of research questions is developed at the conclusion of chapter two.

Chapter three outlines the methodology used in this study, and provides an explanation for the choice of particular concepts and demonstrations for use in this study. The participants of the study are also introduced in Chapter three.

Chapter four discusses the results of the study in relation to the research questions. In addition to this, potential classroom applications are also briefly discussed.

Chapter five outlines a series of six potential lesson plans for the effective introduction of the concepts of force and motion to upper primary aged students. These lesson plans take account of the results outlined and discussed in chapter four.

Chapter six summarizes the results and conclusions of this research project and discusses the limitations of the study and the implications for further research.

Chapter 2 – Literature Review

A detailed search of the literature in the area of student ideas relating to force and motion was undertaken, and the findings are now summarized.

2.1 Student ideas about the world

Students do not enter the science classroom as 'empty vessels', but rather having already developed their own ideas about the world around them and how it functions (Gunstone & Watts, 1985). These preconceived ideas result from prior experience with their world and are employed in making sense of new experiences and as a result must be addressed if significant learning is to take place (Halloun & Hestenes, 1985; Hestenes, Wells & Swackhamer, 1992). Osborne (1985a, p. 41) supports this notion with his statement that "before they come near a science classroom children have already developed ideas about how and why things behave the way they do". A thorough literature search reveals that these ideas are referred to by several different terms including: *alternative frameworks* (Watts, 1983), *preconceptions* (Champagne, Klopfer & Anderson, 1980; Thijs, 1992), *misconceptions* (Postner, Strike & Hewson, 1982), *common sense beliefs, alternative hypotheses* (Halloun & Hestenes, 1985), and *alternative conceptions* (McDermott, 1984). Watts (1983, p. 217) defines *alternative frameworks* as "a person's imagined efforts to describe and explain their physical world". The terms used in this thesis will include *ideas* or *student ideas*, *preconceptions* and *preconceived ideas* as many of the aforementioned terms tend to give the impression that the students' initial ideas are in some manner worthless. In the view of Smith III, diSessa and Rochelle (1993-1994, p. 115) the use of terms that imply the erroneous nature of children's ideas "overemphasizes the discontinuity between students and expert scientists" and is an unduly harsh judgment given that students are only beginning to develop their ideas about scientific concepts.

A number of research methods have been used to uncover student ideas about force and motion. Watts (1983) employed an interview-about-instances approach where students were asked to explain their ideas in relation to flashcards depicting force-related scenarios. Two research groups employed a variety of questions geared to expose student conceptions and used this data to create inventories outlining student ideas (Hestenes et al., 1992; Thijs, 1992). Finally, Champagne, Klopfer and Anderson (1980) had a demonstrator perform experiments and used these as the basis for observation and questioning. The ways in which these student ideas influence their learning in science are now explored.

2.2 How student ideas influence learning

In an early study of the learning of classical mechanics, Champagne et al. (1980) demonstrated situations involving the free fall of objects to college-aged students and asked the students to explain them. Students were also given a Logical Reasoning Test and a Mathematical Skills Test. Nussbaum and Novak (1976 as cited by Champagne et al., 1980, p. 1074) proposed that students naturally "develop conceptions about the physical world which are strongly held and which interfere with the learning of new conceptual relationships during physics instruction".

A pre-test study by Allen (2005) involving 11-12 year-old children found that these students held ideas based on the common sense conception that when two objects of similar size are dropped, the heavier object will fall faster. It was found that the preconceived idea not only influenced the predictions made by students in relation to the free fall experiment, but also influenced the students' interpretation and perception of the results. The students in this study actually perceived that the heavier object reached the ground faster than the lighter object, despite evidence to the contrary. This perception of the results was consistent with the ideas that the students were found to hold in the pre-test. Several authors suggest

that students may view tasks undertaken in a science lesson as isolated from other tasks of similar conceptual content, or perceive the purpose of tasks differently to that intended by the teacher (Osborne & Tasker, 1985; Tasker & Freyberg, 1985). In a situation where a concept is not taught thoroughly, incorrect student ideas may be reinforced and subsequently become more difficult to either alter the conception in the future (Klaassen, 2005; Osborne, 1985b) or to use it as a building block for cognitive development (Smith III et al., 1993-1994).

According to Ausubel (1968) learning can occur in either a reception or discovery form, both of which have their distinct advantages and disadvantages. Reception learning occurs when the final form of the information is presented to students upfront, whereas discovery learning requires students to interact with materials in order to discover new knowledge and gain understanding. Both reception and discovery learning can take place as either rote or meaningful learning. In a rote learning situation, the pieces of knowledge to be learned are arbitrary and require students simply to memorize them. For meaningful learning to take place, however, new information must be in a non-arbitrary form that can be related to the learners' previous knowledge. Teachers must have an understanding of student preconceptions in order to enable them to plan learning experiences which will encourage meaningful learning and cognitive growth. This study deals specifically with the concepts of force and motion and the teaching and learning of these concepts with account taken of the modern physics understanding of the concepts and the requirements of various syllabus documents.

2.3 A modern physics view of force and motion

A modern physics view of force and motion is largely built around the three laws of motion as suggested by Isaac Newton. These laws of motion are outlined in Figure 2.1.

1. In the absence of external forces, an object at rest remains at rest, and an object in motion continues in motion with a constant velocity.
2. The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to the mass. (F = ma)
3. If two objects interact, the force exerted by object 1 on object 2 (F1) is equal in magnitude to and opposite in direction to the force exerted by object 2 on object 1 (F2). Therefore F1 = -F2

(Serwey & Beichner, 2000)

Figure 2.1 Newton's laws of motion

The concepts of force and motion do have common sense connotations if force is defined simply as a 'push or a pull'. It is instinctive that if one applies force to an object that it will most likely begin to move – except in a situation where either the object is too heavy to be moved by moderate force or friction is too great. However, the fact that Newton's first law describes an idealised world, where complicating factors such as friction, air resistance and other external facts are excluded tends to cause confusion in physics education, as people develop their common sense understandings in a world where friction and air resistance are present.

In addition to the concept of force, modern physics refers to the idea of 'net force' (also referred to as total force, or resultant force) whereby forces acting on the same object are added with regard to magnitude and direction. For example, Serwey and Beichner (2000, p. 111) state that "if the net force exerted on an object is zero, then the acceleration of the object is zero and its velocity remains constant". This concept of net force applies to both stationary and moving objects (Serwey & Beichner, 2000). Students find this concept difficult to grasp, even at a university level, so it can be expected that students in the upper primary school might have difficulty (Cangaratna, 1978).

Newton's third law applies to both contact and non-contact forces so therefore interactive forces are equal in magnitude and opposite in direction for gravitational,

magnetic and electrical forces as well as for mechanical forces present when one sits on a bench or pushes against a wall.

With the modern physics concepts of force and motion in mind, the syllabus requirements at the upper primary school level are now discussed.

2.4 Syllabus requirements

Although various education systems use different wording for their requirements of upper primary-aged (Grade 5-6) students in regards to the concepts of force and motion, they each expect that students will be able to recognise forces and combinations of forces, as well as their application to motion. The New South Wales state education system does not have equivalent outcomes at the stage 3 (Grade 5-6) level. However, these concepts are introduced at a stage 2 (Grade 3-4) level during a unit on simple machines. Table 2.1 outlines the syllabus requirements in relation to force and motion for the Australian Union Conference of Seventh-day Adventists, the New South Wales state education system, and the Victorian state education system. In order for the required content to be taught in an effective manner that produces meaningful learning, the common preconceptions in regard to force and motion must firstly be addressed.

2.5 Common preconceptions about force and motion

Some of the more commonly cited preconceptions that students hold in regard to simple mechanics can be grouped into 5 distinct areas, which all bear some relationship to each other. These areas are preconceptions about force, motion, gravity, inertia/momentum, and other related ideas.

Table 2.1
Required learning outcomes in force and motion for VIC, NSW and AUC

Education System	Grade Level	Required outcomes (Force and Motion)	Reference
AUC (Seventh-day Adventist)	5-6	PW 4.5 Designs, builds and describes the operation of simple devices to transfer or transform energy. PW 4.6 Describes the motion of objects in relation to simple combinations of forces.	(AUC, 2001)
Victoria	5-6	Students identify the actions of forces in everyday situations. They can use the words *push* and *pull* in discussing how things can be moved and stopped. They identify forms of energy and energy transformations in the everyday world. They use appropriate scientific vocabulary to describe and explain their observations and investigations	(VCAA, 2005)
New South Wales	3-4	Students will know and understand that simple machines can make moving loads easier.	(NSW BOS, 1993)

2.5.1 Ideas about 'force'

Watts (1983) conducted a study involving 12 children aged between 11 and 18 years. The children were shown flashcards depicting the following scenarios: A golfer hitting a golf ball; a person holding a helium balloon; two torches sitting on a table – one switched on; an astronaut tripping over a crater on the moon; a book lying on a table; and a person diving off a diving board. They were asked to explain the scenarios in terms of their own ideas about force. It was found that some students viewed force as an obligation to overcome, or act against some sort of resistance. That is, in order for an action to be considered a force, it must be large enough to prevail over resistance. Gunstone and Watts (1985) observed that some students viewed force as exclusively related to living things, and therefore a non-living object could not be said to have or exert a force. Eryilmaz (2002) uncovered the ideas of students in years 11 and 12 using the Force Misconceptions Test (FMT) and the Force Achievement Test (FAT). The FMT consisted of conceptual multi-choice questions where the incorrect answers corresponded to possible student misconceptions. The purpose of this test was to uncover student ideas. The purpose of the FAT was to assess student

achievement in regards to force and motion. Most questions in this test were of a quantitative nature. Eryilmaz found that a number of students believed that in order for forces to be considered to be 'interacting', they must be two opposing forces.

In the aforementioned study by Watts (1983) it was also found that a number of students held the idea that an object restrained in position possesses force. In this situation, students may think of force as some form of potential. As many students view force and action as being directly related, it is reasonable that they may come to believe that the amount of force within a system is directly related to the amount of activity taking place within that same system. This may imply that they believe that forces do not act in situations of equilibrium. In other situations children may think that force acts only in situations involving large or extreme actions. Finally, students often see force as some sort of active process, and that passive objects are incapable of exerting a force (Thijs, 1992).

Several of these ideas appear to indicate that students are unable to distinguish between the concepts of force and energy, believing that force may be possessed by an object as opposed to acting upon an object or between two objects.

2.5.2 Ideas about 'motion'

It seems that the most common source of student ideas about motion are those related to the relationship between force and motion. Gunstone and Watts (1985) cite a study involving over 100 students aged 13, 14 and 17 years from London. These students were asked to discuss a picture showing a person riding downhill on a snow sled. It was found that students held the common idea that for an object to be in constant motion or travelling at a constant velocity, there must be a constant force in the direction of motion (Champagne et al., 1980; Eryilmaz, 2002; Gunstone & Watts, 1985; McDermott, 1984; Thijs, 1992; Watts, 1983). Also, students indicated that the amount of motion that an object exhibits is directly

related to the amount of force acting upon the object, and that the more force acting upon an object, the higher its velocity will be (Thijs, 1992).

After asking university-aged students to observe and explain demonstrations involving objects during free fall and the Atwood machine, Champagne et al. (1980) discovered that several of these students held the belief that any force applied to an object will ultimately result in some degree of motion, and that if no force is applied to a moving object, that the object will continually decrease in velocity until it reaches a state of rest. Many of the aforementioned student ideas about motion appear to originate from the student's inability to imagine a world without friction (Eryilmaz, 2002).

When asked about the origin of a force, some students will likely attribute the force to the object which is causing the event or motion to occur. For example, when a golf ball is hit, the force would be described as having come from the golf club. This is true at the moment of impact, but not after the impact has occurred (Watts, 1983). Some students confuse the concepts of velocity and acceleration, and come to believe that there is a linear relationship between force and velocity, rather than between force and acceleration. This was shown during the research conducted by Champagne et al. (1980) when students were asked to explain a demonstration of various objects in free fall (Eryilmaz, 2002).

2.5.3 Ideas about 'gravity'

One idea held by students in relation to gravity is that heavier objects will naturally travel faster in free fall (Allen, 2005; Eryilmaz, 2002; McDermott, 1984). The idea that heavier objects will fall faster is often true in real-world scenarios where body shape is related to air resistance; however, when two objects that have significant but different density while remaining identical in size and surface area, are dropped at the same time from the same height, they will both reach the ground together. Students may also believe that the effect of

gravity alters significantly with distance. For example, they may believe that the effect of gravity on an object one meter above the ground will be less than the effect of gravity upon an object which is five meters above the ground (Eryilmaz, 2002). In other words some students believe that the effect of gravity increases with height above the earth's surface.

2.5.4 Ideas about 'inertia/momentum'

Some students seem to confuse the concepts of momentum and force, believing that a moving object is a force, and that the heavier that an object is or the faster it travels, the more force it possesses. In the golf ball example used by Watts (1983), one child stated that the golf balls got their force from "their height and their speed" (Watts, 1983, p. 225). Students may also use the words 'force' and 'momentum' interchangeably (McDermott, 1984; Watts, 1983). The notion that if no force is present an object is either slowing down or at rest also fits within this category. This idea shows that students do not fully understand the concepts of inertia and momentum, or that they are unable to separate them from the concept of force (Champagne et al., 1980).

2.5.5 Other ideas related to force

There are other student ideas about the concepts of force and motion which have been uncovered by researchers, but which do not fit into any of the above categories. Two such ideas relate to the concept of impetus. Firstly, some students may come to the conclusion that when a force is exerted on a body, it impulsively imparts increased motion (impetus) to the body. This concept can be linked to the way some students explained the movement of the golf ball in the study by Watts (1983). Secondly, from the results of his inventory of student ideas which was formulated from the responses of students to a variety of scenarios such as a car towing a trailer at a uniformly decreasing velocity and a girl cycling down a steep slope, Thijs (1992) observed that students appeared to believe gravity and friction

cause impetus to weaken. Some more advanced students studying moments of force often concluded that in order for a beam to be in equilibrium, it must first be horizontal (Rowlands, Graham & Berry, 1998).

The conceptions that children hold in the areas of force and motion are by no means foreign to science, or without precedent. In fact, many of these beliefs, such as impetus and the requirement of constant force for constant motion, were sincerely supported by intellectuals in pre-Newtonian times. These Aristotelian ideas are prevalent among students due to their common sense appeal (Biener & Smeenk, 2004; Halloun & Hestenes, 1985).

2.6 Summary of student ideas

A summary of the aforementioned student ideas is outlined in Table 2.2.

Table 2.2
Summary of student ideas about force and motion.

Reference	Age/ Grade Level	Illustration	Student Ideas
Champagne et al. (1980)	College Age	▪ Objects during free fall. ▪ Situations on the Atwood machine.	▪ Applying a force to an object creates motion. ▪ When a constant force is applied, an object will move at constant velocity. ▪ The magnitudes of force and velocity are proportional. ▪ If no force is present, an object will either be at rest, or slowing down.
Watts (1983)	11-18 year olds	Interview-about-instances. Flashcards showing: ▪ Golfer hitting a golf ball. ▪ Person holding helium balloon. ▪ 2 torches (one turned on). ▪ Astronaut tripping over crater on moon. ▪ Book lying on table. ▪ Person diving off diving board.	▪ Forces are obligations to complete an action against some resistance. ▪ Objects restrained in a position have force. ▪ Forces are designated to those objects that are causing or will cause events to occur. ▪ When two or more forces come together they can be combined to change the movement of an object. ▪ Moving objects are a force, which is made manifest when the object collides with some other body. ▪ If a body is moving there is a force acting upon it in the direction of movement. If a body is not moving there is no force acting upon it. ▪ Force is an action. The amount of force is proportional to the amount of activity taking place. ▪ Forces are positive actions (only strong/overwhelming actions) that are effective when they come into contact with objects.

Gunstone and Watts (1985)	9-19 year olds.	▪ Balloon inside bell jar – what happens if air from bell jar is removed? ▪ Forces acting on a swinging pendulum. ▪ Falling objects of differing masses. ▪ Why a balloon filled with hydrogen moves up. ▪ A person traveling down a hill on a snow sled. ▪ Person throwing a ball upwards. ▪ Book lying on table. ▪ Objects in circular motion.	▪ Forces are to do with living things. ▪ Constant motion requires a constant force. ▪ The amount of motion is proportional to the amount of force. ▪ If a body is not moving, there is no force acting on it. ▪ If a body is moving there is a force acting on it in the direction of motion.
Thijs (1992)	Grade 9	▪ Apple hanging and falling from a tree. ▪ Car towing a trailer. ▪ Person throwing ball in the air. ▪ Girl cycling down a steep slope. ▪ Boy standing on a bending plank.	▪ Continuing motion implies a continuing force. ▪ There are no forces involved when an object is at rest (or only gravity is present). ▪ When an object is moving at a constant speed, there must be a force acting in that direction. ▪ When a force is exerted on a body, it is imparted on the body as an acquired "impetus". ▪ Entities such as friction or gravity will gradually cause an object's impetus to weaken. ▪ For an object to increase in velocity, there must be an increase in the force in that direction. ▪ Passive objects cannot exert a force.
Rowlands (1998)	College Age	▪ Beams with varying masses at each end.	▪ A beam has to be horizontal to be in equilibrium.
Eryilmaz (2002)	Year 11-12	Force Misconceptions Test (FMT) Force Achievement Test (FAT)	▪ Speed decreases even if the net force is zero (in the case of zero friction). ▪ Application of force is necessary for constant motion. ▪ There is a linear relationship between force and velocity (instead of force and acceleration). ▪ Constant velocity implies a constant force. ▪ "Interaction" of forces is always a struggle between opposing forces. ▪ The heavier the weight, the faster the accelerations during free fall. ▪ Gravity can vary significantly over a few meters.
Allen (2005)	11-16 year olds.	▪ Objects of differing masses falling.	▪ When two objects of the same size and shape are dropped, the heavier will still hit the ground first.

Now that student ideas about force and motion have been addressed, it is necessary to discuss possible ways to assist students in developing concepts which are more in keeping with the scientific view.

2.7 Changing student ideas

Champagne et al. (1980) found in their research project, involving 110 college-aged physics students, that mathematical skills, cognitive development, and preconceptions all play a role in a student's struggle to understand physics concepts. It was found that the preconceptions held by the students were often loose in structure and that new concepts could be assimilated, without the naturally developed preconceptions being altered (Champagne et al, 1980). Thus, students may hold both scientific views and preconceptions simultaneously.

Thijs (1992) favoured a constructivist approach to the teaching and learning of force in *ten* lessons which were taught to grade 9 students. An inventory of student ideas was created after lessons 1 and 9 in order to allow a comparison of student ideas. The intervening lessons (2-8) consisted of practical activities and worksheets. In these lessons the concept of momentum was introduced before force, and explored through a variety of kinematic situations. It was found that introducing the concept of momentum first was helpful to the development of the concept of force, and that the classroom discussions helped students to clarify and articulate their views. This approach was more valued by students who enjoyed learning in an environment in which they could construct their own understandings. The authors found that some teachers and students found the asking of questions and the presentation of arguments to be rather tedious and monotonous. However, they also found that between the two inventories of student ideas (created after lessons 1 and 9), student misconceptions decreased by approximately 14% (Thijs, 1992). Thijs

(1992) concluded that a 'force concept inventory' similar to that outlined by Hestenes et al. (1992) can be given to students whereby they answer a series of questions relating to the concept of force, and from this their ideas can then be accurately diagnosed. According to Hestenes et al. (1992) this is a more thorough way of isolating student ideas than simply testing students to produce a grade.

Theories of learning based around the *assimilation* and *accommodation* of new ideas have been developed (Postner et al., 1982). *Assimilation* refers to the instances where a student may slightly adjust their prior frameworks to absorb new information or make slight adjustments to the new information so that it fits neatly within their existing cognitive framework. However, *accommodation* is a more intense process by which a student must completely restructure their existing schema in order to accommodate the new concept (Coon, 2001; Postner et al., 1982). Postner et al. (1982) interviewed college-aged students who were enrolled in a non-calculus course, and who had previously encountered the notion of special relativity. They suggest that in order for an alternative framework to be altered, several conditions must first be met. The first condition is that the original conception must be shown to be unsatisfactory. Often this becomes the case when a situation is discovered whereby the prior framework is not sufficient to explain or solve the specific problem. The second criterion is that the proposed conception needs to be seen by the student to be intelligible, or to 'make sense'. Next, the new conception needs to be plausible in the situation the student is currently facing. Finally, the new conception needs to appear to have the potential to be extended to further situations. It is suggested that teachers need to first understand the ideas held by their students, develop situations of cognitive conflict with these ideas through the use of demonstrations or activities that are not supported by the current cognitive framework, and then assist students in resolving this conflict with more current scientific views (Eryilmaz, 2002; Philips, 1991; Postner et al.,

1982). It is also necessary for teachers to ensure that they have a satisfactory understanding of the concepts that they are attempting to convey to their students. They must have the ability to translate the knowledge into a form that can be taught to the students in their classes (Mulholland &Wallace, 2005).

Gunstone and Watts (1985) suggest a similar formula for changing student views where the first important step is the realisation that students are not 'empty vessels' and they should be encouraged to articulate their existing views. The next step involves creating cognitive conflict situations with the understanding that it takes time to change student views (Gunstone & Watts, 1985; McDermott, 1984). However, it is important to remember that when a student comes across information that does not fit into their prior frameworks, they may be inclined to discount the findings, or to simply learn it by rote and retain the prior conception (Hynd, Alvermann & Qian, 1997). Although it does take significant time to alter student conceptions, more scientific frameworks can be built up alongside the alternative frameworks and therefore it may not actually be necessary to completely remove alternative frameworks for meaningful learning to occur (McDermott, 1984).

Activity-based learning has become a popular means of teaching science in schools because it not only gives students a hands-on, and therefore more memorable experience, but it also tends to be more relevant to their prior experiences and interests, so their attentions are gained, their individual motivations are sparked and effective and memorable learning is more likely to take place (Wright, 1995). Wright (1995) also advocates discrepant events as a teaching tool as this approach challenges student preconceptions, and awakens their interest in the topic. Discrepant events are situations where the outcome that a student predicts does not occur, so students are forced to reconsider their initial predictions. Chinn and Brewer (1998a, 1998b, 2001) and Chinn and Malhotra (2002) describe such events as anomalous data.

The discussion of ideas is an important step in developing scientific thinking, because as students listen to the ideas of others, and are forced to consider their own ideas more deeply when questioned, it is often necessary for them to change their own predictions about a situation (Cosgrove & Osborne, 1985; Tasker & Freyberg, 1985; Woods, 1994). Greive (2005) used the term 'logical narratives' to describe technical descriptions, explanations and predictions because they were constructed from propositions arranged in a sequential order that is determined by pervading logic. He argued that conversations that describe, explain or predict observed phenomena can clarify and even challenge individuals to reconfigure their preconceptive understanding. According to Greive, guided group discussion can lead to a kind of 'social calibration' of word meanings and individual preconceptive ideas. Thijs (1992) chose to include group discussion in his research based on the expectation that "interpersonal interactions and conflicts are stimulants for a student's conceptual change" (Thijs, 1992, p. 167).

Klaassen (2005) discusses the fact that student preconceptions can either be seen as inherently incorrect, and therefore requiring complete change, or as "resources for cognitive growth" (Smith III et al, 1993-1994, p. 116). When student ideas are viewed as resources which can act as building blocks for further understanding, a child's ideas are then validated, and can have a "productive [role] in the acquisition of expertise" (Smith III et al, 1993-1994, p. 115). Thus there can be an evolutionary pathway in terms of the development of student understanding. The teacher uses an array of techniques such as new and different experiences, questioning and discussion to challenge preconceptive thought and guide it along a developmental pathway (Greive, 2005).

Having outlined the various ideas held by students, their effect on learning, and how these conceptions can be used for the development of more scientific ideas, a number of questions arise for further research.

2.8 Research questions

From this literature review, a series of four research questions were formulated.

1. Are the preconceptions exhibited by upper primary school children in the area of mechanics similar to those held by secondary and college-aged students as revealed in the literature?
2. Which ideas related to force and motion are feasible to introduce and explore with upper primary aged children?
3. Should idealised situations in mechanics (mechanics in a frictionless world) be introduced at the primary school level or should the emphasis be on real world experiences?
4. In the light of questions 1 and 2, is it possible to create a useful teaching and learning sequence about force and motion?

These research questions determine the basis of the methodology of this project, as discussed in Chapter 3.

Chapter 3 – Methodology

The methodology chosen for this project was carefully considered in view of the nature of the research questions and is outlined below.

3.1 Background of research techniques

In the planning of this research project, a number of research methodologies were considered, and those used were selected based on their appropriateness to the particular aims of this project.

3.1.1 Qualitative and quantitative research methodologies

Research projects can be categorized as having qualitative and/or quantitative methodologies, both of which have their distinct strengths and weaknesses and which are appropriate in different contexts. Quantitative research finds its basis in the deductive area of scientific theory (Johnson & Christensen, 2000). It pursues a high degree of objectivity, and due to the often larger sample size, tends to produce results which can be used to make generalizations across a large section of the population (Hara, 1995). Quantitative research produces numerical data which is used to represent abstract ideas (Neumann, 1991). However, the weakness of quantitative research lies in its course-grained structure and impersonal nature (Hara, 1995). On the other hand, qualitative research has its own unique strengths and weaknesses which make it appropriate for a different research situation. Hara (1995) asserts that qualitative research tends to provide a more in-depth, fine-grained insight into the research situation and is a more appropriate manner of accurately describing human interactions. However, the results obtained from qualitative research may not be as widely generalizable as that of quantitative research and, as the researcher is an 'insider' in their research, the results may have more tendency to be influenced by the biases of the

researcher. Ultimately, the research methodology chosen is determined by the nature of the research question (Stake, 1995). This research project has adopted a qualitative methodology in order to gain an in-depth and clear picture of student conceptions about force and motion.

3.1.2 Phenomenology and phenomenography.

Research which is designed with the aim of understanding human experience is termed *phenomenology.* The philosophy of phenomenology is based on the work of Hussel, Schultz, Merleau-Ponty, Gadamer and Ricoeur (Bodner, 2004). Phenomenology is based on the human experience of the world rather than on conceptualizations or reflections of that experience. Research which is based in phenomenology aims to gain deep insight into the world as it is experienced by the subjects rather than as a reflection of that experience (Bodner, 2004).

Where phenomenology aims to find "the common essence that characterizes the phenomenon for all who experience it" (Bodner, 2004, p. 622), phenomenography takes a slightly different approach in assuming that there are several qualitatively different ways in which a person can experience a phenomenon (Bodner, 2004). The intent of phenomenography is to "understand the phenomenon from the participant's point of view" (Bodner, 2004, p. 622). In phenomenography, the researcher is not simply an objective observer but rather they experience the phenomena alongside the research participants, and therefore their knowledge and understanding may be used to assist subjects in more clearly articulating and explaining their responses (Bodner, 2004).

Due to the nature of the research design, phenomenographers do not view the results of their research as absolute truth, but rather as a useful insight into the conceptions and experiences of their subjects about the given phenomenon (Bodner, 2004). In

phenomenography, data is usually collected through open interviews, which aim to comprehensively explore a subject's thinking on a particular issue. This data is analysed by the researcher to develop a conceptual understanding of the subjects' interpretation of their experiences. However, the researcher must be careful when analysing data because the responses themselves need interpretation and the extent to which a researcher's interpretation is consistent with the subject's understanding is a critical issue in research methodology and this issue is now explored.

3.1.3 Determining and analysing student ideas

As discussed in the literature review, students entering a science classroom have already developed ideas about how the world works (Klaassen, 2005). Klaassen and Lijnse (1996) discuss the difficulties in unambiguously interpreting classroom discourse. It can also be difficult for researchers to determine the content of the conceptions held by the students when there is no assurance that the researcher's interpretation of the child's responses matches the intention of the child (Klaassen, 2005). When teachers and researchers attempt to interpret students' statements, they may have a tendency to impose their own frames of reference on the student's words (Klaassen, 2005). Klassen (2005) insists that what many researchers interpret as misconceptions, are in fact correct assertions when viewed from a child's frame of reference. For example, a conception commonly cited as a misconception is that *for constant motion, there must be constant force* (Champagne et al., 1980; Eryilmaz, 2002; Gunstone & Watts, 1985; Thijs, 1992; Watts, 1983). This statement is referring to a constant applied force being required for constant motion whereas Newtonian physics considers constant motion, that is, zero acceleration, to result from a zero resultant force, or in the absence of friction, a zero applied force. However, from a child's perspective of a world involving friction with the emphasis on applied force rather than

resultant force, the statement is correct (Klaassen, 2005). It is because of this, that it often appears that the student and the teacher are living in different worlds, when in reality they are living in the same world, but simply viewing it from different frames of reference (Klaassen & Linjse, 1996).

In order to address the issue of the valid interpretation of students' dialogue whether in written or oral form, Johnson and Gott (1996) suggest three principles for research. Firstly, it is suggested that the task must be on neutral ground, that is, that the content of the task needs to be familiar to both the researcher and the subject. In this research project, the scenarios and objects selected for the interviews and activities were everyday experiences, such as riding a skateboard downhill and the use of magnets, which could reasonably be expected to be familiar to both the researcher and the students. Secondly, the interpretation of dialogue needs to be on common ground, and the researcher needs to be careful not to impose his or her own frame of reference onto the student responses. With regard to this project, interviews were conducted with individual students to check the correlation between the understanding of the researcher and the students. Finally, the method of 'triangulation' is suggested to increase validity and this method is now briefly outlined.

3.1.4 Triangulation

Triangulation is a commonly suggested method of ensuring that a research project gathers valid results (Johnson & Gott, 1996) and of ensuring that a more complete picture of the research situation is obtained (Gay, 1992). By obtaining data from a variety of sources, the researcher is able to then cross-reference the data (Gay, 1992; Hitchcock & Hughes, 1989) and locate such student factors as the instant invention of ideas (Johnson & Gott, 1996). Also, triangulation can provide different perspectives on the same data (Johnson & Gott, 1996) and assist the researcher in looking at a number of variables in the one study (Isaac &

Michael, 1981). This project includes three different data collection methods; group interviews, practical activities and individual interviews; to assist in ensuring that the interpretations of data were as valid as possible. Figure 1 shows the various data collection methods used in this research project as a triangulation. The student profile will determine the exact nature of the research tools, and this profile is now outlined.

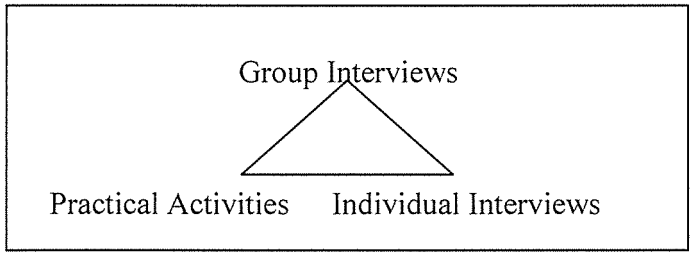


Figure 3.1 Triangulation in this study

3.2 Student profile

The subjects for this project consisted of an entire class of Grade 6 students from a state primary school of about 500 students. Of the 22 students in the class 21 students participated in the interviews or activities in some way. The 21 students who participated in the research consisted of 10 females and 11 males. As the research was conducted at the beginning of February, these students had only just begun grade 6 the previous week. The ages of the students ranged from 10 years and 10 months to 12 years and 3 months at the time of the research. At this stage, students are generally considered to be moving towards the onset of the *formal operations* stage of their cognitive development (Berk, 2006). During the previous stage, *concrete operations,* which spans the ages of 7 to 11 years, children generally develop the skills of conservation, classification, spatial reasoning, and the ordering of objects. However, students may demonstrate these skills when relating only to concrete objects (Berk, 2006). During *formal operations* children of age 11 and older develop a more abstract pattern of thinking and are then able to handle *hypothetico-*

deductive reasoning where they are able to take a problem and deduce hypotheses using abstract objects, and to also assess the logic of propositions without the need to relate them to a concrete example (Berk, 2006). As the students in this study are only approaching the onset of the formal operations stage of their cognitive development, concrete examples of the more abstract concepts of force and motion were chosen as scenarios so as to ensure that the students could relate to the examples and that students who may not yet have fully developed through their concrete operations stage would not be disadvantaged.

From this student profile, a research profile has been created, outlining the various aspects of this research project

3.3 Research profile

Given the student profile, and the research orientation of exploring student ideas regarding the concepts of force and motion, curriculum documents relating to the requirements for the teaching and learning of force and motion at the upper primary level were initially examined.

3.3.1 Syllabus documents

As discussed in the literature review, the concepts of force and motion are usually introduced at the grade 3-4 level (NSW BOS, 1993; VCAA, 2005). As this study was conducted in a Victorian state primary school, the outcomes required for these students are as follows:

> Students identify the actions of forces in everyday situations. They can use the words *push* and *pull* in discussing how things can be moved and stopped. They identify forms of energy and energy transformations in the everyday world. They use appropriate scientific vocabulary to describe and explain their observations and investigations (VCAA, 2005).

Syllabus documents provide only a brief outline of the concepts to be developed and since most studies on mechanics as shown in the literature review have been carried out with

secondary and tertiary-aged students, one is left with choosing or adapting illustrations that could possibly suit primary-aged students. The central aim of this research project is to create a summary of student ideas related to the concepts of force and motion which have the potential to act as building blocks for learning and to determine the feasibility of building a set of lesson plans around these ideas. The research design chosen to create such a summary is now discussed.

3.3.2 Summary of student ideas

As previously explained, three sources of data were used to develop the summary of student ideas for grade 6 students in a primary school. Each of these is now separately discussed.

3.3.2.1 Focus groups

Due to the fact that it would have been unnecessarily time consuming to interview 21 students individually, four focus groups were used in this study. The focus group sessions were conducted during normal class time. Focus group interviews involve more than simply interviewing a number of students simultaneously. The main aim of focus groups is to have those within the groups interact with each other in relation to the subject at hand (Cohen, Manion & Morrison, 2000; Morgan, 1997). It has been suggested that it will be more appealing to research participants to meet with others who are perceived to possess similar levels of understanding and other characteristics (Gay, 1992; Morgan, 1988). The use of focus groups can enhance the data collected as subjects have opportunity to interact with one another in the expression of ideas (Carey, 1994). It was intended that the classroom teacher play an integral role in the selection of the groups. However, as it was only the second week of the school year, the relative abilities of students had not yet been determined. Focus groups were formed according to the same gender to help put students at

ease. Focus group 1 contained four boys, focus group 2 contained four girls, focus group 3 consisted of five boys, and there were four girls in focus group 4. Each of the four groups participated in two sessions. During the first session, students were asked to respond to flashcards similar to those used by Watts (1983) but adapted for this study in an interview-about-instances style (White & Gunstone, 1992). As primary-aged children are very familiar with the use of magnets, it was also decided to investigate their understanding of forces when manipulating magnets. The content and interview questions associated with the flashcards were checked by two physicists for validity. The flashcards used are shown in Figure 3.2 and the interview questions for the first focus group sessions are shown in Figure 3.3.

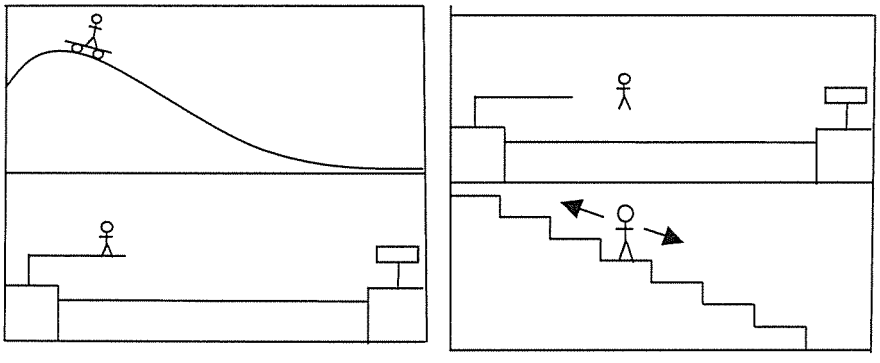


Figure 3.2 Flashcards used in Focus Groups

Students explained what they perceived to be occurring in each picture or situation and were asked to describe the forces that were acting. The flashcards depicted everyday scenarios to which the students could relate. Also in these group sessions, students were asked to give their own definitions of the words force, energy, speed, acceleration, and gravity in order to gain insight into whether students were aware of the scientific meanings of these words. The second focus group sessions adopted more of a teaching focus, where students were taught about different types of forces. The interview questions for the second focus group sessions are shown in Figure 3.4.

Question Plan for Focus Group Session 1

1. Introductions – children thanked for participating and informed that it is their choice, and if they wish to stop participating, then that is fine. **[2 mins]**

2. Non-contact forces **[8 mins]**
   a. Children experience playing with 2 magnets.
      i. *Bring the magnets closer together – what do you feel?*
      ii. *Why do you think this happens?*
      iii. *Was there a force between the 2 magnets*
      iv. *Is magnet A exerting a force?*
      v. *Is magnet B exerting a force?*
   b. Children play with 1 magnet and a metal peg.
      i. *If you bring the magnet closer to the peg, what happens?*
      ii. *Was there a force between the magnet and the peg?*
      iii. *Was the magnet exerting a force?*
      iv. *Was the peg exerting a force?*
   c. Paper and comb experiment/demonstration.
      i. *What happened? Why?*
      ii. *Was the comb exerting a force?*
      iii. *Was the paper exerting a force?*

3. Contact forces / Net force **[5 mins]**
   a. Two students push against one another.
      i. *If both students move backwards, is there a force between the two students?*
      ii. *If neither student is moving is student A exerting a force?*
      iii. *If neither student is moving is student B exerting a force?*
      iv. *Is there any overall force?*
      v. *What if student A falls over? (ask above questions again)*
   b. One student pushes against the wall.
      i. *Is the student exerting a force?*
      ii. *Is the wall exerting a force?*
      iii. *What if the wall falls over? (ask above questions again).*

4. Flashcards – Gravity **[2 minutes each = 6 mins]**
   a. Skateboard flashcard
      i. *What would happen if we let the skateboard go at the top of the hill?*
      ii. *What makes the skateboard go down the hill?*
      iii. *Will the skateboard get faster or slower or stay the same speed?*
   b. Jumping into water card
      i. *What will happen if the man steps off the diving board?*
      ii. *Will he get faster/slower/stay the same speed?*
   c. Standing on stairs card
      i. *Is it easier to go up or down stairs? Why?*
5. Bowling example **[4 mins]**
   a. Photo of ball hitting pins (See Appendix 2)
      i. *What makes the ball move to start with?*
      ii. *Does the ball get faster/slower/stay the same speed? (From when you're holding it at the start of the lane)*
      iii. *What keeps the ball moving?*
      iv. *What forces are acting upon this ball?*

6. Word meanings **[5 mins]**
   a. Display flashcards, and ask for definitions
      i. *Force*
      ii. *Speed*
      iii. *Momentum*
      iv. *Gravity*
      v. *Energy*

Figure 3.3 Question Plan for Focus Group Session 1

Question Plan for Focus Group Session 2

1. Greetings/recap last session **[2 mins]**
   Tell students that today we will be focussed on what scientists think about force.
2. Force **[3 mins each = 12 mins]**
   a. Defining force
      i. *Can you define Force in 5 words?*
      ii. My definition of force is **a push or a pull.**
   b. Non-scientific uses
      i. *Can you think of some everyday uses of the word force?*
   c. Contact and Non-contact forces
      i. *What do you think the difference between contact and non-contact forces is?*
      ii. *Can you think of some examples of each?*
      iii. *Think back to what we talked about last session – which were contact/non-contact forces?*
      iv. There's always 2 objects exerting a force (Newton's law)
      v. *So when the student was pushing against the wall – was the student/wall exerting a force?*
   d. Net Force
      i. *Can you think where there might be an overall force?*
      ii. "You know that there's an overall force there if something starts moving, stops moving, gets faster or slower, or changes direction."
      iii. *So now, in which activities in the last session was there an overall force?*
3. Speed **[8 mins]**
   a. Worksheet (see Appendix 3)
      i. *Students complete the worksheet*
      ii. *Students come up with an alternative name to write on worksheet*
4. Weight **[3 mins]**
   a. Place a book on the table.
      i. *What stops the book from falling down?*
      ii. *Are there any forces acting on the book?*
      iii. *Is gravity still acting on the book?*
5. Friction **[4 mins]**
   a. Slide a book across the carpet.
      i. *Why does the book stop?*
6. Thank-you **[1 min]**

Figure 3.4 Question Plan for Focus Group Session 2

Also in this second session, students completed a worksheet, shown in Appendix 3 which required them to rank four varying inclines as to which they thought would result in a ball reaching the bottom of the incline first. All sessions were audio-taped, and later transcribed in order to allow a more thorough analysis of student responses.

Trial interviews were conducted with one group of five grade 6 students from the same school in December 2005 to assess the validity and usefulness of the focus group materials. From these trials, minor changes were made to the flashcards in order to make them less ambiguous. For example, a bicycle rolling down a hill (with no rider) was replaced by a skateboard to help students to focus on the motion of the object down the hill rather than

issues such as the bicycle falling over. These interviews also provided an opportunity to test the recording process and ensure that the tape recorder would effectively record the conversations for later transcription.

3.3.2.2 Practical activities

The inclined plane apparatus is one of historical relevance to the study of force and motion, and was chosen for its potential to demonstrate the concepts of force, speed and acceleration.

An inclined plane apparatus was created using a retort stand to support a 'v shaped' length of aluminium metal. Experimentation was conducted by rolling ball-bearings of differing mass down the plane and taking time measurements using differing starting points and heights (thus creating different lengths and angles). Data was transferred to an *Excel* spreadsheet which was then used to plot the relationships between distance and time (shown in Figure 3.5) for a given ball-bearing and inclined plane height. Other relationships such as that between distance and the square of the time and that between the distance and the square of average speed were plotted successfully but these were considered too difficult for upper primary-aged students. An attempt was made to find a value for acceleration due to gravity (g) using the results from this apparatus, but due to factors such as rotational energy and friction, the attempt was not successful. Measuring time and plotting distance-time data as shown in Figure 3.5 was considered difficult enough for upper primary students.

Three groups of children, two groups of two girls and one group of three boys, participated in 20 minute practical sessions based on the inclined plane apparatus previously tested. A ball-bearing was allowed to roll down the plane from different initial starting points and students were asked to record the time taken for the ball to reach the bottom of the inclined plane. Using the time and distance travelled measurements, students

were asked to calculate average times, plot a graph on a worksheet as shown in Appendix 4, and were then asked to discuss the acceleration, deceleration, or consistent speed of the ball rolling down the plane. Also, graphs of other scenarios, shown in Appendix 5, were presented and the students were asked to determine if the object was accelerating, decelerating or travelling at a constant speed. As with the focus group sessions, these activities were audio-taped and later transcribed.

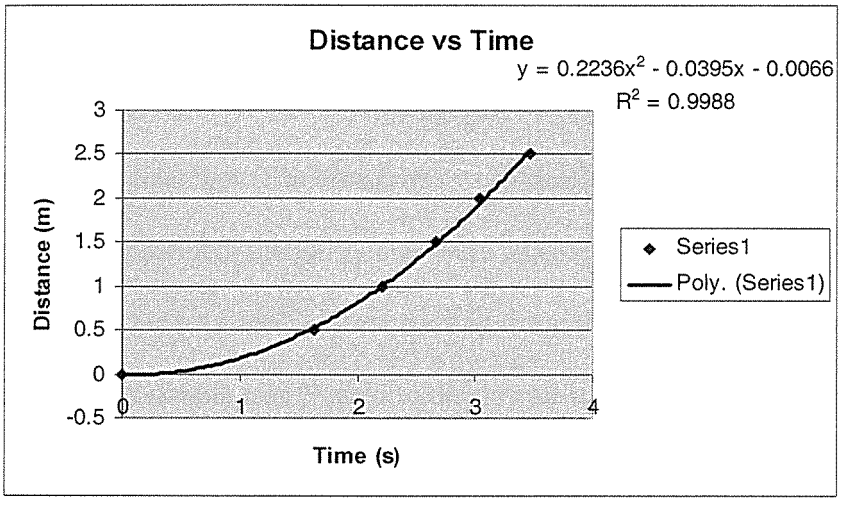


Figure 3.5 Graph of distance vs. time using inclined plane apparatus

3.3.2.3 Individual interviews

Six individual interviews were conducted. Three of these involved students who had previously taken part in the focus group sessions; the other three participants had not taken part in the focus group sessions. The three students who had participated in the focus groups were asked to give more information regarding answers they had provided on their worksheets in focus group session 2, and were also asked questions relating to the direction of forces. These students were asked to draw arrows representing forces. The three students who had not taken part in the focus groups were asked an abridged version of the questions from both focus group sessions. This ensured that the maximum amount of data was obtained from the maximum number of students possible, and also gave an opportunity to

compare the answers given by students in group and individual situations to the same questions. These individual sessions were also audio-taped and later transcribed. Although it was attempted to keep all activities in a casual and non-threatening atmosphere to encourage participation and spontaneity, it was considered important to create a question outline, as already shown in Figures 3.3 and 3.4, for each focus group session to ensure all content was covered.

3.3.3 Analysis of transcripts

Tapes of the focus group interviews, practical activities and individual interviews were transcribed by the researcher. The transcripts were checked by a faculty staff member for reliability. Once transcribed, the interviews were analysed carefully to find common themes and student ideas. This was done by first reading through the transcripts to gain an overall view of themes; next a table was created to display all student responses for each of the different questions in quote form; then various aspects such as issues of literacy, numeracy and correspondence with student ideas recorded in the literature were highlighted, and quotes recorded. A search for new ideas was also undertaken. Interpretations of the transcribed material were also checked by a faculty member for validity and following discussion, adjustments made until a consensus of opinion was reached. An example of the transcripts is shown in Appendix 6, and the remainder of the transcripts can be found on the disk found at the end of this thesis.

3.3.4 Researcher journal

A journal was kept throughout the sessions with the four groups, the practical activities and the individual interviews outlining the perceived strengths and weaknesses of the project, as well as any challenges met. Entries into this journal were consulted as the data from the transcripts was analysed.

3.3.5 Teaching and learning sequence

From the summary of student ideas and the diagnoses made in the researcher journal, a series of lessons was developed with the aim of introducing students to a scientific view of force and motion in the contexts of the ideas they already possess. The initial investigations with inclined planes were used to determine which concepts could be taught using the inclined plane apparatus as an object lesson. In this teaching and learning sequence, a hands-on approach was taken, with students able to perform experiments using the apparatus. Other subject areas, such as Mathematics and English, have also been incorporated in order to create an integrated teaching and learning sequence with practical applications for the classroom.

3.4 Schedule of tasks

As this project had limited time available, a schedule of tasks needed to be clearly planned to ensure that there was adequate time available for each task. Table 3.1 outlines this time schedule.

Table 3.1
Approximate timeline for this study

Approximate Date	**Activity**
Sept-Oct 2005	Content Analysis (Inclined Plane Experiments)
Late November, 2005	Ethics Committee Application (See Approval Letter in Appendix 1)
Early December, 2005	Trials of interview material
Dec, 2005 – Feb, 2006	Refining of interview material and writing of literature review and methodology sections
Feb – March 2006	Interviews
March-Early July 2006	- Transcribing and analysis of interviews. - Summary of student ideas created. - Learning Sequence designed based on student ideas.
Late July-Mid Oct 2006	Writing of Thesis.
October 20 2006	Submission of Thesis

3.5 Summary of methodology

The methodology of this study can be broken down into six steps:

1) In the light of syllabus requirements and preconceived ideas of the age group involved as outlined in the literature, experimentation was performed using the inclined plane apparatus. Flashcards and questions, based on the literature and the world of the primary school child, were then created for use in a focus group setting. These were checked by physicists for reliability.
2) A preliminary trial was held using flashcards and questions for focus groups. This trial aimed to see whether the cards and questions were adequate to establish an inventory of student ideas.
3) The flashcards and questions were modified according to the findings of the preliminary trial. Modifications were designed to make the questions and cards less ambiguous and more conducive to discussion about the force and motion concepts.
4) A class of upper primary students was divided into 4 focus groups, consisting of 4-5 students per group and interviewed. These focus group interviews were audio-taped for later transcription.
5) Student ideas were explored as found in the interview transcripts, focussing specifically on student views about force and motion.
6) Using the summary of student ideas and information from the inclined plane study, a teaching and learning profile was compiled and used to create a series of lesson plans for the introduction of the concept of force and motion to grades 5 and 6 students.

Chapter 4 – Results and Discussion

From a careful analysis of the transcripts, a number of key themes and ideas have emerged. These themes and ideas relate to the way students view and relate to magnets, static electricity, gravity, contact forces, and the inclined plane apparatus as well as students' own definitions of scientific words.

4.1 Magnets

During the first focus group sessions, students were given the opportunity to hold and feel the attraction and repulsion of two bar magnets. Students were questioned as to whether a force existed between the two magnets and were then asked to isolate the action of each magnet. Students were also questioned about the interactions of one bar magnet and a small plastic peg with metal fastenings. This questioning uncovered some student ideas regarding how it is possible to detect the presence of a force within the system, and also the ways in which forces act within the system.

4.1.1 Presence of force

When students were originally asked to indicate what could be felt when moving the magnets close together, many labelled the attracting or repelling sensations that were felt as 'force'.

Ally: I can feel force.

Initial responses such as these could be attributed to the students' parents having indicated to them that the discussions they would be taking part in would be about force, as conveyed in the permission letter signed by the parents as shown in Appendix 7. However, the student responses were spontaneous because of the tangible sensation of the interacting magnets and the students had no hesitation in identifying this sensation as a force. Students

described the feeling of these forces as 'pushing' and 'pulling' before any formal definition of force as a 'push' or a 'pull' had been discussed. Once part of the concept had been suggested by the interviewer, however, students readily identified the other part of the concept as illustrated below.

Interviewer: Did it... was it pulling?
Jackson: Yeah and pushing.
Glenn: No... pulling...
Darren: Pulling and pushing, depends on which side you put it on.

The fact that students intuitively used these labels in the context of playing with magnets suggests that this context might form a useful starting point for introducing the 'force' concept in the upper primary school.

On another occasion when asked to describe the force between the two magnets, students used terms which were already familiar to them to explain the scenario. Several students seemed to use terminology from their understanding of electricity, or to use words which they had previously heard used in a scientific context.

Julie: ... its like a genetic force, ah, negative and positive up against it and its like, the other way is positive and positive.

Other students attributed the magnetic force to a 'special metal' within the magnet itself, although they were unsure of which 'special' metal magnets were made of.

Megan: Um, because they have a special metal inside, and it makes them go together.
Ally: Like one would be normal metal and the other might be Titanium, Stainless Steel or that sort of thing.

Mark: Stuff... Mercury... isn't it Mercury...
Gavin: That's what... Gold you mean.
Mark: Yeah but isn't Mercury in mag... mag... mag...
Interviewer: Magnets?
Mark: Magnets, where they pull metal?

As described by Halloun & Hestenes (1985) and Hestenes et al. (1995), students tend to use their prior experiences in making sense of the world and hence this hypothesis could perhaps be attributed to the students' experience of magnets attracting each other, and that

of metals being attracted to magnets, and therefore this experience is extrapolated to mean that magnets are made of a 'special metal'. As students had already experienced the attraction and repulsion of the two magnets, they had no difficulty agreeing that a force of a push or pull nature *existed between* the magnets. But the belief that the magnets possessed a special metal also meant that students were comfortable with describing magnets as *possessing* force.

Darren: Is that the way you test which one has force or whether they both exert a force?

Megan: I reckon this [the peg] has some force.

Strictly speaking in scientific terms, forces are exerted by objects on other objects, and this distinction in the way one uses scientific terms will become important as students continue their science education.

Gunstone and Watts (1985) suggest that students of this age tend to view the world in a quite human-centered, or anthropocentric, manner. Students in this study showed a tendency to describe objects and phenomena in terms of human experience, and to giving these objects and phenomena human characteristics and attributes. In describing the actions of the two magnets in relation to one another, students gave the following responses.

Megan: Like they want to be together.
Paige: They're best friends.

In describing what happens to the magnet and the peg, Fred identifies the presence of an attractive force as follows.

Fred: Because the magnet wants to get to the peg

It is quite common for students at this stage to explain phenomena in terms of what the object 'wants to do'.

The force operating between two magnets is an example of a non-contact force. Students were first introduced to the differentiation between contact and non-contact forces

in the second focus group sessions. Before the concept was fully explained, students were asked to brainstorm potential examples of contact and non-contact forces.

Interviewer: We can have two types of forces, we can have contact and non-contact forces.
Jackson: Like magnets.
Interviewer: Yeah, so what sort were the magnets.
Jackson: Contact.
Glenn: Contact.
Darren: Un-contact because they pulled each other, the force was pulling them together but they weren't touching yet.

While Darren was able to identify 'contact' with 'touch' and categorize magnetic force as a non-contact force, other students initially had some difficulty classifying forces into these two categories. Some students classified attractive force as a contact force and a repulsive force as a non-contact force as follows.

Ally: [contact forces are] forces where they push each other together.
Paige: And non-contacting is going away.

Other students classified push and pull forces as contact forces and the colloquial use of the term 'force' as a non-contact force.

Melinda: Yep, I know, contact forces is like a push and pull and non-contact forces is like 'I force you to do something'.

Once the distinction between contact and non-contact forces was made, students from all groups were readily able to identify magnetism as a non-contact force. In addition to the identification of magnetic force, some of the students' ideas relating to the actions of such forces were made apparent during the focus group sessions.

4.1.2 Actions of force

Discussion in relation to the actions of magnetic force was first hindered by a lack of understanding of the word 'exert'. Some students expressed that they did not know the meaning of this word.

Paige: What does exerting mean?

This highlights the importance of ensuring that teaching and learning occurs on 'common ground' (Johnson & Gott, 1996) with regard to the language used. This means ensuring that all students understand all scientific language used within the lesson. This may involve including a short segment at the beginning of a lesson in which students are taught the meanings of relevant words. Once students had an understanding of the meaning of 'exerting a force' they were in a position to consider the individual forces acting in the system.

In the first focus group sessions, students were asked whether a force existed between the two magnets. All students seemed to correctly believe that there was in fact a force present between the two magnets. One group gave the following responses to this question.

Interviewer: Alright, is there a force between the two magnets?
Gavin: Yes.
Mark: Yeah.
Nick: Yes.
Phillip: Yes.
Dale: Yeah.

Students were then asked whether magnet A was exerting a force on magnet B, and then if magnet B was exerting a force on magnet A. When the idea of magnet A, or magnet B exerting a force on the other was presented, students originally identified only one magnet as exerting a force. However, in the case of several of the groups, the conclusion was finally reached that there was in fact a force exerted by both magnets. Group 1 gave the following responses to this questioning.

Interviewer: Do you think that magnet B is exerting a force?
Darren: Uh, no.
Interviewer: No? You guys just reckon that magnet A is exerting a force?
Darren: I reckon both.
Glenn: I reckon...
Darren: I reckon...
Glenn: No, it can't be both Darren... Oh, wait are...
Jackson: B!
Darren: Both.
Glenn: Oh, because they've got separate sides.
Jackson: B.

Darren: Yeah, I reckon its both because if you put one here [magnet A], and you had this one here [magnet B], like close enough, it will suck [attract] that one that way and if you turn... if you do it the other way, and if you do it the other way...

In the above example, the student was demonstrating that if magnet A is restrained in position, then magnet B will move towards it, and if magnet B is restrained, then magnet A will move towards it. Students in Group 3 responded as follows.

Interviewer: Is magnet A exerting a force on magnet B?
Mark: Yes, it is a pulling force.
Interviewer: Ok.
Nick: A's pulling it.
Dale: B could be pulling A.
Phillip: A's pulling B because I can feel it.
Interviewer: Is B pulling A too?
Students: Yeah.
Gavin: Sometimes, but...
Nick: Like if you have it one way A will pull B, and if you have it the other way, B will pull A.

Thijs (1992, p. 167) suggests that "it is also to be expected that interpersonal interactions and conflicts are stimulants for a students' conceptual change". Discussion and conflict between students requires students to explain and often re-think their conceptions and hence is a useful exercise in the teaching and learning of mechanics (Eryilmaz, 2002). When students are required to think about their own conceptions and learning, it is possible for them to devise their own examples and theories.

Students generally agreed that a force existed between the magnet and the peg but when questioned more deeply about the scenario involving the one magnet and the small peg, the clear majority of students indicated that they did not believe that the metal in the peg was exerting a force on the magnet, but rather that all of the force in this system could be attributed to the magnet.

Darren: Only the magnet is making force to pull the peg.

When the peg was restrained the students observed that it did attract the magnet, but only when the magnet was brought very close to the peg.

Interviewer: And the magnet jumped over to be with the peg.
Glenn: The magnet didn't do it.
Jackson: The magnet did.
Darren: The magnet made... oh no, cos that was the second time, which meant that the magnet had put some stuff inside the, magnetic force inside the peg.

A small number of students responded in partial favour of the understanding that both objects within the system exert a force of some degree on the other. When asked whether the small metal peg was exerting a force on the magnet, Chelsea and Glenn gave the following response.

Chelsea: Sort of because its got a magnet in itself because of the metal, but it doesn't really have it because its only got a little charge.

Glenn: Oh, it does, but only a small one.

This concept relates directly to Newton's third law of motion in that because of the magnetic force being exerted by the magnet on the peg, there is an equal and opposite force being exerted on the magnet by the peg. While this may be perceived to be true for two equivalent magnets, the equality of forces is not obvious for different sized objects like the magnet and the peg. However, one student came up with the following example which demonstrated the intuitive understanding that bigger objects require more force to be moved.

Glenn: No, but if you had a cupboard like that [motions to the large metal cupboard in the interview room], you could put the magnet near it, and the magnet would go to the cupboard, but the cupboard won't come to the magnet.
Interviewer: Why?
Glenn: Because its too big.

In direct relation to the magnet and peg example, another student gave the following example demonstrating this understanding.

Julie: But it doesn't do as much because the magnet is more heavier than the peg. And the peg can't really handle the weight.

It is when students begin to show these signals of understanding that teachers have a great opportunity to enhance cognitive growth. In these focus group sessions, there were several

examples of times when students began to ask in-depth questions about the activities, and thus they were fully engaged in their learning. During the discussions about magnetism and whether both magnets were exerting a force on the other students made these comments.

Paige How can you tell that like, the peg does and doesn't? [exert a force]

Darren Is that the way you test which one has force or whether they both exert a force?

Paige: Its sort of one of those things that you sit down puzzled for a while.

It is in these situations that student conceptions can be used as "resources for cognitive growth" (Smith III et al, 1993-1994, p. 116) and that truly effective learning can occur. However, magnetism was not the only example in which important student ideas became apparent. The concept of static electricity was also explored and discussed with the students.

4.2 Static electricity

It had been intended to demonstrate the concept of static electricity with a short demonstration involving a charged hair comb attracting a small piece of paper. Unfortunately, this was not possible as on the day of the interview the weather was quite humid and hence this demonstration was unsuccessful. However, when questioned about this demonstration, students were quite familiar with it and similar activities.

4.2.1 Presence of force

When the demonstration was explained to students, and they were questioned in relation to the expected results, students were readily able to explain what was supposed to occur.

Interviewer: What would normally happen, Glenn?
Glenn: It would bring it up... like...
Darren: The static electricity would make the paper stick to the brush.

This is a clear indicator that this activity falls on 'common ground' (Johnson & Gott, 1996), that is, it is familiar to both the student and teacher. Once the original example had been

explained, students were readily forthcoming with other related examples such as the following.

Paige: I saw it on 'Backyard Science' where you just rub it on a piece of fabric and then you get all the paper out of the salt.

Julie: Just like with the balloon when you rub it on the carpet or something, and then you put it on your hair.
Interviewer: And your hair stands up on end?
Julie: Yeah.

Clearly, elementary examples of static electricity are commonplace for upper primary-aged children. Students in the second focus group sessions were asked to identify the examples of non-contact forces that had been explored in the first focus group sessions, and the majority of groups did this with little difficulty after having explored the meaning of the word 'contact'.

Interviewer: Can you think of some other examples of non-contact force? We talked about three yesterday. The magnets were one, the magnetic force.
Fred: The comb?
Interviewer: The comb and the hair, what sort of force was that?
Glenn: Static electricity.

In addition to the identification of static electricity as a non-contact force, one student gave an example which indicated her ability to make links between the demonstration and her daily life experiences.

Julie: Like I have a jumper, and when I take it off I get really zapped from taking it off because it rubs against my hair when I take it off.

Although it is not necessarily the hair which actually causes the static electricity in Julie's jumper, she appears to have made a link between the hair causing the charge in the comb and her own experience with static electricity. Other students gave explanations of the actions of static electricity in terms of magnetism and friction.

Interviewer: Have you ever rubbed a balloon on your hair?
Students: Yeah.
Megan: Its like got a magnet in it, and it sticks to your hair...
Paige: No, its friction.

In these instances, students seem to have framed their explanations of static electricity in terms of their previous experience of magnetism causing an attraction between objects, or friction being caused by two objects rubbing together. Once students had established the presence of static electricity, they were questioned regarding its actions within the system. These situations are now expanded.

4.2.2 Actions of force

Similar to the example involving the magnet and the small peg, students were questioned as to whether the comb was exerting a force on the paper, and/or the paper was exerting a force on the comb. Although students seemed to easily understand that the comb must be exerting a force on the paper for the paper to be lifted, some students did not seem to believe that there was an equal and opposite force from the paper. This is understandable, however, given the fact that, unlike the peg attracting the magnet, the paper is unable to visibly attract the comb.

Interviewer: Now, does the paper exert a force?
Students: No.
Jackson: Maybe, I dunno.
Glenn: Because it hasn't rubbed against anything.

However, some other students agreed that there needed to be a force from the paper but actually gave a reason that implied that the comb was exerting a force on the paper rather than the paper on the comb. One student gave the following response when asked if the paper was exerting a force on the comb.

Phillip: Yes, yes, yes, actually it does, because the paper actually gets attracted to the comb, where the comb...

Many of the students at this stage are still functioning in a very human-centered manner. This was shown when many students focused more on the action of the hair in instilling the static charge, rather than the comb and the paper within the system.

Abby: No, it's your hair, with the [inaudible] bits of your hair go up into the comb and it's the static electricity.

Chelsea: So when you're brushing your hair you rub it together and the paper – so its part hair and part the comb.

After the discussions about the magnetism and static electricity demonstrations, students were presented with a number of flash cards and questioned about the forces acting in the situations depicted.

4.3 Gravity

Students were presented with three flashcards relating to gravity. The first of these showed a person standing on a skateboard at the top of a hill and the students were questioned regarding what would naturally happen to this skateboard. The second gravity-related scenario was shown on two flashcards; the first showing a person standing on a diving block, and the second showing the same person hovering over the water after stepping off the diving block. Students were asked what would happen to the person next and then asked to explain their response. The final card relating to gravity showed a person standing in the middle of a flight of stairs, and students were asked whether it is easier to walk up or down stairs, and then asked to explain further. Later in the first focus group session, students were also asked to express their own definition of the word 'gravity'.

4.3.1 The nature of gravity

When the students were asked to give their own definition of the word gravity, the majority of students responded in terms of the effect of gravity on humans and other tangible objects. Students in one group gave the following responses.

Melinda: Gravity is what keeps you on the ground.

Julie: It's just like in space and there is no gravity and you go weeeee!

Abby: Same as them.

Chelsea: Keeping everything on the ground.

As well as defining the word 'gravity' in terms of human experience, students also tended to explain the action of gravity in terms of human experience.

Ally: Wait, no! There's too much gravity or something keeping us down so when we jump off it will take us straight down...

Although students seemed to understand gravity as an attractive force towards the earth, the occasional student described gravity in terms of a 'pushing' force rather than a 'pulling' force.

Ally: ... pushing somebody down, keeping people on the earth, unless you jump up, if you go too high it will just force you down.

This could simply be due to the student not feeling that the distinction between 'pushing' and 'pulling' in regards to gravity is important, or it could indicate a confusion between gravity and air pressure as indicated in the following response.

Student Um, isn't gravity air pressure. The pressure on the air like more dense and stuff and that's what keeps us on the ground.

It seems that students intuitively possess the concept of gravity. However, in the second focus group session when students discussed non-contact forces, some students identified gravity as a non-contact force because they viewed it as an unseen entity located in the middle of the earth, rather than as a force from the earth. When group 2 was asked why we consider gravity to be a non-contact force, they gave these answers.

Megan: Because you can't see it, you can't, you just can't.
Ally: Yeah, you can't see it because gravity is pulling us down, but you can't see it and its no, its pulling you down but you're not touching it. It's like in the middle of the earth or something like that, its like under the ground.

Other groups argued as to whether gravity was in fact a contact or a non-contact force. Group 3 gave these responses.

Gavin: It's going through gravity, so its still contact.
Interviewer: It's going through gravity is it?
Gavin: Yes.
Dale: But that doesn't mean that gravity is contacting it.
Mark: It's pulling you down like a magnet.
Nick: But gravity is still touching you though.

Phillip: What if you're in a parachute though. It goes down real slow.

Students in this group may again confuse the concept of gravity with air pressure, as an object affected by gravity would travel 'through' the air towards the earth, and so could be seen to be in contact with the air.

Students were also likely to attribute the actions of gravity to other objects or phenomena. When students were presented with the skateboard scenario and asked what would make the skateboard roll down the hill, many students attributed the movement to the various parts of the skateboard, the hill or the person on the skateboard. One student gave this response.

Paige: Because its got wheels, and plus the slope and if he didn't go down, he'd be on a pretty lumpy surface.

Another student who had participated in the practical inclined plane activity made the connection between the inclined plane apparatus and the skateboard on the hill.

Abby Its like an inclined plane.

This shows links being created between previous and new learning experiences. One student linked the question regarding the man jumping into the water with his previous understanding of magnets.

Phillip What if you were metal and the water was magnet?

This comment shows great potential for this student in the understanding of non-contact forces, as he is already linking two different kinds of non-contact forces through analogical reasoning. Although some of the details quoted by students were unscientific, the students in this study appeared to have an intuitive idea of the actions of gravity.

4.3.2 Actions of gravity.

As the 'skateboard on a hill' flashcard was presented to one student, she made the following comment.

Ally: He can't just stand there, he'll go down, the way it's sloping he'll go down.

This student possessed an intuitive understanding that an object sitting at the top of a hill will roll down the hill unless restrained. As the phenomenon of gravity is natural in a common sense view of the world, some students see it as unnecessary to explain why objects tend to fall downwards if not restrained.

Darren: They'd fall because they'd fall.

Thus, students may not always attribute the actions of gravity to the phenomenon of gravity, but rather to the lack of 'support' to stop the object in question falling. When one student was asked why a tape sitting on a table did not fall straight down, he gave the following response.

Interviewer: Ok, if I have this tape, this one, and I sit it on the table, what stops it from falling straight down?
Mark: The table cos its standing up and its on the table and the table doesn't fall down.

Even when the students did not attribute the effects of gravity to gravity itself, they still seemed to have an understanding of phenomena such as acceleration due to gravity. In relation to the person standing on the skateboard going down the incline, the increase in speed is explained as follows.

Gavin: They gain speed as the gravity is pulling them down

Jackson: They're going down, and as you go down you get faster.

In addition to the exploration of the various non-contact forces, students also explored examples of contact forces in the focus group sessions.

4.4 Contact forces

During the first focus group sessions, students viewed examples of contact forces where two students pushed against each other, and where one student, or the interviewer, pushed against the wall. Students were asked whether the student was exerting a force on the wall and then if the wall was exerting a force on the student. Also, in the second focus group

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session, the concept of a 'contact' force was introduced along with Newton's third law of motion implying that a wall must exert a force on the person pushing against it.

4.4.1 Defining contact forces

When students were originally asked during the second focus group session what they thought the term 'contact force' meant, many students gave examples of the common-place usage of the word 'contact' such as.

Abby: I got contact lenses.

Megan: To look at each other or, maybe go together.

Despite a discussion just minutes before defining the word force as 'a push or a pull', listing non-scientific uses of the word 'force', and informing students that in this session we were to use the 'push or pull' definition of force, one student still responded with the following answer.

Melinda: Yep, I know, like, contact forces is like push and pull and non-contact forces is like 'I forced you to do something'.

Again the students' anthropocentric orientation (Gunstone & Watts, 1985) was apparent in the examples of 'contact forces' given by students. The most common examples given by students related to a person pushing, pulling or in some other way touching another person, or concrete object. Some students gave the following responses.

Nick: When you touch them.

Mark: Um, pushing someone.

Darren: Pushing like when Fred and I was pushing.

Although students found it relatively straightforward to identify that both students were exerting a force in the case of two students pushing against each other, many students found it difficult to understand that the wall was also exerting a force on the student who was pushing against it.

4.4.2 Newton's third law of motion

Newton's third law of motion states that if two objects interact, the force exerted by object 1 on object 2 (F1) is equal in magnitude to and opposite in direction to the force exerted by object 2 on object 1 (F2). Therefore F1 = -F2 (Serwey & Beichner, 2000, p120), or as it is more commonly quoted; 'for every action there is an equal and opposite reaction'. This implies that in the situation where a student was pushing against the wall, the wall was in fact exerting an equal and opposite force on the student. All students could easily understand that when two students push against one another, they both exert a force on the other and that there can be said to be a force between the two students. When shown the example of the two students pushing against one another, group 1 gave the following responses.

Interviewer: Alright, is there a force between them?
Darren: Yes.
Fred: Yes.
Jackson: Oh, maybe, I don't know.
Glenn: Because Darren's still, they're pushing each other, but they've just been braced.
Interviewer: Ok, so Glenn thinks that even though they're not moving, there's still a force between them?
Glenn: Yeah.
Interviewer: What do you think Darren?
Darren: Yeah, yes, because like we've been showed with rulers that if something is pushing against each other hard enough, it'll slip eventually because of the force.

In the situation where two people are each pushing, the students possess first hand experience of the feeling associated with pushing against another person. The main problem that seemed to be encountered by students in relation to this demonstration was that one group was unsure if there was a force between the students because each student's force was equal.

Interviewer: Is there a force between you?
Paige: No, I don't think so, I'm not sure, but I don't think so because we're at the same force.
Interviewer: So are you pushing against her?
Paige: No, yes and no, because she's pushing the same force onto me, and I'm pushing the same force onto her.

Although students could recognise a force being exerted by a student, a large percentage of the students answered 'no' when asked if the wall was exerting a force on the student.

Interviewer: Am I exerting a force on the wall?
Students: Yes.
Gavin: But the wall's not exerting a force on you.

Students acknowledged that there was a force exerted on the wall, and that the wall remained standing despite that force, but did not see the reaction of the wall as a force. When questioned about her response, one student gave the following explanation.

Chelsea: Because the wall is solid. But it's not pushing against you. You're trying to push against it but it won't budge, unless you use a chainsaw or a sledge hammer.

There are two possible explanations for this student idea found in the literature. Firstly, the Gunstone and Watts (1985) study conveyed the student idea that forces are only to do with living things, and thus an inanimate object cannot exert a force. The wall in this study may be seen by students as an inanimate object, and therefore as unable to 'push or pull' another object. The second possibility is an extension of the notion of 'support vs. falling' described by Bliss and Ogborne (1993), whereby students do not see the action of gravity as an interaction of forces, but rather simply that if an object is not supported, it will fall. It is possible that students in this study view the wall as 'supporting' the person pushing against it or 'absorbing' the force exerted on it by the person, rather than exerting an equal and opposite force.

Interviewer: Is the wall exerting a force?
Student: No. No, it's absorbing a force

That said, there were some students in this study who with a little prompting did recognise the force exerted by the wall.

Interviewer: Can you feel it stopping you from pushing?
Darren: Yeah... its got some force.
Fred: Its because of its weight.

Glenn: Its weight and its...
Fred: Its weight makes it have force.

Prior to participating in the focus group sessions, seven students participated in practical activity sessions centred on the inclined plane apparatus.

4.5 Inclined plane apparatus

During the practical activity sessions, students worked in pairs or a group of three to measure the time taken for a ball-bearing to reach the bottom of the inclined plane apparatus from various starting points. Students then used the data collected to calculate the average time taken from each starting point, and then plotted them on a graph of distance against average time. Students were then given time to explore the meaning of these graphs and other graphs of distance against time to explore whether the ball-bearing was accelerating, decelerating or travelling at a constant speed. Although this apparatus had the potential to be used to explore the concept of gravity, time constraints meant that the concept of averaging, the use of stopwatches and calculators and the plotting and interpreting of graphs became the main focus of these sessions. The problems that students faced in these sessions centred largely on numeracy, and the measurement, recording and interpretation of data.

4.5.1 Numeracy

During these sessions it was noted that several students tended to read digits after a decimal point as whole numbers. An example of this is given below.

Melinda: I got two point twelve.

This method of reading decimals tended to cause students problems as they attempted to plot points relative to one another on the graph.

Interviewer: Alright, so you can try to find where you think the next one would go.
Bree: Where's that?

Melinda: About... there... somewhere [Indicates a point on the 0.5m line which is greater than 1.5 seconds].
Interviewer: Is that... 0.5m? Make sure its not on the 0.5m, make sure its with the 1m and not the 0.5m.
Bree: About there? [indicates a point on the 1m line which is greater than 1.5 seconds].
Interviewer: It's 1.36, do you think that would be past 1.5?
Melinda: Mhmmmmm.
Interviewer: It's one point three something, will it be past 1.5?
Melinda: Well its 1.36 [thirty six], and that's 1.5. so would it?
Interviewer: Well, have a look. What you can do is you can actually [writes a zero after 1.5 to make 1.50]. So its 1.50.

Here the student thought that 1.36 was a bigger number that 1.5 because 36 is a larger number than 5.

The Victorian Educational Learning Standards document (VCAA, 2005, p. 57) states that students at this age should "use place value to determine the size and order of whole numbers to tens of thousands, and decimals to hundredths". So it can be reasonably expected that the students participating in this study have been exposed to the concepts of ordering decimal points to the magnitude required for this activity. This issue supports the notion outlined by Smith III (1993-1994, p. 120) that students tend to apply their prior knowledge of whole numbers to other situations, such as decimals and fractions. This also highlights the importance of specific and deliberate teaching of mathematical concepts in science and technology contexts as well as in mathematics class.

The students in this study found difficulty in calculating speed and averages. Students were required to take three time measurements and calculate the average time. One group's dialogue whilst plotting the results shown in Figure 4.1 is outlined below.

Interviewer: That's great! So, do you know how to work out the average of those three?
Melinda: I beg your pardon?
Interviewer: Do you know how to work out the average of those three?
Melinda: What do you mean?
Interviewer: If I say, ok, if I have one that was 1.15, one that was 1.22 and one that was 1.0, can you pick out the one that's like, in the middle? Or an average of those three? Have you ever worked out averaged before?
Melinda: Um, it's the first one. Cos that's in the middle.
Interviewer: What we can also do, is if you add all these three together and then divide it by three, it can work it out, and it helps us to be a bit more accurate. So if you add those three together, and divide it by three. That's why you've got your calculators.

Melinda: Um, it equals 3 seconds and 37...
Interviewer: Did you divide by three?
Melinda: Oh. That's what I got.

Distance (m)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average Time
0.5m	1.15	1.22	1.06	1.12
1.0 m	1.22	1.34	1.53	1.36
1.5 m	1.57	1.75	1.56	1.62
2.0 m	1.82	1.90	1.91	1.87

Figure 4.1 Results obtained in Inclined Plane Experiment by Melinda (Group 1)

Students needed to have the calculation of averages explained to them in a step-by-step manner, and even after this had taken place, some students still required assistance for each calculation. Some students like Melinda (above) did however identify that the average should lie between the largest number and the smallest number even though she did not know how to do the calculation. When questioned whether they had previously calculated speed, the students participating in the practical activities indicated that they had not previously done this. When attempting to calculate average speed under instruction, students attempted to use an averaging formula, or to add the numerator and denominator of the fraction. The Victorian Educational Learning Standards (VCAA, 2005, p. 54) prescribe that at this stage "students learn important common measures relating to money, length, mass, time and temperature, and probability – the measure of the chance or likelihood of an event. Other measures include area, volume and capacity, weight, angle and derived rates such as density, concentration and speed". So therefore at least some of the students in the study should reasonably be expected to be able to calculate speed.

During the inclined plane activity, one student commented that she had noticed a pattern in the 'average time' results being calculated as the ball travelled greater distances along the inclined plane.

Abby I've noticed that it keeps going up every time we do higher. That's gone up, and that's gone up.

At this age, students begin to notice patterns in numbers, and how they interconnect. Mathematical reasoning and numeracy are an essential part of the quantitative study of science. When integrated effectively with the science curriculum, students should be able to calculate numerous quantities, such as speed, distance and average time, and be exposed to the patterns and logic involved in the study of force and motion.

4.5.2 Measuring, recording and interpreting data

When students were asked to draw a graph during the practical activities session, students indicated that they had previously drawn graphs. However, they tended to confuse the two axes, and struggle to plot points in appropriate positions. An example of the plot of distance against time for the third practical activity group is shown in Figure 4.2.

Distance (m)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average Time
0.5m	0.95secs	1.22 s	0.93 s	1.03
1.0 m	1.85 s	1.76 s	1.81 s	1.81
1.5 m	2.22 s	2.09 s	2.22 s	2.18
2.0 m	2.03	2.25	2.12 s	2.13

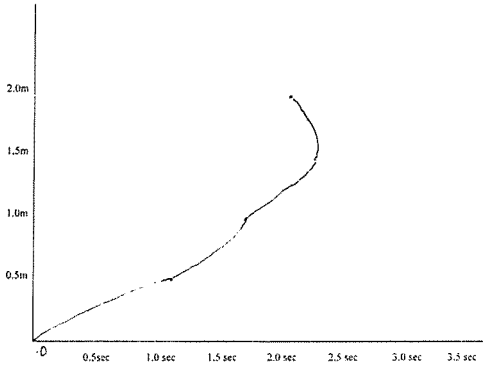


Figure 4.2 Plot of distance against time (Chelsea, group 3)

When plotting this graph, Chelsea placed all of the points in approximately the correct position. However, the position of the first point [0.5m, 1.03sec] was located closer to 1.25 seconds on the horizontal axis. Also worth mentioning is the fact that the time recorded for the ball-bearing to travel 1.5m is larger that that for the ball-bearing to travel 2m. This is most likely due to inaccurate measurement. Students not only struggled in the drawing of graphs, but also in the interpretation of graphs.

When asked to interpret their own and other graphs, some students viewed the graphs as 'hills' and therefore concluded that the steeper the 'hill', the faster an object must be travelling. This student was shown the graph which depicted distance vs. time of an object which was decelerating similar to that shown in Figure 4.3. The following comment was made by the student.

> Student Would that ever happen in real life? Cos if you put that, if its like as steep like this, it would probably go faster.

According to the Victorian Educational Learning Standards (VCAA, 2005, p. 58) students at this stage should "use a column or bar graph to display the results of an experiment". Therefore, line graphs are not within the syllabus requirements for children at this stage. However, they were included in this study as an attempt to stretch the students' understanding of motion.

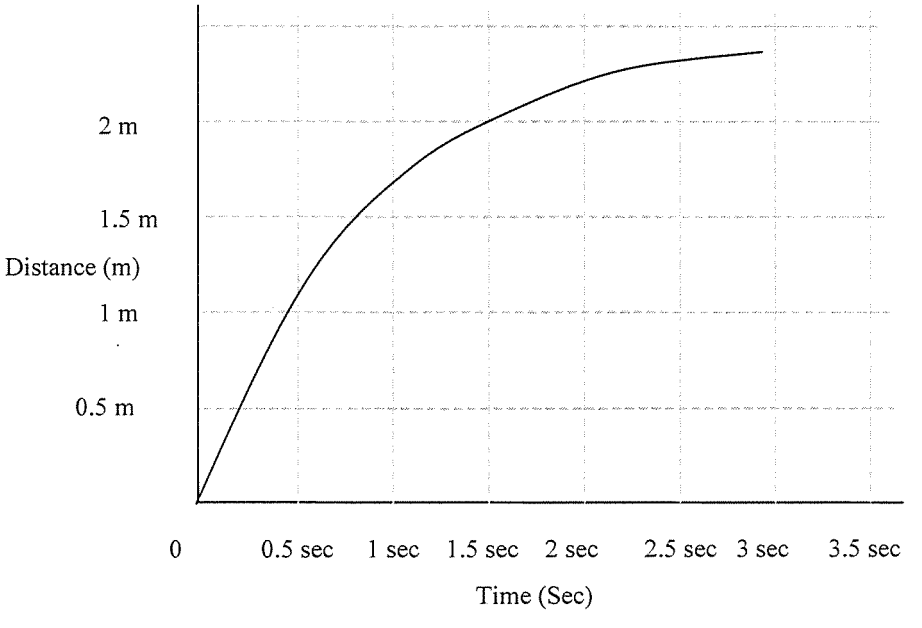


Figure 4.3 Graph of Distance vs. Average time for a decelerating object

Although all students participating in the practical activity sessions had used calculators and stopwatches previously, several students had difficulty starting and stopping the stopwatches, and reading the times correctly. However, one student was able to read the

time from the stopwatch in terms of seconds and milliseconds. When using calculators, students often pressed the wrong keys, or did not know which buttons they needed to press. This could reasonably be attributed to the lack of development of fine motor skills at this age. In addition to the mathematical skills which impact on the teaching and learning of science at this level, there needs to be a common understanding of the language used by both the student and the teacher.

4.6 Language

In order for effective teaching and learning to occur, both the teacher and students need to have the same understanding of the language used (Johnson & Gott, 1996). In order to examine student understanding of scientific terms, at the end of the first focus group session, students were asked to give their own definitions of the words force, speed, momentum, gravity and energy. The responses given by the students were rooted mainly in their everyday experience of the world. Some of the responses given are listed below.

<u>Force</u>	
Fred	Pushing power
Gavin	Um, like you're pushing something it's the force to move
Julie	That's off Star Wars
<u>Speed</u>	
Jackson	Fast, speed is fast
Bree	Um, how fast something is going
<u>Momentum</u>	
Abby	Momentum is like, its like force and speed put together, except is like a different type of force.
Glenn	Yeah, you think you can do it. Faith in you
<u>Gravity</u>	
Megan	Keeping something from floating away
Paige	… if someone's in the air, gravity pulls them back down
<u>Energy</u>	
Jackson	Um, energy's like the power you've got in your body
Mark	Stamina because you can lose energy, and without stamina you get puffed and everything
Abby	You get energy by eating

The definitions given understandably tend to lack precision. However, a large proportion of these responses have the potential to be used as "resources for cognitive growth" (Smith III et al, 1993-1994, p. 116), in that they are not entirely unscientific and could be used as a starting point to build student understanding of scientific concepts. For example, Megan's understanding of gravity as a phenomena which is 'keeping something from floating away', is a useful starting point for discussion on the actions of gravity from which a full explanation of gravity can be given. There were several examples that could be termed 'signatures for cognitive growth' located within the transcripts, which can be best described as opportunities where the dialogue becomes productive.

4.7 Signatures for cognitive growth

Throughout the focus group sessions, conversation varied between highly productive dialogue and less productive dialogue. Points of highly effective dialogue have been identified as 'signatures for cognitive growth' as they indicate that students are fully engaged in their learning and show potential for cognitive growth. Two conversations have been selected from the transcripts to illustrate this idea. The productivity of the conversation is displayed in Figure 4.4 and Figure 4.5 in the form of a graph depicting the productivity of conversation on the vertical axis, and time on the horizontal axis.

Interviewer:	Ok, magnet A – that one – Is magnet A exerting a force?
Glenn:	Ah, yes.
Jackson:	Maybe.
Glenn:	Can I see? [looks at the magnets]. Yes.
Jackson:	Maybe.
Glenn:	A, it's A.
Jackson:	Maybe.
Interviewer:	What do you think Darren?
Darren:	A
Jackson:	No, B.
Darren:	Yeah, A.
Jackson:	B.
Interviewer:	Do you think that Magnet B is exerting a force?
Darren:	Uh, no.
Interviewer:	No? You guys just reckon that magnet A is exerting a force?

Darren: I reckon both.
Glenn: I reckon...
Darren: I reckon...
Glenn: No, it can't be both Darren! Oh, wait are...
Jackson: B!
Darren: Both.
Glenn: Oh, because you've got on separate sides.
Jackson: B.
Darren: I reckon its both because if you put one here, and you had this one here, like close enough, it will suck that one that way and if you turn... if you do it the other way, and if you do it the other way...
Glenn: It's A.
Darren: A to B. That's why its both.
Glenn: It's both!
Interviewer: Both?
Jackson: I reckon it's B!
Interviewer: Ok, you think just B?
Jackson: Yup.
Interviewer: What do you reckon Fred?
Fred: Both.
Interviewer: Ok, we have three say both, and Jackson says just B.

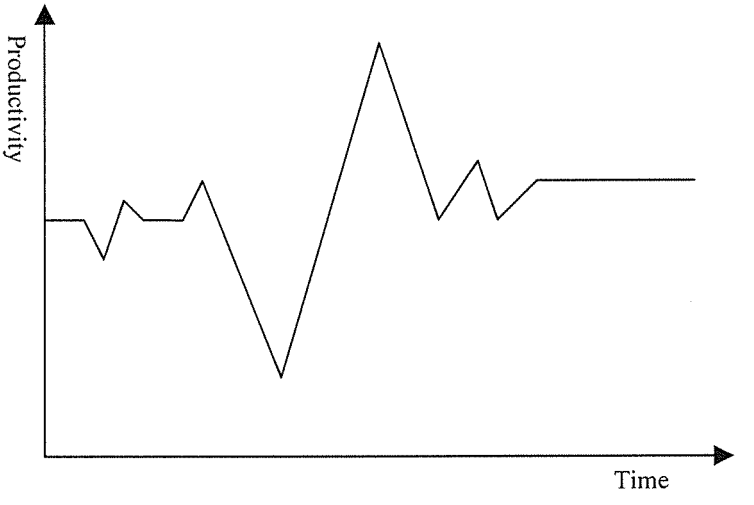


Figure 4.4 Graph of Productivity vs Time for Focus Group 1 Discussion (Magnets)

The large peak in Figure 4.4 represents the point in the conversation where Darren demonstrates his experimentation that if Magnet A is restrained in position, that it will attract Magnet B to itself, and that if Magnet B is restrained in position that it will attract Magnet A to itself. As students begin to experiment with new ideas, they are receptive to new information and learning, and hence, questioning and experimenting is classified here

as a signature for cognitive growth. The largest of the dips in this graph occurs when the students are engaged in meaningless argument, and the smaller dips are largely indicative of the constant answers of 'maybe' given by Jackson. Answers such as these were common from this student, and although it was not noticed during the interviews, this student was rarely engaged in the learning process and often distracted other students. The second section selected from the transcript includes the discussion in Focus Group 2 regarding the interaction between the magnet and the small peg.

Interviewer: Alright, ok, what about if I have, see this little peg? I chose it because its got a little bit of metal through there, the rest of it is all normal plastic sort of thing. There's nothing magnetic in there, its just the metal piece that wants the magnet.
Megan: If you put the opposite sides together that don't want each other and put that in the middle, would it hold it up?
Paige: You know [inaudible] they actually built it to be like that so they'd stick in the middle.
Interviewer: Yeah, so maybe it's the... so that's what happens there [demonstrates the peg between the two magnets].
Megan: So it doesn't hold it up?
Interviewer: No, because it grabs there. But, um, if I have that there and I bring the magnet close and closer...
Paige: It'll push it away... Oh... [sees what actually happens] It pulls it in.
Interviewer: It pulls it in.
Megan: Oh, can you go like this? You just attach it...
Ally: Can I feel the magnet?
Interviewer: The magnet, yep.
[Sound interrupted by Ally playing with the magnets on the table near the tape – loud scratching noise]
Megan: Yeah, like that.
Ally: I had it like that. They actually push each other away.
[Sound interrupted by Ally playing with the magnets on the table near the tape – loud scratching noise]
Interviewer: Yep, ok...
Paige: I knew someone who put a magnet up his nose.
Interviewer: Oh no!
Megan: But I had one of those magnetic... magnetic noses...
Interviewer: Nose rings?
Megan: Yeah, but it went up there and made me not breathe.
Interviewer: Ewww.
Ally: Up your nose?

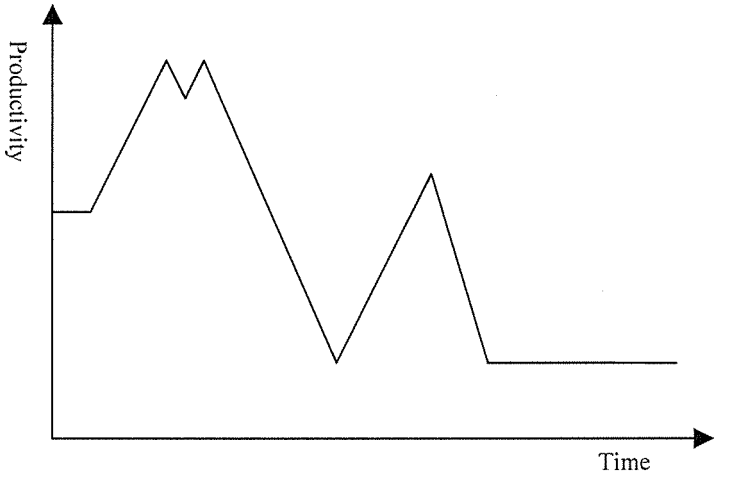


Figure 4.5 Graph of Productivity vs Time for Focus Group 2 Discussion (Magnet and Peg)

The initial peak in this graph indicates the question posed by Megan as to what would occur if the peg was to be placed between two magnets posed to repel each other. The second peak represents the hypothesis made by Paige that the peg and magnet would repel one another. Although these comments may appear trivial, and the hypothesis proved incorrect, as students begin to think in this manner, their minds become ready to learn new information and effective cognitive development can occur. Other *signatures for cognitive growth* uncovered in this study pertain to the spontaneous generation of analogies to previous experience. When the flashcard depicting the man stepping off the diving board was displayed, one student made the following analogy.

Phillip What if you were metal and the water was magnet.

Analogies such as this show that links are being created between the varying concepts within the students' mind. This same student posed another question relating to gravity.

Phillip What if there's no gravity?
Gavin If there's no gravity you'd float up in the air

This kind of questioning has the potential to be used in classroom dialogue as a springboard for learning. When a question such is this is posed, the teacher could guide the conversation

to the actions of gravity, the consequences of the absence of gravity and even to discuss objects such as the moon where there is less gravity present than on the earth. The dips in Figure 4.5 indicate the times that students were distracted and recalled a time when a friend inappropriately used a magnet.

The research questions for this study emerged from a detailed investigation of the literature. Answers to these questions have been uncovered from a thorough analysis of the transcripts.

4.8 Conclusions

The research questions for this study originated from a detailed search of the literature. A thorough analysis of the transcripts has revealed answers to these four questions.

The first research question asks whether the preconceptions about force and motion held by students in the upper primary school are similar to those held by students at the secondary or tertiary level as described in the literature. This study has found that there are some similarities in ideas held by the students interviewed in this study and those reported in the literature, and these have been discussed throughout this chapter. These similarities are summarized in Table 4.1

However, as students in the upper primary school are at a different stage of cognitive development to those in the secondary and tertiary level, and the syllabus has different requirements of these students, it is difficult to make an accurate judgement as to whether or not the ideas held by primary-aged students are held consistently through their schooling. Taking into account student ideas, it is important to consider carefully which concepts are feasible for introduction at this stage.

The second research question discusses which ideas are feasible to be introduced to students at the upper primary level. The concept of net force, resultant force or 'overall force' seemed to be too difficult for the students in this study to grasp.

Table 4.1
Summary of support for previous research

Student idea quoted in literature	**Reference**	**Support from this study.**
Forces are designated to those objects that are causing or will cause events to occur	Watts (1983)	Students in this study attributed all force in the scenario involving the magnet and the small peg to the magnet. Similarly, all force was attributed to the comb in the static electricity example.
There are no forces involved when an object is at rest (or only gravity is present).	Thijs (1992); Gunstone & Watts (1985)	When questioned if any forces were acting on a cassette tape stationary on a table, most students answered 'no', otherwise that only gravity was acting.
Passive objects cannot exert a force.	Thijs (1992)	The majority of the students indicated that they did not believe that the wall could exert a force on the person pushing against it; or that the small metal peg could exert a force on the magnet which was attracting it; or that the small piece of paper could exert a force on the statically charged comb.
Forces are to do with living things.	Gunstone & Watts (1985)	In the scenario involving a person applying a force onto a wall, a large proportion of students did not believe that the non-living wall could exert a force on the living person.

As described by Watts (1983) students tended to confuse the concepts of force and net force. Even after the concept of 'overall force' had been explained to students, students still struggled to make this distinction. For example, although students in group 4 seemed to understand the basic definition of 'overall force' more advanced questioning revealed that they had not yet fully grasped the concept.

Interviewer: Just say you're riding your bike along, right, and you're going at 5 km/h, and you get to the bottom of a hill, and you want to stay going the same speed.
Chelsea: Yeah.
Interviewer: So you start pedalling even harder, and you're still going at 5 km/h up the hill, is there an overall force?
Chelsea: Yes, because it's pushing you back this way.

Interviewer: Mmmm.
Chelsea: Because you're pedalling faster...
Melinda: There's an overall force because, um, its slowing down because there's a hill and, um...
Interviewer: But you're not because you're pedalling harder so you're still going 5 km/h.

The concepts of contact and non-contact forces however, seemed to be quite easily within the reach of the students in this study, and could be a viable way to introduce students to the various types of force.

The third research question asked whether idealised mechanics should be introduced at the upper primary level or if the focus should remain on real-world scenarios. As students at this stage have not yet fully progressed through the *concrete operations* stage of their cognitive development, they are likely to be unable to comprehend abstract examples, and thus it is recommended that examples used in the instruction of force and motion at the upper primary level be mainly of real-world origin, and be examples that students can readily relate to their own experiences. One example of this can be found in discussion about the skateboard on a hill example. Students typically focussed on non-idealized elements such as air resistance, the possibility of square wheels and the surface of the incline.

The final research question asks whether or not it is possible to create an effective teaching and learning sequence for the introduction of the concepts of force and motion in the upper primary school context. Such a teaching and learning sequence will depend on the relevant findings of this study which are summarized in Table 4.2. A series of six lesson plans has been created based on the results of this study and is presented in Chapter 5.

Table 4.2

Summary of the findings of this study pertinent to teaching and learning

Findings	Research Episode
Contact and non-contact forces have potential for introduction at the upper primary level.	In the second focus group sessions, once the terms 'contact' and 'non-contact' had been defined, students were able to differentiate between contact and non-contact forces.
Students are able to make links between the various forms of 'non-contact' forces.	Students spontaneously described the 'person jumping into water' scenario in terms of the water as a magnet and the man as a metal. Also, students described the static electricity example in terms of magnetism
Magnets are a useful tool for discussing non-contact forces, and also for introducing Newton's third law of motion.	Students are able to 'feel' the force between the two magnets. Also, when one magnet is restrained in position, it is possible to illustrate to students that both magnets exert a force on the other.
The inclined plane apparatus has the potential to be a useful tool in relation to these concepts.	Students enjoyed the practical activity sessions and were engaged in their learning due to the 'hands-on' nature of the activity.
Students are able to identify that there is a force present within a whole scenario, but may find it difficult to isolate the actions of particular objects within the system.	Students agreed that there was a force present between the two magnets, but there was some dispute when students were asked if magnet A was exerting a force on magnet B or magnet B was exerting a force on magnet A.
The concept of net force is too difficult for students at this age to understand.	Students found it difficult to distinguish between 'overall force' and 'force'. Also, when students were asked more advanced questions, they tended to revert to the original 'force' concept.
The bowling alley example was not found to be useful (See Appendix 2)	Although students could easily relate to the bowling alley example, its main usefulness would be the differentiation between force and momentum which was found to be too difficult for students at this stage.
The worksheet used in the second focus group sessions (See Appendix 3) did not reveal any useful data.	The majority of students answered this worksheet correctly. With those students who did not answer the worksheet correctly, the explanations given indicated that the students were simply focusing on external factors such as the impact of the ball at the bottom of a steep hill rather than the actual incline.
Students struggled with the mathematical component of the inclined plane activity. Numeracy is an important aspect of the teaching and learning of the concepts of force and motion.	Students were unable to calculate averages, and seemed to struggle in ordering decimal places. Students also tended to have difficulty in plotting and interpreting graphs.
Literacy (language) is an important component of the teaching and learning of science. Many students tend not to acknowledge the scientific meanings of words.	Students in this study did not know what the word 'exert' meant and therefore found difficulty in answering the questions about whether one object was exerting a force on the other.
Students tended to define and use scientific words in their common place contexts.	When asked to define the words force, energy, speed, momentum and gravity, students mostly used language and definitions which were anthropocentric, and which described how those concepts related to the individual ie. 'Gravity pulls you down'.
Students exhibit 'signatures for cognitive growth' when they are fully engaged in their learning and potential for cognitive growth is highest.	When conversation was most productive students were fully engaged in their learning and asked in-depth questions, made hypotheses and analogies, or created experiments to further explore the situation being discussed.

Chapter 5 – Applications

As a direct application of the results of this study and in answer to research question 4, a series of six lesson plans has been created for use in effectively introducing the concepts of force and motion to upper primary-aged students. These are summarized in Figure 5.1. The sequence of content in these lessons is as follows:

Lesson 1	Introduction to the concept of Force
Lesson 2	Non-contact forces – Magnets and Static Electricity.
Lesson 3	Non-contact forces – Gravity.
Lesson 4	Contact forces vs. Non-contact forces
Lesson 5	Inclined Plane Experimentation 1
Lesson 6	Inclined Plane Experimentation 2

Figure 5.1 Lesson Topics

These lessons have been designed to coincide with the relevant Australian Union Conference outcomes for use in Seventh-day Adventist schools. However, as shown in Chapter 2, the Victorian Essential Learning Standards (VCAA, 2005) outlines comparable learning outcomes.

During the teaching of these lessons, or lessons similar to these, teachers should be aware of the various *signatures for cognitive growth* found in this study such as the asking of probing questions, the making of hypotheses, the generation of analogies, or the creation of experiments, so as to make the best use of them as windows of opportunity to further develop student understanding.

As students of this age have not yet fully developed through the *concrete operations* stage of their cognitive development, the scenarios used in these lessons have been based on real-world experiences to which the children will be able to easily relate. Activity-based learning, as recommended by Wright (1995) has also been included where possible to assist in fully engaging students in their learning.

Lesson Plan #1

KLA: Science
Strand: Physical World
Topic: Introduction to Force
Time: 1 hour

Learning Focus: The purpose of this lesson is to introduce students to a scientific view of force.

Learning Outcomes: PW 4.6 Describes the motion of objects in relation to simple combinations of forces.

Outcome Indicators:
At the end of this lesson, each student will be encouraged to:

- Define the word 'force'.
- Distinguish between scientific and non-scientific usage of the word 'force'.

Learning Context: This is the first lesson in a series about force and motion.

Learning Resources: Paper, Pens, Whiteboard, Markers, Students' science workbooks, safety goggles.

Learning Procedure:
INTRODUCTION
10 mins Brainstorming
In 7 minutes, groups of 3-5 students must construct, by brainstorming, as many sentences which use the word *force* as possible.

DEVELOPMENT
2 mins Explaining
Give each student a pair of goggles and explain that we are going to think like scientists. Explain that sometimes scientists see things differently than we do, and hence we are going to look at the world through our 'scientist goggles'.

8 mins Questioning
Ask students to read out the various sentences that they have produced which use the word force.

10 mins Dictionaries
Students look up and list the various meanings of the words 'force' and 'exert' in the dictionary. Ask students to work out what it may mean to 'exert a force'.

10 mins Explaining
Explain to students a 'scientific' meaning of the words 'force' and 'exert' (then a meaning of the word 'exert a force').
Force – "A push or a pull"
Exert – "To put to use or effect, or to put forth"

For example – I can exert a force on the wall by pushing on it.

CONCLUSION

20 mins Sorting

Students categorize their brainstormed sentences as either 'scientific' or 'non-scientific'. Discuss the various uses of the word force and emphasize the use of the scientific meaning in science class.

Lesson Plan #2

KLA: Science
Strand: Physical World
Topic: Non-contact forces – Magnets and Static
Time: 1 hour

Learning Focus: The purpose of this lesson is to explore the action of magnets and static electricity.

Learning Outcomes: PW 4.6 Describes the motion of objects in relation to simple combinations of forces.

Outcome Indicators:
At the end of this lesson, each student will be encouraged to:

- Indicate whether or not a specific object within a system is exerting a force on other objects within the system.
- Explain the actions of magnetic force, and static electricity.

Learning Context: This is the second lesson in a series on force and motion. In this lesson, students are introduced to the various forms of non-contact force.

Learning Resources: Magnets, small metal object, comb, small pieces of paper.

Learning Procedure:
INTRODUCTION

5 mins Magnets
In small groups students experience the feeling of magnets pulling together (attracting) and pushing apart (repelling). Also, students experience a magnet attracting a small piece of metal.

DEVELOPMENT

15 mins Discussion
As a class discuss:
1. Whether there is a force between the 2 magnets.
2. Whether magnet A is exerting a force on magnet B?
3. Whether magnet B is exerting a force on magnet A?

10 mins Discussion
In the light of the fact that both magnet A and magnet B are exerting a force on one another, discuss:
1. Whether there is a force between the magnet and the metal.
2. Whether the magnet is exerting a force on the metal?
3. Whether the metal is exerting a force on the magnet?

5 mins Explaining/Demonstrating
Demonstrate to students that the metal does in fact exert a force on the magnet by holding the metal stationary and watching it attract the magnet to itself.

CONCLUSION

15 mins Demonstrating/Discussing

Demonstrate to students how a comb charged by combing hair will attract a small piece of paper (Note. This demonstration may not work on an overly humid day).

Question students:

1. Is the comb exerting a force on the paper?
2. Is the paper exerting a force on the comb?

Explain that just like with the magnet and the metal, there is always 2 forces acting, and therefore the paper is exerting a force on the comb but the comb does not move (due to its larger size).

POSSIBLE *SIGNATURES FOR COGNITIVE GROWTH* THAT MAY ENCOURAGE LEARNING (as demonstrated in this study)

- Students ask questions regarding a magnet which can pick up a car and put it down again.

  For example:

  Phillip: Have you seen that big magnet in Melbourne where they pick up the junk, the car, and they squash all the cars up, and they put this big magnet around the car and they put on the magnet... the car just goes straight up.. and then they go around and if they want it in a spot they, then they press the button and it turns the magnet off and it drops, the magnet stops, because the magnet has a generator in it and the magnet stops and it just goes...

- Questions such as this could lead to a discussion about electromagnets, as opposed to permanent magnets.

Lesson Plan #3

KLA: Science
Strand: Physical World
Topic: Non-contact forces – Magnets, Static and Gravity
Time: 1 hour

Learning Focus: The purpose of this lesson is to revise the action of magnets and static electricity and to introduce the concept of gravity.

Learning Outcomes: PW 4.6 Describes the motion of objects in relation to simple combinations of forces.

Outcome Indicators:
At the end of this lesson, each student will be encouraged to:

- Identify the action of gravity within a system.
- Explain the actions of magnetic force, static electricity and gravity.

Learning Context: This is the third lesson in a series on force and motion. In this lesson, students revise magnetism and static electricity and are introduced to the concept of gravity.

Learning Resources: Magnets, small metal object, comb, small pieces of paper, flashcard depicting person jumping into pool, a variety of objects to drop from varying heights (ie, feather, stone, balls, books etc.)

Learning Procedure:
INTRODUCTION

10 mins Revision
Revise the demonstrations discussed in the last lesson involving the magnets, peg, paper and comb. Remind students that if there is two objects in a system, then there is always two forces acting.

DEVELOPMENT

20 mins Questioning
Display the 'person jumping into pool' card.
Ask students:
1. What will happen when the person steps off the diving blocks?
2. Why?

Discuss the action of gravity in pulling objects towards the earth.

20 mins Demonstration/Discussion
Give students a variety of objects, such as a feather, a stone, balls of different sizes, and have them drop them from different heights.
Discuss how objects fall, what slows them down (air resistance) and what it is that makes them fall towards the ground (gravity)

CONCLUSION

10 mins Directing/Monitoring

Direct students to draw in their science books an object being affected by gravity (ie, an apple falling from a tree; a person jumping off a balcony etc.)

POSSIBLE *SIGNATURES FOR COGNITIVE GROWTH* THAT MAY ENCOURAGE LEARNING (as demonstrated in this study)

- Students questioning about what would happen if there was no gravity present. For example.

  Phillip What if there's no gravity?

  Gavin If there's no gravity you'd float up in the air
- This question could lead to a discussion on the effects of gravity, the differences between gravity and air pressure, or what life would be like on the moon where there is less gravity than on the earth.
- The concept of gravity also has potential for discussion of the topics of weight and mass.

Lesson Plan #4

KLA: Science
Strand: Physical World
Topic: Contact vs. Non-contact forces
Time: 1 hour

Learning Focus: The purpose of this lesson is for students to learn to differentiate between contact (touching) and non-contact (non-touching) forces.

Learning Outcomes: PW 4.6 Describes the motion of objects in relation to simple combinations of forces.

Outcome Indicators:
At the end of this lesson, each student will be encouraged to:

- Categorize forces as either contact or non-contact.
- Use Newton's third law to explain that static objects can 'exert a force'.

Learning Context: This is the fourth lesson in a series on force and motion. In this lesson, students learn to differentiate between contact and non-contact forces.

Learning Resources: Wall, Magnets, small metal object, comb, small pieces of paper, flashcard depicting person jumping into pool, Students' science workbooks, Whiteboard, Markers, spring.

Learning Procedure:

INTRODUCTION

5 mins Demonstrating
In pairs, students push against each other, then students push against the wall of the classroom.

DEVELOPMENT

15 mins Discussing
Discuss with students whether student A and/or student B is exerting a force on the other?
Develop this concept by discussing/explaining that the wall must exert a force on the person otherwise the wall would fall over.

10 mins Dictionaries
Students are given 10 mins to use their dictionaries to look up the word 'contact' and come up with a hypothesis of what the terms 'contact forces' and 'non-contact forces' mean.

10 mins Explaining
Explain the difference between contact and non-contact forces in terms of 'touching' and 'non touching' forces. Brainstorm some examples of each.

5 mins Experimenting

Students experiment with depressing springs. When the spring is fully depressed, the students can 'feel' the force 'pushing' back against their hand. Link this experience to the student pushing against the wall.

CONCLUSION

15 mins Categorizing

In their science books, students create a table of 'contact' and 'non-contact' forces, with a short explanation of the meaning of each.

Lesson Plan #5

KLA: Science
Strand: Physical World
Topic: Inclined Plane Experiment 1
Time: 1 hour

Learning Focus: The purpose of this lesson is to allow students to practice measuring and the use of stopwatches to collect data of the time taken for a ball-bearing to roll down an incline.

Learning Outcomes: PW 4.5 Designs builds, and describes the operation of simple devices to transfer or transform energy.

Outcome Indicators:
At the end of this lesson, each student will be encouraged to:

- Describe the motion of a ball-bearing down an inclined plane.
- Measure the time taken for a ball-bearing to roll down an inclined plane from a given starting point.

Learning Context: This is the fifth lesson in a series on force and motion. In this lesson, students participate in a practical activity to demonstrate the action of gravity and aspects of motion.

Learning Resources: Inclined plane apparatus (Retort stand, angled metal, clamp), ball-bearings, stopwatches, worksheets, calculators, flashcard of skateboard on a hill.

Learning Procedure:
INTRODUCTION

5 mins Discussing
Discuss flashcard of skateboard on a hill, and why the skateboard would roll down the hill ie. Gravity.

DEVELOPMENT

30 mins Experimenting
First demonstrate and practice using the stopwatch to take time measurements. Students then experiment with the Inclined Plane Apparatus (after practicing first) to obtain three time measurements for each starting point. Explain that multiple measurements are taken to get more accurate results. Also explain that the inclined plane is much like a 'hill'.

20 mins Instructing/Demonstrating
Teach students how to calculate averages, explain that we take averages because we cannot possible obtain the same reading every time, and we need a way of ensuring that our results are as accurate as possible.
Have students calculate the average time for the ball-bearing to reach the bottom from each of the starting points on the inclined plane.

CONCLUSION

5 mins Questioning

Question students about how long the ball took to reach the bottom from each starting point. Discuss whether it took more or less time as the ball traveled further. Ask students for suggestions of how it is possible to compare these numbers (tables, graphs, etc)

Lesson Plan #6

KLA: Science
Strand: Physical World
Topic: Inclined Plane Experiment 2
Time: 1 hour

Learning Focus: The purpose of this lesson is to allow students to teach students how to draw graphs and to practice this skill with the data obtained from the inclined plane experimentation.

Learning Outcomes: PW 4.5 Designs builds, and describes the operation of simple devices to transfer or transform energy.

Outcome Indicators:
At the end of this lesson, each student will be encouraged to:

- Describe the motion of a ball-bearing down an inclined plane.
- Draw a graph displaying distance against average time for a ball-bearing to roll down the inclined plane

Learning Context: This is the sixth lesson in a series on force and motion. In this lesson, students use data obtained in the last lesson to create a graph showing distance against average time for a ball rolling down the inclined plane.

Learning Resources: Worksheets, graphs of accelerating object, decelerating object, and an object travelling at a constant speed.

Learning Procedure:
INTRODUCTION

10 mins Discussing
Revise the time and average time data obtained in the last lesson.

DEVELOPMENT

20 mins Instructing/Demonstrating
Teach students how to plot points on a graph (link to mapping if this has been previously taught).
Students plot points on their worksheets from the data obtained in the last lesson.
Have students create a curve from the points plotted on their graphs.

20 mins Displaying/Discussing
Display the three example graphs (accelerating object, decelerating object, and object remaining at a constant speed). Have students guess which one is which, check their answers by first reading how long it took the object to travel the first meter, and then how long it took to travel the second meter.

CONCLUSION

10 mins Discussing

Discuss with students which one of the graphs displayed is most like the one that they have drawn (should be the graph of an accelerating object), ask students whether their ball-bearing was getting faster, slower, or staying at the same speed. Explain that gravity tends to make objects speed up, and that it was gravity that made the ball-bearing travel down the incline.

POSSIBLE *SIGNATURES FOR COGNITIVE GROWTH* THAT MAY ENCOURAGE LEARNING (as demonstrated in this study)

- Students may question whether 1.36 or 1.5 is the larger number. This kind of questioning could lead to a more in-depth discussion about place value.

Chapter 6 – Conclusion

This study has explored the ideas held by one class of grade 6 students relating to the concepts of *force* and *motion*. Student conceptions were explored through the use of focus group interviews and individual interviews in addition to practical activity sessions which were centered on the inclined plane apparatus. During the first focus group sessions, students were questioned about force-related scenarios involving magnets, static electricity, gravity, and contact forces. Students were also asked to provide their own definitions of the words *force, energy, gravity, momentum* and *speed* in order to compare students' understanding of these words with the understanding held by the interviewer. The second focus group sessions took more of a teaching approach with the concepts explored during the first focus group sessions further examined from a scientific perspective. Three of the six individual interviews consisted of an abridged version of the two focus group sessions in order to obtain the maximum amount of data from the maximum number of students, while the remaining three were used to gain additional insight into answers provided by students in the focus group sessions. Three groups of students participated in practical activity sessions which involved the collection and analysis of data from the inclined plane apparatus. Audio recordings of these interviews were transcribed and carefully analyzed in order to obtain the results of this study.

6.1 Results of the study

The analysis of student responses obtained during these interview and practical activity sessions found that students at the upper primary school level shared a small number of ideas related to force and motion as outlined in the literature. However, due to varying syllabus requirements and their earlier stage of cognitive development, students in the upper primary school hold a largely unique set of beliefs regarding these concepts. It must

also be considered that the current literature regarding student ideas about force and motion is heavily focused on the secondary and tertiary age bracket. Therefore the results of this study fill a significant gap in the literature.

The feasibility of introducing a number of concepts at the upper primary level was explored. It was found that although the concept of net force, resultant force, or 'overall force' appears too abstract for students at this stage, the concepts of contact and non-contact forces were within the reach of these students following explanation from the interviewer. As the students in this study were at the beginning of the *formal operations* stage of their cognitive development, they were not fully able to understand abstract concepts and hence it is recommended that scenarios selected for use with students of this age are those which students can relate to in their everyday experience of the world. When students are able to relate to the scenarios presented to them, they become more fully engaged in their learning, and hence there is more potential for cognitive growth.

As the conversations of students were further analyzed, it was noted that there tended to be a large amount of variance between highly productive dialogue and unproductive dialogue. When this productivity was graphed against time, definite peaks of productivity emerged in situations where students were most engaged in their learning. These 'signatures for cognitive growth' were apparent when the students began asking probing questions, making hypotheses, generating analogies and creating their own experiments to further explore the concepts discussed. Teachers must be aware of these signatures in order to best capitalize on them, and allow the greatest opportunities for cognitive growth. The notion of 'signatures for cognitive growth' is consistent with a constructivist view of learning as it allows students to construct knowledge based on what they already understand, and to continue along a developmental pathway towards more detailed scientific understanding (Greive, 2005).

With the student ideas and 'signatures for cognitive growth' in mind, a series of six lesson plans was created for the introduction of the concepts of force and motion in the upper primary school. The lessons include careful consideration of language and definitions, as this issue became clear in the interview sessions, in addition to exploration of contact and non-contact forces, and experimentation with the inclined plane apparatus. Issues of numeracy were also considered and addressed during the inclined plane lessons. This study managed to answer the research questions in a satisfactory manner. However, there were some external and uncontrollable factors which limited the effectiveness of the research.

6.2 Limitations of the study

There were a number of limitations faced by this study which must also be addressed. Firstly, as the interviews needed to be conducted within a one week period, and to take place at convenient times for the classroom teacher, time was limited during the interviews. This not only led to time pressures during the actual interviews, but also meant that there was insufficient time between interviews for an accurate researcher journal to be kept. Secondly, although this study involved one whole class of grade 6 students, this may not necessarily portray a generalizable result for the population as the students in this class were all from a similar geographic area and socio-economic background. Despite these limitations, this research project has uncovered a number of potential areas for further research, and these are discussed here.

6.3 Implications for further research

The results of this study have implications for further research in the area of the concept of force and motion in the upper primary school context. Although tentative answers have been suggested to research questions 3 and 4, more research needs to be conducted in order

to obtain more conclusive results. For this to occur, student interactions with ideas relating to both real and idealized situations should be explored, the suggested lesson plans from this study tested in a classroom setting, and their appropriateness and practicality determined. Also, the attitudes of teachers towards the concepts of force and motion and the syllabus requirements in this area could be explored. In addition to this the attitudes and preparedness of pre-service teachers in relation to this concept may form the basis of a new research project. Another future research project could potentially explore more thoroughly the use of magnetism and static electricity as a means of introducing the concepts of force and motion. The concept and nature of 'signatures for cognitive growth' needs to be further explored, as this notion has the potential to greatly impact science education on a classroom level. As there is little previous research in regards to the concepts of force and motion in the upper primary school, there are endless opportunities for further research into this area.

This study has addressed questions relating to the teaching and learning of the concepts of force and motion in the upper primary context. It has uncovered a number of student ideas relating to these concepts, as well as investigated the effectiveness of introducing the concepts of net force and contact and non-contact forces. A series of lesson plans has been created as a suggested format for effectively introducing the concepts of force and motion to students in the upper primary school. Further research is required into this area, and that of teaching other scientific concepts in the upper primary context in order to ensure that students in the upper primary school are taught science effectively and in such a way that will build on their prior understanding.

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Appendix 1 – Ethics Committee Approval Letter

[redacted]

Avondale College
CHRISTIAN HIGHER EDUCATION

7 December 2005

Ms Rebecca Carruthers
C/- Dr Kevin de Berg
Faculty of Science and Mathematics
Avondale College
PO Box 19
COORANBONG NSW 2265

Dear Rebecca

Research Project: **The Teaching and Learning of the Concepts of Force and Motion in Upper Primary School Education**

Thank you for your sound application for ethics approval of the above research project.

The Avondale College Human Research Ethics Committee has voted to approve your application for the above research using human subjects, subject to the following conditions:

- In the parent/guardian information/consent letter, correct the following typographical errors:
  - Fax number of HREC secretary is 4980 2118 .
  - Last paragraph, first two sentences: "...have **your** child participate..." and "If **you** are willing..."
- Find out if the school you use *does* have a policy requiring a teacher to be present, and include this information in the consent letter.
- Amend the last sentence of the consent letter so it reflects that fact that the parent should ask the child if they are willing to participate, eg "We would be delighted to have your child participate in this study if s/he is agreeable."
- Include in the consent letter the fact that (a) the child may withdraw from participation at any time, and (b) you will verbally inform the children that they may withdraw from participation at any time.
- That you recognise that the data must be shredded within five years (this is not clearly stated in your response to section 12.2 of the application form.)

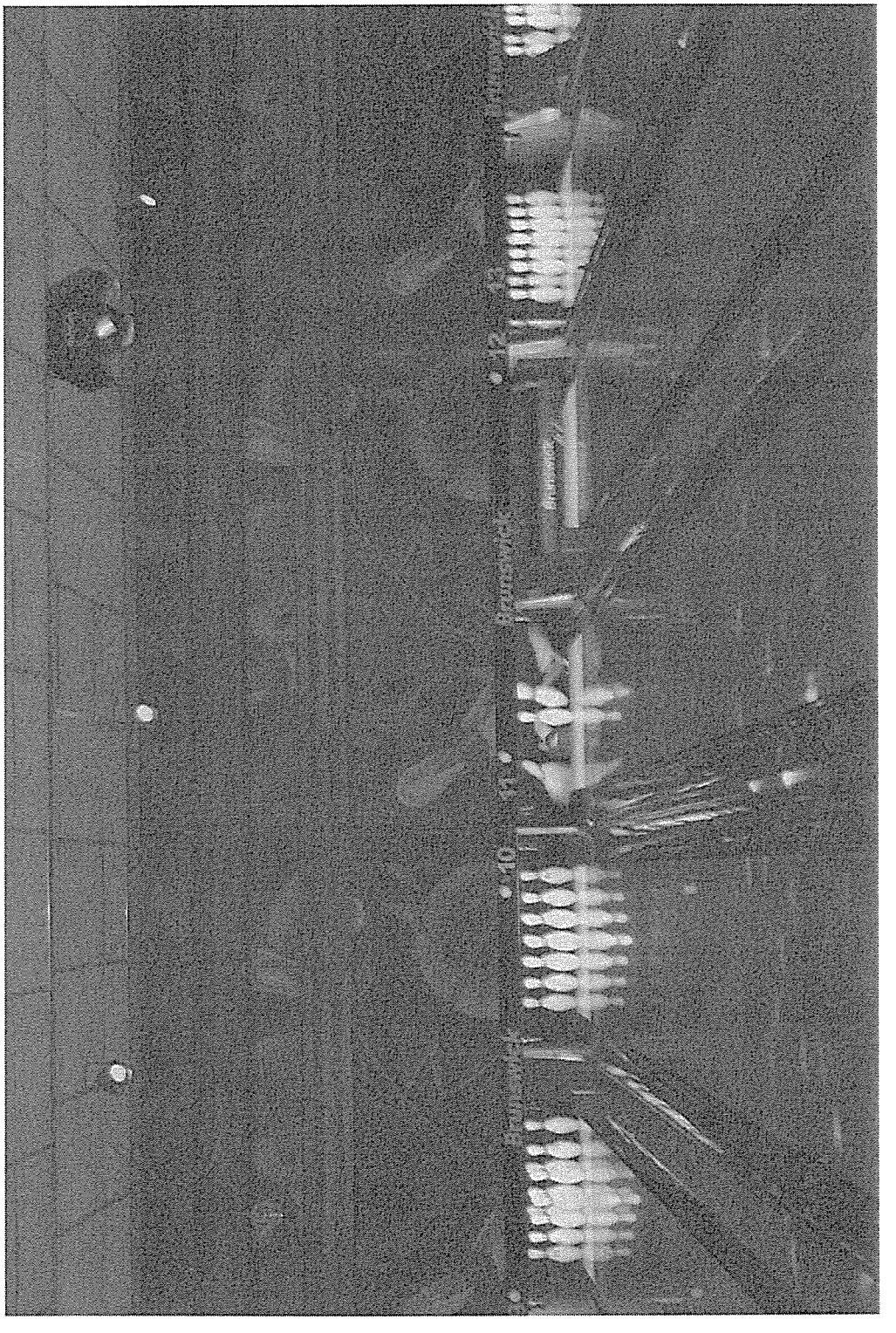
As a condition of approval, we require that you notify the committee of any changes to circumstances or research design which might require a review of the ethics approval. We note that this project is due to finish in December 2006, and look forward to receiving your report at that time. We wish you well with this research.

Sincerely

Dr Robyn Pearce
Acting Chair
Human Research Ethics Committee

582 Freemans Drive PO Box 19 Cooranbong NSW 2265 Australia Telephone 02 4980 2222 Facsimile 02 4980 2118
Avondale College Limited ACN 108 186 401 ABN 55 108 186 401

Appendix 2 – Bowling Alley Photo used in Focus Group session 1

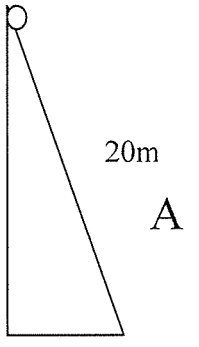


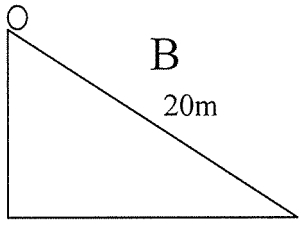
Appendix 3 – Worksheet used in Focus Group session 2

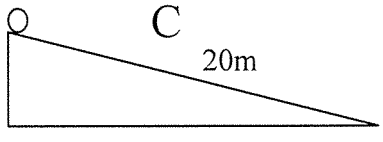
Name:_____

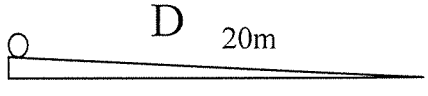
Number the inclines in order of which ball you think will reach the ground first (1 = first, 4 = last).
Also, number the inclines in order of which ball you think will be traveling fastest when it reaches the bottom (1 = fastest, 4= slowest).

First Fastest









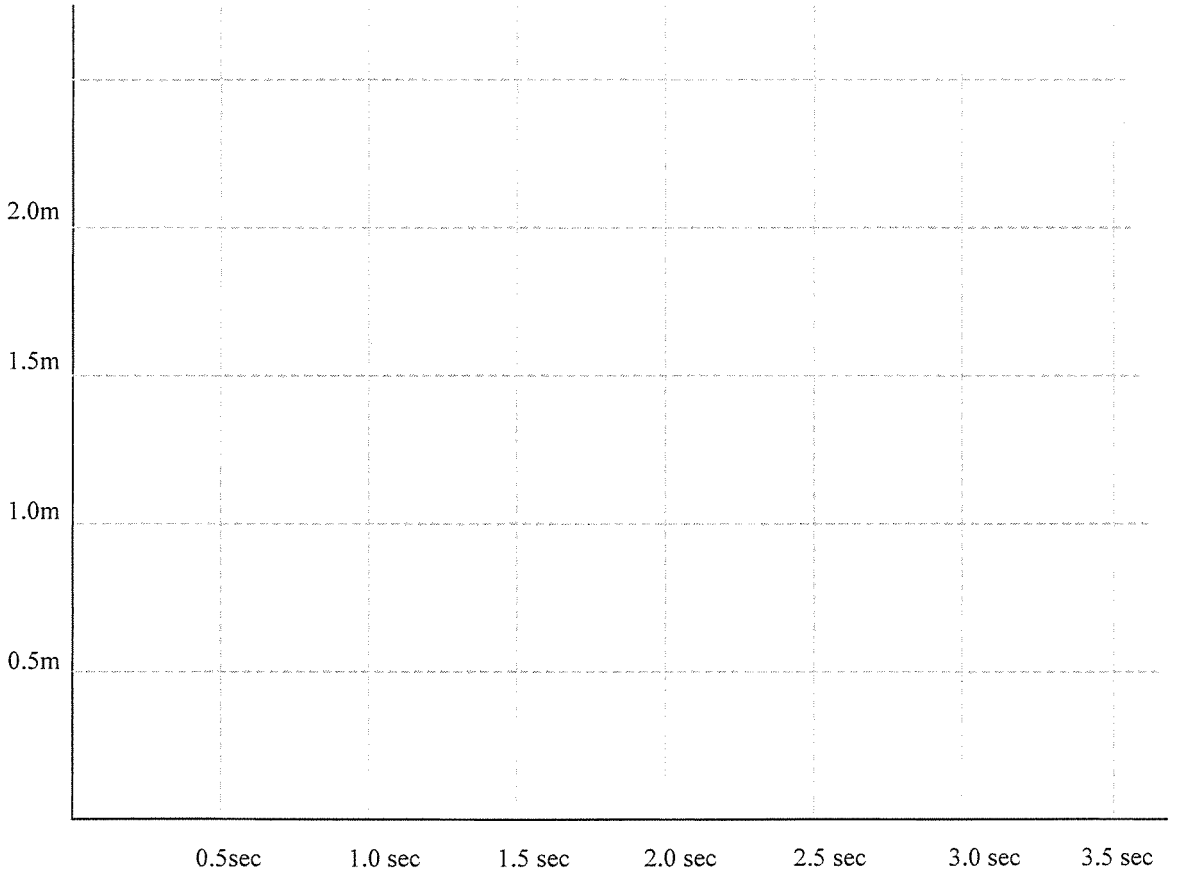
Please explain your answers:
I think the ball on incline _____ will reach the bottom first because _____
_____.
I think the ball on incline _____ will be traveling fastest when it reaches the bottom because _____
_____.
_____

Appendix 4 – Worksheet used in Practical Activity session

Name: _____

Roll the ball down the inclined planes at different distances from the end: 0.5m, 1m, 1.5m, and 2m.
Record your results on the table below, and then draw a graph of your results.

Distance (m)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average Time
0.5m				
1.0 m				
1.5 m				
2.0 m				

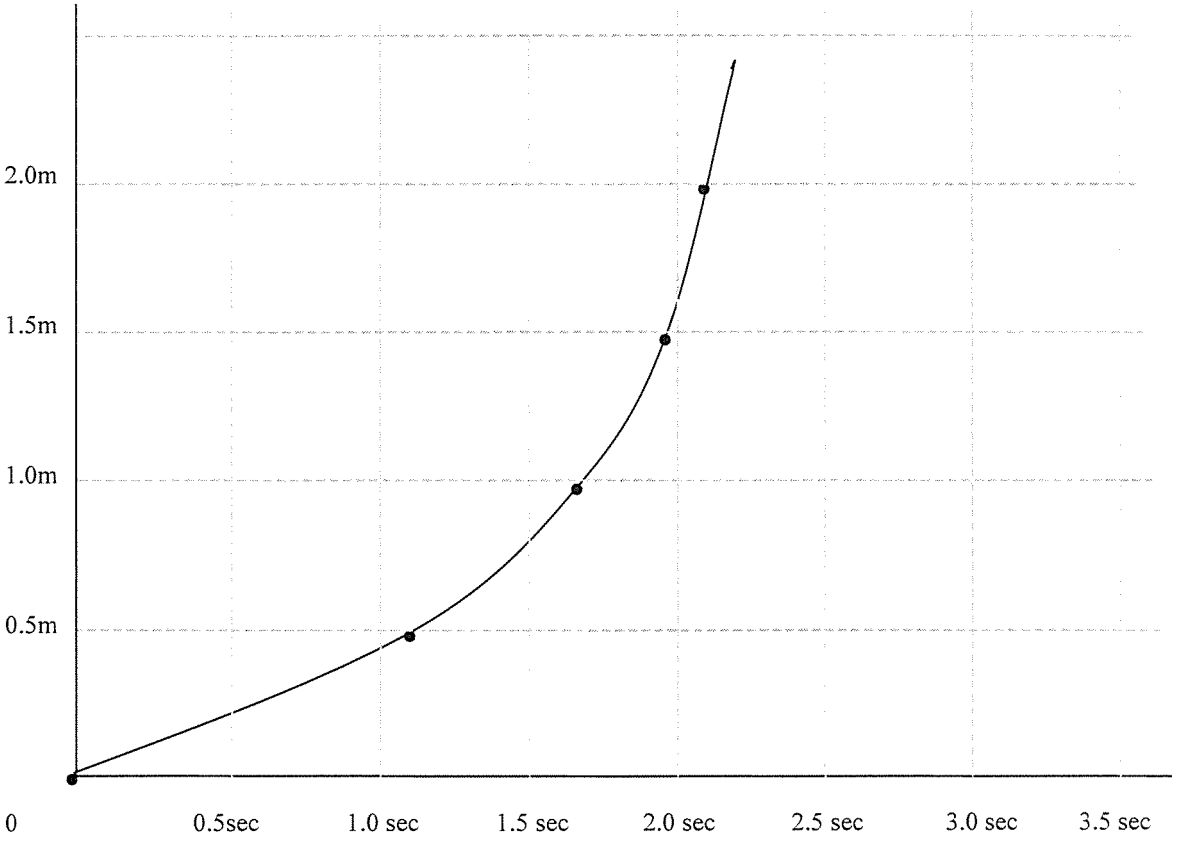


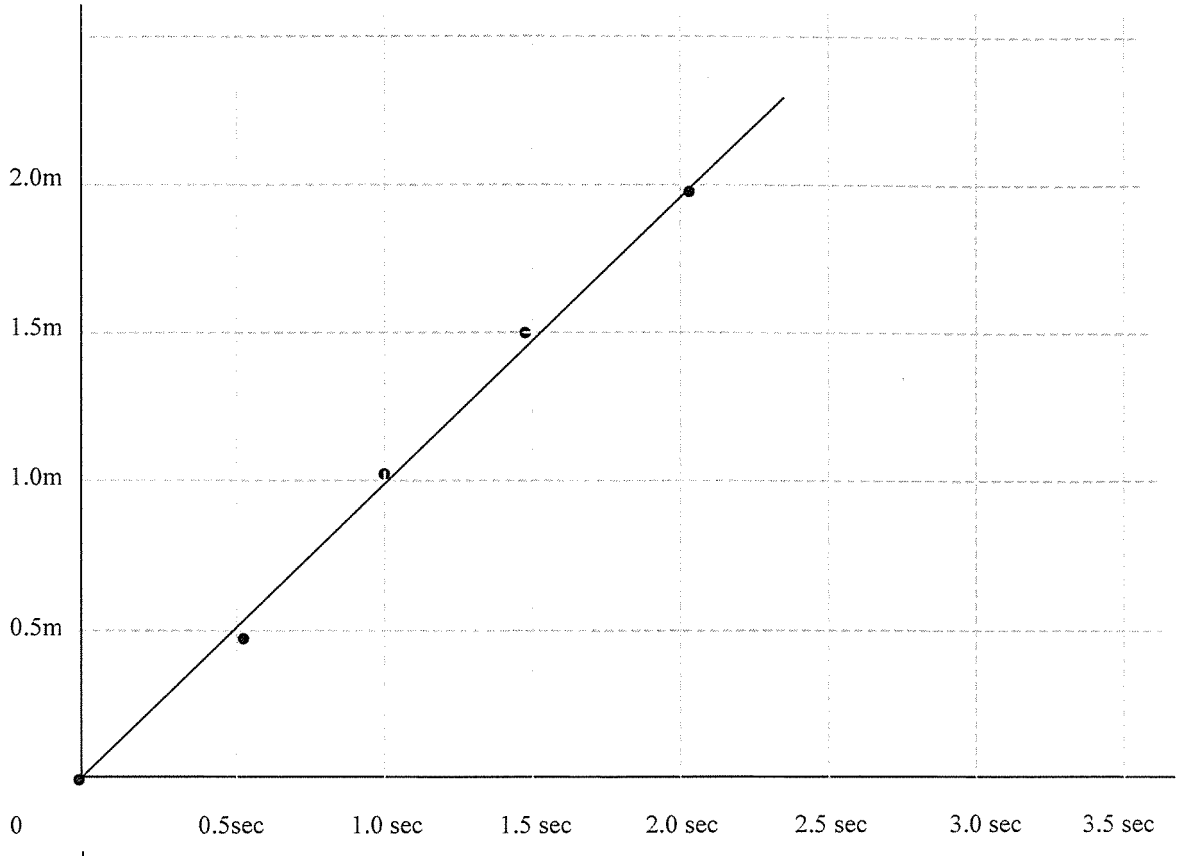
Is the ball getting faster/slower/same speed? _____
Can you work out the average speed of the ball over 2m? _____ m/sec

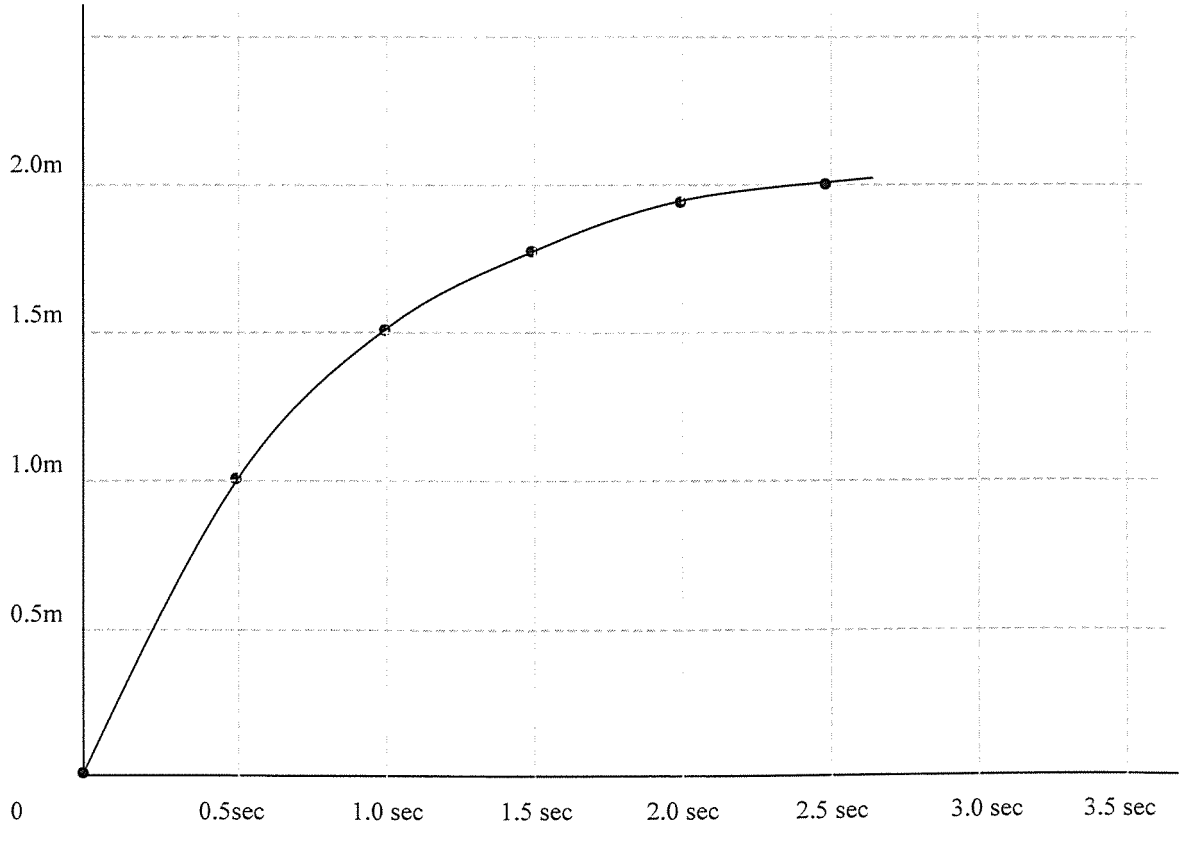
= _____ m/s

Appendix 5 – Graphs used in Practical Activity Sessions

Graphs of Distance vs Average time for an object which is accelerating (first graph), travelling at a constant speed (second graph), or decelerating (third graph)




2.0m
1.5m
1.0m
0.5m
0
0.5sec
1.0 sec
1.5 sec
2.0 sec
2.5 sec
3.0 sec
3.5 sec


2.0m
1.5m
1.0m
0.5m
0
0.5sec
1.0 sec
1.5 sec
2.0 sec
2.5 sec
3.0 sec
3.5 sec

Appendix 6 – Sample Transcript

Individual Interview 1
Student: Alana
Date: 6th February, 2006

Interviewer: ... before we get going that, you being here is all by your choice, if at any stage you don't want to be here or you want to stop it or pull out, that's fine, it's all your choice, and its not going to be a problem.
And thank you so much for helping me out.
Alana: That's alright.
Interviewer: Um, I have some words for you. I had them on flash cards, but I don't have them with me, so I'll just ask you what they mean. Basically I just want you to tell me what those words mean to you, and just in your own words what you think they mean.
Ok, the first word is force.
Alana: Like, the pressure pulling, or like pushing.
Interviewer: Alright, that's a good one, how about speed?
Alana: Speed, fast, going fast.
Interviewer: Good, how about going slow? Is that to do with speed aswell?
Alana: Yes.
Interviewer: So it's how... sort of... fast you're going.
Alana: Yeah.
Interviewer: That's spot on. Um, have you ever heard the word momentum before?
Alana: I have but, like, only... I dunno. I have, but I don't know what it means.
Interviewer: That's cool. Um, gravity?
Alana: Like.... It's like, kind of something that...
Interviewer: Yeah, what does it do?
Alana: Pulls you, um, pushes you... up... I dunno, I dunno.
Interviewer: That's alright.
Alana: Up or down.
Interviewer: Yep, or energy?
Alana: Energy, um, like when you have heaps of energy and you can...
Interviewer: So what can you do when you've got heaps of energy.
Alana: Run, do heaps of sport and stuff.
Interviewer: Yep, that's cool.
Ok, if I push against this wall here, am I putting a force on the wall?
See, is the wall putting a force on me?
Alana: Yep. You're putting a force on the wall.
Interviewer: Yeah, but is it putting a force back on me?
Alana: Yep.
Interviewer: Yeah, how do you know that?
Alana: Because, I dunno.
Interviewer: Well what would happen if the wall wasn't putting a force back on me?
Alana: You would, your hand wouldn't be on it.
Interviewer: Yeah, it would probably fall over wouldn't it.
Alana: Yeah.
Interviewer: Yep, what about if, if I have a magnet, and a little bit of metal. What's going to happen? If I bring them closer together.
Alana: They'll stick.
Interviewer: Yep, the bit of metal will stick to the magnet. Is the magnet putting a force on the bit of metal? Is the bit of metal putting a force on the magnet?
Alana: No.
Interviewer: No?
Alana: Ah, yeah, yeah, they're both putting force on each other... I think.

Interviewer: You think? Why do you think that....
Alana: The magnet's putting the force on it.
Interviewer: Mmmm.
Alana: Because it's why it sticks to it.
Interviewer: Yeah. That's a good one.
Then we talked about with our group interviews that we did, we talked about how there's always like... If there's a force happening, if there's a force between two objects, there's always two forces happening.
Do you know what I mean? Like, if I pushed against you and you pushed back on me. I'm putting a force on you, and you're putting a force on me.
And if I push on the wall, I'm putting a force on the wall and the wall is putting a force on me. It's the same with the magnet, and the, um, but of metal.
Alana: Mmmm.
Interviewer: What about gravity? The earth's pulling us down, or if gravity is pulling us towards the earth. What other forces could there be?
... Are we putting a force on the earth as well? Like, the earth's pulling us towards it, are we...
So why is it that the earth doesn't move towards us?
Or why is it that this magnet pulls this little bit of metal, but the metal doesn't drag the magnet towards it?
Alana: Because....
Interviewer: Stumped? That's alright.
Alana: I can't explain it, because I know, like, but I can't explain it...
Interviewer: That's fine. The reason that I think it is, and the reason that a lot of scientists think it is is because the magnet is so big, and the little bit of metal is so little. And the world's so big, and compared to the world, we're so little. So that our force on the world isn't big enough...
Alana: Mmmmm.
Interviewer: ... to make it move towards us, does that make sense?
Ok, while we're here, I'll get you to do one of these for me as well, it's just a really easy worksheet. And again, it's just what you think.
Can you put your new name up there, the one that you chose.
Ok, and basically we've got four inclines and they're basically just like hills, but imagine riding your bike down a hill, and we've each got a ball at the top, they're the same length and you see how it says first, and its got four lines underneath it, can you order... so put a one next to the first one and a two next to the second one... which ball you reckon will get to the bottom first.
Alana: Ok.
Interviewer: So you put the one there... yep, and then the second one....
Ok, so we've got down here 'please explain your answer' so 'I think the ball on incline'... you put A didn't you... ' will reach the bottom first because, so just a one sentence.
Alana: So do I put A there?
Interviewer: Yeah. And just... even just a couple of words why you think it will.
Alana: Because its more steep and the ball will roll down it faster.
Interviewer: Yep, that's good.
Alana: And not that because.....
Interviewer: It's so flat.
Alana: Is it double 'e'?
Bec: Yep.
That's a good one, and this one here, it just says fastest. So when the ball gets to the bottom of the hill, which of these balls do you think will be travelling the fastest by the time it gets to the bottom of the hill?
It's the same, 2nd...
And, same... explanation.
Alana: Do I just write that again?
Interviewer: If that's what you think the answer is!

It's alright, you're not getting graded on this.
Nice, told you it was easy didn't I!
What else can I ask you?
Have you ever been ten pin bowling?

Alana: Yep.

Interviewer: Alright, what is it that makes the ball move in the first place?

Alana: The slippery, um, um, bowling alley thing, and you throwing it.

Interviewer: That's good. What is it that keeps it moving?
So if your pushing it makes it move, what is it that keeps it moving?

Alana: The slippery alley…. I dunno.

Interviewer: And why… why do the pins fall over?

Alana: Because you're hitting them with the ball.

Interviewer: Ok, that's a good one. Um, if I was standing at the top of a hill, on a skateboard, and if I took my foot off the ground and just stood on the skateboard, what would happen.

Alana: You'd roll down the hill.

Interviewer: Roll down the hill? Yep.
What makes me go rolling down the hill?

Alana: Because you um, because there's nothing to stop you because you've taken your feet off the ground and put them on the skateboard.

Interviewer: Yep, and would I be getting faster, or slower, or staying at the same speed?

Alana: Fas…. Um…

Interviewer: As I go down the hill.

Alana: Faster.

Interviewer: Faster, good answer.
We get through this so much faster when there's just two of us!
Can you think of some everyday uses of the word force? Like, ways you might here people use the word force that aren't necessarily the way scientists would think.
Like if I give you an example… Have you seen Star Wars?

Alana: I've seen number one…

Interviewer: 'May the force be with you'
That's one, can you think of any others.

Alana: Nup.

Interviewer: No?

Alana: I don't really hear people saying force much.

Interviewer: What about, I'm going to force you to do your homework?

Alana: Yep.

Interviewer: You've heard that one?
Alright, my definition, just so that you can learn something, my definition of a force is 'a push or a pull', and that's a scientists… I get that from scientific people… It's basically anything that's pushing something or pulling something.
Is gravity pushing or pulling?

Alana: Pushing… pushing I think.

Interviewer: You think its pushing?
Is…

Alana: Is it pulling or pushing?

Interviewer: It's pulling.

Alana: Oh.

Interviewer: That's alright.

Interviewer: Is, um, me opening that door, would I be pulling or pushing?

Alana: You'd be pulling.

Interviewer: Yep, um, if… yeah, we know that they're all pushing or pulling.
And I think that's all we've got time for.
Thank you for helping me out Alana, I really appreciate it, can you…

Appendix 7 – Parental Consent Letter

Rebecca Carruthers
Avondale College
Cooranbong, NSW 2265

Dear Parent/Guardian,

I am a 4th year BEd (Primary) Honours student studying at Avondale College. I am conducting a research project to identify student ideas about the concepts of force and motion.

I would like to carry out a series of small group interviews with your child's class taking approximately one hour each. In these interviews, students will be asked to respond to a series of flashcards/photos about force, and also to complete a short written task. In these instances, opportunity will be given for your child to learn new concepts during the interview process.

Also, approximately four children from your child's class will be asked to participate in individual interviews, in which they will further elaborate on their ideas about force and motion. These individual interviews will take up to 20 minutes.

Three pairs of students will be asked to take part in a hands-on activity, which will also involve a written task, and the interpretation of graphs. This will take up to 30 minutes.

Interviews will take place in the first 2-3 weeks of Term 1, 2006. In line with school policy, another teacher will be supervising each of the sessions.

From this research, I will be looking to gain insight into the ideas held by upper primary school children about force and motion, and to recommend a teaching and learning sequence which takes these ideas into account.

While interviews will be audio taped, confidentiality will be maintained through the changing of student names, and the name of the school in any documents, including my thesis.

Your child may withdraw from this study at any time without penalty, and will be informed of this in the first session. Any questions can be addressed to either myself (Rebecca Carruthers – Honours Student) via the school or to my supervisor (Dr Kevin de Berg) on (02) 49802215.

This research project has been approved by the Avondale College Human Research Ethics Committee (HREC). Avondale College requires that all participants are informed that if they have any complaint concerning the manner in which a research project is conducted it may be given to the researcher, or if an independent person is preferred, to the College's HREC Secretary, Avondale College, PO Box 19, Cooranbong, NSW 2265 or phone (02) 4980 2121 or fax (02) 4980 2118.

We would be delighted to have your child participate in this study if he/she is agreeable. If you are willing to allow him/her to take part, please fill out the form below, ticking one or more interviews/activities in which you are willing for you child to participate.

Thank you for your time,

Rebecca Carruthers
(Honours Student)

Dr Kevin de Berg
(Principal Supervisor)

I _____, give permission for my child _____ to:

_____ Participate in small group interviews.
_____ Participate in individual interviews.
_____ Participate in the experimental activity.

I understand that participation in this study is voluntary, and that I may withdraw permission at any time.

Signed:_____ Date:_____

AVONDALE COLLEGE LIBRARY