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Performance and Confidence Levels of Students Entering Physics at Three South African Universities

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Performance and Confidence Levels of Students Entering Physics at Three South African Universities

by

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Submitted in partial fulfillment to satisfy the requirements for the degree of Master of Science in Science Education

Faculty of Natural, Agricultural and Information Sciences

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Dr E. Gaigher

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DECLARATION

I declare that the dissertation that I hereby submit for the degree in Masters of Science (Science Education) at the University of Pretoria has not previously been submitted by me for the degree purposes at any other university.

Setswamohlokong Esther Malatje

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Last but not least, I would like to thank God Almighty for giving me the strength and courage to persevere in this study.

DEDICATION

This dissertation is dedicated to my mother Maisaka Margaret Mushi, my late father Lori Lawrence Mushi, my late brother Malesela Michael Mushi and my late aunt Manthepe Rosina Mabusela.

ABSTRACT

A test instrument, made up of 25 items, derived from existing standardized tests from literature, was used to probe for the students' knowledge and understanding of basic mechanics concepts, as well as the confidence in the correctness of their answers. The test was administered to 982 first entering physics students; enrolled at three South African universities, at the beginning of the year before any formal instruction could take place. Data collected for this study included students' responses from multiple-choice questions and open-ended explanations to their chosen answers. The analysis of the multiple-choice responses and the written explanations revealed the existence of alternative conceptions among students and that the students' accuracy of judgment about their knowledge and understanding of basic mechanics concepts is different among the different cohorts.

Physics education research, has over a number of years, revealed that students have alternative conceptions about physical processes. These alternative conceptions are accumulated from the students' past personal experiences, interactions with people around them and the environment they live in. It was found from the study that the strength of the known alternative conceptions differs among the different cohorts. There are those alternative conceptions that are easier to correct with sound teaching. These alternative conceptions exist mostly in worst performing cohorts and less so in the best performing cohorts. There are those alternative conceptions that persisted despite better teaching. These alternative conceptions are found in all the cohorts.

The certainty of response analysis revealed the differences in the relationship between performance and confidence among the students from the three universities. It was also found that students make incorrect judgment about their knowledge and understanding of basic mechanics concepts. The overall trend emerging from the study was that students seem to be overconfident about their knowledge and understanding of basic mechanics concepts, but that students with a good command of mechanics concepts made the best judgment about the correctness of their answers.

The item-by-item analysis of students' responses revealed that in most cases the best performing students make quality judgment about their performance, while poor performing student always make inaccurate judgments about their performance. Analysis of the students' written explanations and item difficulty revealed that the Hasan *et al.* (1999) study is lacking in the differentiation between lack of analytical skills and the presence of alternative conceptions. Lack of analytical skills cannot be classified as evidence of the presence of alternative conceptions. The student may be having knowledge of the necessary concepts, but lack higher order analytical skills to be able to interpret situation presented.

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CHAPTER 1 INTRODUCTION

1.1 Background

The landscapes in the South African education system are changing. This is due to the introduction and implementation of Outcome-Based Education (OBE) in the South African education system. Universities used the previous education systems as basis for structuring their teaching practices and syllabi. The universities were well informed about the educational background, demographic background, and skills, which their prospective students possessed. Students taught according to OBE have different attitudes and skills (amongst others) as compared to students taught according to the previous provincial education systems (Potgieter *et al.*, 2005a). Since the teaching practices and syllabi at universities are informed by the proficiencies of students coming from secondary schools, and with the changing landscapes, more students taught according to the OBE format will register at universities, therefore the universities need to be prepared to accommodate these changes. The universities need to be well informed about conceptual understanding, skills development, and educational background of their prospective students (Potgieter *et al.*, 2005b).

1.2. The South African Context

Zaaiman *et al.*, (2000) documented in their study that there are imbalances in terms of the educational background of students at the secondary school level in South Africa. One of the imbalances is the quality of secondary school the students are coming from. The quality of schools that students come from differs in terms of infrastructure and the competency of teachers offering physical science at secondary schools. Most rural schools in South Africa are faced with overcrowded classrooms, making it harder for teachers to give individual attention to students, than in the schools in more privileged environments. These types of schools have as such limited resources for experimental activities. According to social constructivists, the student has to "see', "read" and "hear" in order for him/her to construct his/her own understanding of concepts (Thanasoulas, http://www3.telus.net/linguisticsissues/constructivist.html)). Seeing, hearing and reading are part of the interactions that a student has with the environment. Lev Vygotsky (1962), a proponent of the constructivist theory of learning, emphasized the importance of social interaction on learning and understanding of concepts (Scanlon *et al.*, 2002).

Shortage of qualified teachers of physical science is another contributing factor to the poor conceptual understanding of students in mechanics. Most of the South African physical science teachers, at secondary schools, went to colleges of education for their professional diplomas. At colleges of education they studied the textbooks they will be using when teaching and are normally not trained to be subject specialists. The teachers are therefore not fully equipped with much content knowledge of the subject. Such teachers end up teaching only the sections they understand, or rushing through the syllabus not paying attention to the understanding of students. On the other hand, learning for understanding, is regarded as a social activity. Interactions of the student with his/her environment and social agents, such as teachers, contribute to a greater extent to the learning and understanding of the student. If teachers are poorly equipped with the content knowledge of the subject, "scaffolding" (McKenzie, 1999) as an effective form of teaching will not be possible. According to McKenzie (1999) scaffolding means that with guided and appropriate help from a teacher, a student can be able to perform difficult tasks he or she is not able to perform while working alone. The teacher at the same time regulates his/her degree of help, so that the student can develop understanding and skills necessary for applications of concepts in future.

Lack of resources mostly in rural schools also contributes to the limited knowledge and understanding of concepts. The students from these schools only get textbooks, but no additional learning materials to study. Experimental activities are hardly done because of lack of experimental facilities. The students rely on what the teacher tells them. The teacher, on the other hand, ends up "performing" the experiment theoretically, and thus telling the students what they are supposed to observe while performing the experiment. The students are thus not exposed to experimental learning or observation, and hence cannot infer on the observations made. Understanding of the learning material is thus not achieved, because one understands better what one observes and gets involved with, rather than what one is told will happen, or has happened. Some of these students end up registered at universities. The universities thus have a huge task of accommodating the imbalances in the educational background of the prospective students. In addition, the universities have to be well informed about the content knowledge and conceptual understanding the students have, upon entry and whether common sense ideas about physical processes are accepted scientific ideas or not.

1.3 Alternative Conceptions

Physics education research explores common sense ideas, alternative conceptions and preconceptions which refer to the students' intuitive ideas that are acquired before formal instruction has taken place. These are the ideas that students have as a result of their observations and interactions with the environment they live in. These ideas that students have, about physical processes, are sometimes different from acceptable scientific ideas. Hasan *et al.* (1999:294) defines misconceptions as "strongly held cognitive structures that are different from the accepted understanding in the field that are presumed to interfere with the acquisition of new knowledge", and the Longman Dictionary of Contemporary English (1995: 906) defines misconceptions as "An idea which is wrong or untrue, but which people believe because they do not understand it properly". However, misconception is a rather strong word, and Ramaila (2000) indicated that the use of the word misconceptions is inappropriate as it ignores the rational basis of the students' conceptions about physical processes prior to formal instructions. For the purpose of this study alternative conceptions, common sense ideas and preconceptions will be regarded as synonymous to misconceptions, and common sense ideas and alternative conceptions will be used in this study.

Physics education research documented that students have alternative conceptions about physical processes, which are developed from very young ages. These alternative conceptions developed through their observation and interactions with the environment, and from past experiences. These ideas form a foundation for the learning and understanding of basic mechanics, since mechanics is a part of physics that is closer to the students' daily life experiences about motion and forces (Planinic *et al.*, 2006; Ramaila, 2000).

A minimum level of conceptual understanding in mechanics is taken for granted by lecturers at universities, especially at first year level. Over the past years, there have been a number of studies focusing on the students' understanding of physics concepts. Jimoyiannis & Komis (2003) and Knight (1995) documented that secondary and university physics students have limited basic knowledge and thus have difficulties in the understanding of mechanics. This lack of basic knowledge and understanding has an impact on the understanding of other more complex topics at higher levels of physics.

Hasan *et al.* (1999) and Planinic *et al.* (2006) developed techniques to reveal the presence of alternative conceptions by studying whether students are making correct judgment about their understanding of physics concepts. Hasan *et al.* (1999) used the certainty of response index (CRI) to classify students into those having lack of knowledge and those having strongly held alternative conceptions. The study by Planinic *et al.* (2006) indicated that students show higher confidence levels on Newtonian mechanics than on electromagnetism, and that the higher confidence levels associated with incorrect answers indicated strongly held alternative conceptions. The students were confident about their responses, even though they gave incorrect answers. This thus indicated that the students made incorrect judgments about their understanding of basic concepts.

This study investigated the students' knowledge and understanding of basic concepts of mechanics upon entry into some of the South African universities. The study was conducted at the University of Limpopo (UL) Turfloop Campus, the University of

Pretoria (UP) and the University of Cape Town (UCT). Existing standardized tests were used in this study to probe the students' knowledge and understanding of basic mechanics concepts. Items from the Force Concepts Inventory (FCI) (Hestenes *et al.*, 1992) and Mechanics Baseline Test (MBT) (Hestenes & Wells, 1992) were selected for the study. Items in these test instruments probed for conceptual understanding of basic mechanics. The mechanics part was chosen because it is the part of physics that is closer to the daily experiences and activities that the students encounter (Planinic, *et al.*, 2006; Ramaila, 2000).

This study follows a correlational research design, which explores relationships between variables. The variables investigated in the study are conceptual understanding, test performance and confidence level. Descriptive statistics were used to analyse the quantitative data collected for the study. The analysis of conceptual understanding was done by coding of the students' written explanations of their chosen options.

1.4 Rationale

The South African education system is in the process of phasing out the previous systems of teaching and learning employed by various provincial education departments, and replacing it with the OBE system of teaching and learning. This will have some bearing on the teaching activities and syllabi at secondary schools and universities, and these changes will affect the profiles of students entering the universities. This study is thus aimed at investigating the students' profiles upon entry to tertiary education. Do students know and understand basic mechanics concepts? Are students able to make accurate judgment about their knowledge and understanding of these concepts?

Galili (1995) conducted an investigation about alternative conceptions in both electromagnetism and mechanics. The author documented that alternative conceptions in mechanics influenced alternative conceptions in electromagnetism. Mechanics forms the basis for the learning and understanding of the other topics in physics. Learning and understanding in higher levels of physics will thus become a struggle for a student having difficulties in understanding mechanics.

Students having poor knowledge and understanding of basic concepts will experience failure somewhere in their study at universities, and will ultimately take a longer time to complete their degrees programmes (Santiago & Einarson, 1998), a fact that has some bearing on the finances of a number of stakeholders, i.e. the parents and the government. Over and above, this has also some bearing on the students' academic progress; the students may not complete their programmes on time or could possibly drop out without completing their programmes. This, together with other factors, affects the retention and throughput rates of universities, which has become a serious concern due to changes in government funding formulae.

The results of study will inform lecturers, particularly at first year level about the conceptual understanding and misconceptions present among the students. Knowing what the students do not understand and how they think, will require commitment and active intervention from the lecturers. Such intervention and commitment by the lecturers could possibly lead to improvement in the students' understanding of the concepts. This could have positive consequences in that the students' problem solving abilities improve and students' performance, which is linked to understanding, could also improve, thus an improvement in the throughput rate at tertiary institutions.

The science education literature has a range of studies that investigated aspects of students' confidence and how such confidence impacts on the students' test performance (Metcalfe, 1998; Pallier *et al.*, 2002). Hasan *et al.* (1999) used a certainty of response index to differentiate between students' strongly held alternative conceptions and their lack of knowledge. However, they did not have the means of checking their hypothesis. The significance of this study is that students' written explanations of answers given for multiple-choice questions were analysed to check this hypothesis. This study provides results that could be of use to the science education research community as well as to tertiary educators in physics.

CHAPTER 2 LITERATURE REVIEW

2.1. Background Literature

Research work on self-efficacy and confidence levels has been conducted mainly in the social sciences (Bandura, 1982). In the sciences a number of studies have been conducted on some aspects of student confidence and how such confidence impact on the students' test performance (Metcalfe, 1998; Pallier *et al.*, 2002).

2.1.1. Self-efficacy

Bandura (1986: 391) defines self-efficacy as "The judgment of one's capabilities to organize and execute courses of action required to obtain designated types of performance." Self-efficacy refers to students' confidence about their ability to accomplish a task. For example, if students have high, positive self-efficacy about mastering chemistry or physics, then they believe that they have the power and abilities to pass chemistry or physics and ultimately succeed in their studies. On the other hand, students with low self-efficacy feel that they do not have the power and abilities to master components of a discipline, thus admitting failure from the start. Students with high self-efficacy are more likely to succeed at learning and also to be more motivated to seriously study. Highly motivated students work hard, persevere in the face of difficulties, and find satisfaction in the successful accomplishment of a learning task (Barnhardt, 1997)

A number of studies have found that self-efficacy and academic performance are related (Andrew, 1998; Chacko & Huba, 1991). These studies have been conducted at different academic settings. Sottile *et al.* (2002) conducted a study on the school culture, science achievement and mathematics achievement; and found achievement and self-efficacy are related among in-service teachers. Several studies have been undertaken about relationships between confidence and academic achievement (Cavallo & Rozman, 2004; Gillibrand *et al.*, 1999) and between self-efficacy and performance (Kranzler & Pajares, 1997). In these studies it is shown that a student whose performance is high has high self-efficacy, and the one with low performance has low self-efficacy.

2.1.2. Confidence

Longman Dictionary of Contemporary English (1995: 284) defines confidence as "The belief that you have the ability to do things well or deal with situations successfully." For the purpose of the study self-efficacy, confidence levels and confidence would be used synonymously.

Potgieter *et al.* (2005b) conducted a study on the initial understanding and knowledge of basic chemical concepts of students upon entry into some of the South African universities. The authors documented that students do not make correct judgments about their understanding of basic chemical concepts. Students tend to be overconfident about their competencies. The students' poor judgment about their competencies could indicate lack of knowledge or strongly held alternative conceptions. They attributed the fact that students in the University of Pretoria Foundation Year Programme (UPFY) have very high levels of confidence to be partly due to their experiences leading to selection in the programme. As a result, experiences of failure do not impact significantly on their confidence. Students with high levels of confidence may dismiss messages of failure because it does not fit into their self-perception. Another factor could be that the student has never failed or repeated a grade before, hence their overconfidence. Therefore when such a student enters the university and meets those whose performance is above his/hers, the environment thus proves that there is a lot that he/she does not know, in other words his/her knowledge is limited. However, if this message is not accepted and acted upon in time, failure may be inevitable.

2.1.3 Alternative Conceptions

Spencer Kagan (1992) indicated in his book "Cooperative Learning" that students do not come to institutions as "empty" vessels. They have knowledge based on their observations and interactions with the environment they live in and from past experiences. These experiences with mechanics developed from a very young age. Even before formal instruction takes place, children have observed donkeys pulling a cart in their villages. They have observed their mothers balancing buckets of water on their heads. They have observed busses speeding up the roads past their villages. This implies that children have observed and experienced motion and forces from very young ages. Therefore even students at secondary schools have developed their own understanding of mechanical problems before formal instructions in mechanics have taken place. Upon entry to university, students bring with them alternative conceptions about physical processes, and have meanings attached to these physical processes. Physics education research concur with Spencer Kagan (1992), and has, over a number of years, documented that students have some ideas about physical processes in physics, and already have common sense explanations for these processes. However, these ideas that students have, are in many instances, incompatible with accepted scientific ideas

(Halloun & Hestenes, 1985a; Maloney *et al.*, 2001). The alternative conceptions that students bring along to class are the major influences of what they (students) will learn in the physics course. Mundalamo & Grayson (2006) conducted a study on the performance of foundation and non-foundation physics I students, at some South African universities. They reported that, even though the students came from different educational backgrounds, there were some indications that the students had little knowledge of certain concepts in mechanics. Their study indicated that the students performed badly in items that related to gravitational acceleration. The concepts of gravitational forces and acceleration are regarded as basic in elementary mechanics. The success of students in their physics first year of study is determined, among others, by their conceptual understanding and knowledge of basics mechanics principles. Galili (1995) conducted a study to investigate the presence of alternative conceptions in mechanics and in electromagnetism. The author documented that the presence of alternative conceptions is stronger in mechanics than in electromagnetism.

2.1.4 South African School Situation

In South Africa there are unique problems which negatively affect the acquisition of knowledge and understanding in physics and the development of justified confidence in physics, e.g. lack of discipline, insufficient resources, poor morale, inadequate parental involvement, inadequate transfer of relevant skills, classroom environment and student-teacher ratio, amongst others. Zaaiman *et al.* (2000) indicated that the majority of the secondary schools in South Africa, have inadequate or non-existent physical infrastructures. The majority of the teachers are not qualified to teach physical science.

These teachers are not enthusiastic, confident and competent in their teaching, and are unable to fulfill one of their responsibilities, helping students to learn in meaningful ways. Barlia & Beeth (1999) seem to concur with Zaaiman *et al.* (2000), and reported in their research that these are some of the reasons why students tend to have negative attitudes towards sciences, and low motivation in learning sciences for understanding. The students' awareness of affection and individual needs are not taken into consideration, since the teacher and the teaching environment is not supportive and conducive to learn science for understanding.

2.2. Research Questions

The study is aimed at answering the following questions:

1. What are the performance and associated confidence levels of first entering physics students registered at selected South African universities?
2. Is there a correlation between the confidence and performance of students in mechanics?
3. Can the relationship between confidence and performance be used to reliably identify the presence of misconceptions in mechanics?

CHAPTER 3 THEORETICAL FRAMEWORK

3.1 Introduction

The theoretical framework within which this study is situated is social constructivism. According to Kim (2001), social constructivism emphasizes the importance of culture and the society in which knowledge is constructed. This theory is closely associated with Vygotsky's constructivist theory of learning.

Vygotsky, (1962) viewed learning as a social process. Through observations and interactions with the environment, a student is able to acquire knowledge. Vygotsky emphasizes that learning cannot take place in isolation, but takes place within individuals who interact with each other and as well as the world around them. Students must be more actively involved in activities with each other and their teacher to generate new understanding (Epstein & Ryan, 2002).

Proponents of social constructivism believe that knowledge is constructed through human activities, and can be constructed socially and culturally (Kim, 2001). Learning is an activity that takes place within students who are engaged cooperatively with each other, and thus learning can only take place among a number of individuals interacting with each other.

3.2 Alternative Conceptions

This study explores students' prior knowledge and their ideas about the physical processes, upon entry into the first year physics programmes at universities. The students' prior knowledge in mechanics includes a number of alternative conceptions. Many of these alternative conceptions were formed outside physics classrooms through their everyday experiences of moving objects, donkeys pulling carts, bulls pushing each other during their fights for dominance, etc.

The study will utilize the Hasan et al. (1999) model in order to interpret and analyze the students' responses. This model employs the Certainty of Response Index (CRI) as a way of requesting students to provide their own assessment of the confidence they have in the correctness of their answers. If the certainty of response is low, the implication is that guesswork played a major role in the determination of the answer, which in turn implies that the student has lack of knowledge. If the certainty of response is high, it means that the student has high confidence in his/her choice of the laws and methods used to arrive at the answer. Hasan *et al.*'s (1999) certainty of response will be used in conjunction with the answer to an item to differentiate between lack of knowledge and the presence of alternative conceptions.

Four possible combinations of the answer (correct or incorrect) and certainty of response (high or low) are shown in Table 3.1, on the part of an individual student. For a given item, if a student chose the correct answer and reported a low certainty of response, it would indicate lack of knowledge; this implies that the student obtained the correct answer through guessing. If a student chose an incorrect answer and reported a low certainty of response, this would imply that the student lacks knowledge of the concept. If a student chose a correct answer and reported a high certainty of response, this would signify knowledge of the correct concepts. The student is classified as having adequate knowledge and understanding of the concept. If a student chose an incorrect answer and reported a high certainty of response, this would signify the presence of alternative conceptions. The student is confident about his/her choice; however his/her confidence is misplaced. When dealing with a group of students the identification of alternative conceptions will be done in the same manner as the analysis for the individual student, but the average value for the certainty of response will be used and the percentage of students choosing the correct answer will be utilized instead of an answer given by single student.

Analysis of groups of students' responses rather than individual responses would require the use of averages for both the performance and confidence, which could render the application of the Hasan et al. (1999) model to groups rather than individual respondents to be less reliable. Whether this is indeed the case, will be investigated in this study. The manner in which Hasan et al. (1999) applied this model to a group of students as an aid to teaching activities in physics classrooms will now be presented.

A 36-item multiple-choice test was administered to students. Each item was allocated a mark of 1 if correct and a mark of 0 if incorrect. For each item, a student was requested to provide the degree of certainty he/she has in his/her ability to apply and use scientific laws and principles to arrive at an answer. The sum of all the students who answered an item correctly was divided by the total number of responses, and this gave the number of correct answers as a fraction of the total number of students. Students were also requested to express their certainty of response to each item on a six-point scale of zero (0) to five (5). For a given item, the sum of the CRI for correct answers was divided by the number of students who had given a correct answer and this gave the average CRI for a correct answer. Similarly the sum of the CRI for incorrect answers was divided by the number of students who had given an incorrect answer and this gave the average CRI for incorrect answers, for a given item. In order to decide whether a CRI value is low or high, the authors adopted a threshold value of 2.5. A CRI value above or below 2.5 was considered high or low, respectively.

Table 3.1. Decision matrix for an individual student and for a given question, based on combinations of correct or wrong answers and of low or high average CRI (Hasan et al., 1999: 296).

	Low CRI (<2.5)	High CRI (>2.5)
Correct answer	Correct answer and low CRI. Lack of knowledge (lucky guess)	Correct answer and high CRI. Knowledge of correct concepts
Wrong answer	Wrong answer and low CRI. Lack of knowledge.	Wrong answer and high CRI. Misconceptions

Average CRI values for correct and incorrect answers were utilized in conjunction with a fraction of students choosing the correct answer, to decide whether students have alternative conceptions or are lacking knowledge and understanding of principles and concepts. For example, a high average CRI for a correct answer and a high average CRI for an incorrect answer coupled with a low fraction of students choosing the correct answer is interpreted to suggest the presence of alternative conceptions. While a low average CRI for a correct answer and low average CRI for an incorrect answer coupled with low fraction of students choosing the correct answer is interpreted to suggest lack of knowledge of the principles and scientific laws. In situations where, for a given item, the average CRI value for correct and incorrect answers were very close to 2.5, the authors utilized the fraction of correct answers in order to decide whether the CRI value is high or low, and hence decide on the presence of alternative conceptions. For example, if the CRI for incorrect answers is very close to 2.5, and a large fraction of students have chosen the incorrect answers, then the implication is the large number of students who have chosen the incorrect answers were quite confident about their choices. This situation thus signals that a large fraction of students have alternative conceptions. The suggestion is that teaching should be geared toward addressing the specified alternative conception. On the hand, if the CRI for correct answers is very close to 2.5, and a large fraction of students have chosen the correct answers, then the implication is that a large number of students have chosen the correct answers and are not quite confident about their choices. This would indicate that only a small fraction of students has alternative conceptions. In this case the authors suggest that nothing special needs to be done, since only a small fraction of students seem to have alternative conceptions.

In this study the Hasan et al. (1999) model as described above will be used for individual students as well as for groups of students. The percentage of students choosing the incorrect answer in conjunction with their average confidence levels will be used to gauge the strength of the alternative conceptions among the groups of students. Item difficulty, in terms of the percentage of students choosing the correct answer, and the difference in average confidence associated with the correct and incorrect answer will be used also to determine the accuracy in the judgment of the knowledge and understanding of correct concepts. Positive and large differences would imply the justified confidence in the laws and methods used to arrive at the answer. Negative and smaller differences would signify poor judgment in the knowledge and understanding of correct concepts. In addition to the four possible combinations used by Hasan et al. (1999), coded written responses and the percentage of students, from the UL and UPmaj cohorts, will be utilized (i) to distinguish between the students' lack of knowledge and the presence of alternative conceptions, and (ii) to determine the strength of the misconceptions among the students.

CHAPTER 4 RESEARCH METHODOLOGY

4.1. Research Design

The study followed a correlational research design, which explored relationships between variables. The variables in this study are performance in the test instrument; knowledge and understanding of basic mechanics concepts, and confidence levels. This study attempts to determine whether relationships exist between these variables. The study is meant to establish the presence of a relationship(s), and not to establish a cause-effect relationship (Gall *et al.*, 1996; Gay, 1987).

4.2. Test Design

A test instrument consisting of thirty (30) multiple-choice items was developed from existing standardized tests from the literature. The test was first given to grade 12 physical science teachers in the Limpopo Province and physics lecturers from UL during the month of August 2005, and then piloted to the UNIFY students at UL, during October 2005. Based on the results of the pilot study and the comments of the educators, the test was modified and refined, and five items were removed from the test.

The final paper-and-pencil test consisting of twenty-five (25) items had two sections. Section A, consisting of 5 items, required the students to report on their educational background. In this section the students had to indicate gender, language used at home (mother tongue), language of instruction used at the secondary school he/she attended, the language used by their grade 12 physical science teacher, and the type of secondary school he/she attended. Section B, consisting of 20 items, probed for students' conceptual understanding six of the concepts in mechanics. Items in Section B were obtained from existing sources in the literature. Twelve (12) items were taken from the Force Concept Inventory (FCI) (Hestenes *et al.*, 1992) and seven (7) items taken from the Mechanics Baseline Test (MBT) (Hestenes & Wells, 1992). In order to get a reasonable number of items covering the six chosen concepts in mechanics, one item was obtained and adapted from a question in "The Physics Classroom" from the Internet (www.http://physicsclassroom.com/Newtonlaws/html). This item addresses Newton's Second Law of Motion.

The two tests, FCI and MBT, were chosen because they are complementary to each other. They probe for the students' understanding of the most basic concepts in mechanics, and the scope of the tests is limited to the concepts that are addressed in elementary physics at levels starting from high school. Items in the test instrument focused on the students' conceptual understanding of basic mechanics, no mathematics was required (Hestenes *et al.*, 1992).

Each item in Section B of the test instrument had three parts. The first part was a statement in the form of a question followed by five options (A, B, C, D, and E) to choose from. The second part required that the students give written explanations for their chosen options. This part was included so that the student's knowledge and understanding of certain concepts could be explored (Planinic *et al.*, 2006). The third part required that the students indicate their confidence levels, given by a certainty of response index (CRI) (Hasan *et al.*, 1999). The student indicated on a scale of A to D their confidence in the correctness of their answer [certain (D), almost certain (C), almost a guess (B), or a totally guessed answer (A)].

Table 4.1 Basic mechanical conceptual dimensions included in the test instrument (adapted from Hestenes *et al.*, 1992 (FCI); Hestenes & Wells, 1992 (MBT))

	Concept	Item number (correct option)
1	Kinematics: Velocity discrimination from position, Acceleration discrimination from velocity Constant acceleration	15(E) 16(D) 9(D), 19(B), 20(D), 23(E)
2	Newton's First Law: No force Canceling forces	24(B), 25(B) 10(B), 11(B), 13(B), 18(C)
3	Newton's Second Law: Constant acceleration, Direction of acceleration and the resultant force, Dependence on mass	23(E) 21(A,D) 12(D), 17(A)
4	Newton's Third Law: Impulsive forces	7(E), 11(B)
5	Superposition Principle: Vector sum Canceling forces	14(B), 10(B), 11(B) 13(B), 18(C), 22(C)
6	Gravitation Acceleration independent of weight Parabolic trajectory	8(D) 6(C) 9(D)

The understanding and interpretation of forces form a foundation for basic mechanics in physics. Once a student has good understanding of forces, the interpretation and application of forces in the other dimensions of mechanics and physics in general do not pose a problem. The test items chosen for this study address concepts like: linear and circular motions; Newton's laws of motion; superposition principle; and gravitational free-fall. Table 4.1 lists the mechanical concepts involved, the corresponding item number in the test, and the scientifically acceptable answer for each item is given in brackets.

4.3. Pilot Study

A test instrument consisting of 30 items was first given to twenty educators, i.e. sixteen grade 12 physical science teachers in four circuits of the Limpopo Province, and four physics lecturers at the University of Limpopo, during the month of August in 2005. The educators were chosen because of their willingness to participate in improving and refining the test instrument. The test instrument was given to: three teachers from the Bolobedu circuit, seven teachers from Mankweng circuit, two teachers from Thabammoopo circuit, three teachers from Mahwelereng circuit, three lecturers from mainstream physics and one lecturer from the physics section of the University Foundation Year (UNIFY) programme at the University of Limpopo (Turfloop campus). The purpose of giving the test instrument to the educators was to verify whether the test items are based on concepts that are within the physics content of the grades 11 to 12 physical science curriculum as prescribed by the South African Department of Education, and also to check for clarity of language and presentation of the test items. The UNIFY Programme was initiated in 1992 at the then University of the North (now known as the University of Limpopo, as a result of the merger between the University of the North and the Medical University of South Africa, which took place on the 1st of January 2005) to improve the number and quality of learners from disadvantaged backgrounds admitted into the science faculties. It is a pre-degree foundation year programme in Mathematics, Sciences, and English and Study Skills. The students entering UNIFY do not satisfy the necessary requirements to be admitted into science degree programmes directly (Smith & Cantrell, 1995; Mabila *et al.*, 2006).

The test instrument was then piloted at UNIFY during the month of October 2005. A sample of 115 UNIFY students wrote the test. Based on the comments from the educators, and the results of the pilot study some items were removed, others were refined and improved for inclusion in the final test to be used in the main study. In its first version the test instrument had a section where the students were required to rephrase the questions in their own simple words. The results of the pilot study indicated that the majority of the students skipped the section without answering it, and it was felt that it (the section) does not serve the intended purpose, and was therefore removed. After these modifications and refining, the final test instrument had 25 items. The final version of the test instrument is included as Appendix B.

4.4. Sample

The final version of the test instrument was administered to first entering physics students at three South African universities, at the beginning of the year, during the month of February 2006, before any formal instruction could take place. The participants in the main study were 982 first entering students registered for physics at the three universities (UL, UP and UCT), in South Africa. These are the students who study physics either as a major or as an additional course. At UL three groups of first entering physics students took part in the study. The groups were: 102 students registered for the foundation physics module, PHYS 010, as part of the University of Limpopo Foundation Year (UNIFY) programme; 43 mainstream students who registered for the physics module, PHYS 111, and may opt to take it as a major course in their degree programmes; and 79 students who registered for the physics module, PHYS 151, offered as a service course for science professional degrees (e.g. nursing, pharmacy, nutrition, etc.).

At UP four groups of students took part in the study. The groups were: 33 mainstream students who registered for the physics module PHY171, and may opt to take it as a major course in their degree programmes; 31 students registered for the physics module JFK110, as offered for professional science teachers degrees, 68 students registered for module PHY101, as part of the Extended Programme for students who are under-prepared for mainstream science, and 483 students registered for module PHY131, offered as a service course for biological sciences degrees.

One group of students at UCT took part in the study: 143 students who registered for the physics module, as part of their Academic Development Programme.

For the purpose of this study the student modules will be given different codes, as shown in Table 4.2 below. The capital letters in the code refer to the tertiary institution and the lower case letters describe the cohort as follows: teach refers to teachers in training; adp refers to academic development programme; sc refers to a service course; maj refers to a cohort who may select physics as major for their B.Sc degree and fy refers to a foundation programme.

Table 4.2 Codes of student groups participating in the study

Name of Module	Description	Code to be used in the study
JFK110	Physics course for pre-service teachers at UP	UPteach
PHY101	Physics course in Extended Programme at UP	UPadp
PHY131	Physics service course at UP	UPsc
PHY171	Physics for science majors at UP	UPmaj
UCT ADP	Physics course in Academic Development Programme at UCT	CTadp
PHYS010	Foundation physics course at UL	ULfy
PHYS151	Physics service course at UL	ULsc
PHYS111	Physics for science majors at UL	ULmaj

4.5. Test Validity and Reliability

4.5.1. Content Validity

Validity is concerned with the degree to which a test measures what it is supposed to measure (Blaikie, 2004; Gall *et al.* 1996; Gay 1987). Sixteen grade 12 physical science teachers from four circuits in the Limpopo Province, and four physics lecturers from UL, were given the test instrument and asked to evaluate the test individually before it was administered to the students. The educators were asked to assess the test and make judgment concerning how well the items represented the intended content area. The intended content area in this case is mechanics in the physics section of the grade 12 physical science curriculum in the South African context.

4.5.2. Reliability

Reliability is defined by Gay (1987) as the degree to which a test consistently measures whatever it is supposed to measure. Reliability is usually expressed as a numerical coefficient; a high coefficient indicates high reliability and a low coefficient indicates low reliability. Different methods are used to assess the reliability of a test. For the purpose of this study the split-half and the Cronbach alpha methods were used to assess the reliability of the test.

4.5.2.1. Split-Half Method

The test was divided into two halves, i.e. in odd numbered and even numbered items. The scores for the individual students in each half were computed. Each student had two scores, a score for the odd numbered items and a score for the even numbered items. The two sets of scores were correlated. Using data obtained in this study and the computer software SPSS, the split-half reliability of the test was found to be 0.57. However, literature indicates that longer tests tend to be more reliable, and the split-half reliability represents the reliability of a test that is half as long as the actual test. The Spearman-Brown prophecy formula (Gall *et al.* 1996; Gay 1987) was thus applied to the correlation. For example, the split-half reliability coefficient for a 20-item test was found to be 0.57. The 0.57 was based on the correlation between scores on 10 even items and 10 odd items, not on a 20-item test. The Spearman-Brown prophecy formula (Gall *et al.* 1996; Gay 1987) was needed to estimate the reliability of the 20-item test. The formula is given as

$$r_{total-test} = \frac{2 \times r_{split-half}}{1 + r_{split-half}}$$

Where r represents the split-half reliability coefficient, and applying the formula

$$r_{total} = \frac{2 \times 0.57}{1 + 0.57} = 0.73$$

Therefore the split-half estimate for 20 items was calculated to be 0.73. The test reliability coefficient for the test is therefore 0.73.

4.5.2.2. Cronbach Alpha Coefficient

Cronbach alpha coefficient is another approach to measure the internal reliability of a test. According to Blaikie (2004), Gall *et al.* (1996) and Gay (1987), the value of this coefficient ranges from 0 to 1; a high value indicates high level of consistency among the test items, while a low value indicates low level of consistency among the test items. Using the data obtained in this study the Cronbach alpha coefficient was calculated using computer software package called the SPSS. The Cronbach alpha coefficient for the test items was calculated as 0.68. Comparing the value obtained when using the split-half method and the value obtained when using the Cronbach alpha method, one realizes that the two values, 0.68 and 0.73, are comparable. The values revolve around a value of about 0.7. A correlation coefficient of about 0.7 is regarded as a high value. This value indicates that there is consistency among the test items and that test reliability is high.

4.6. Ethical Issues

The participants were informed about the study and had an option of not participating in the study (Onwuegbuzie, 2001). They were, in addition to this information, given a consent form (Appendix A) to read and complete before the start of the test (Witt-Rose, 2003). Information about students' responses and participation is kept strictly confidential, and the researcher is the only one having access to this information. Acronyms and codes were used instead of the students' names and student numbers. Data is stored in both hard copy and electronic form (CDs and flash discs) in a safe place at the offices of the UNIFY programme.

CHAPTER 5 RESULTS AND ANALYSIS

5.1. Introduction

The results of the first five questions on the school background of the participants will be reported both in a narrative form as well as in a table form (Appendix E). This study was aimed at investigating the relationship between performance and confidence levels, and to investigate the presence and the strength of alternative conceptions among first entering students at some universities. The influence of factors such as school background, gender, language of instruction, etc. on performance and confidence levels of students is however, beyond the scope of the study, and probably may be revisited for future work. The conceptual understanding of the students will be analysed using item by item analysis which will also be given in both narrative and tabular form.

5.2. Educational Background

Participants in the study were 468 male students and 514 female students. The students had different home languages i.e. 434 students had an African language as their home language, 264 students were Afrikaans speaking, and 257 were English speaking, 15 had "Another European language" as their home language, while 12 had their home language classified as "Other". In the South African Education System, initially the official medium of instruction at secondary schools was either English or Afrikaans. However, this has since changed; all the eleven official languages can be used as medium of instruction at secondary schools. From the results it was found that 50 students had their medium of instruction as an African language, and Afrikaans was a medium of instruction for 252 students, while 679 students had English as the medium of instruction, and one student was taught in "Another European language" at the secondary school. The language of instruction used by the Physical Science teacher at secondary schools is found to differ among the students. In this study 34 students indicated that their teachers used an African language as a medium of instruction, and 231 students indicated that their teachers used Afrikaans as the medium of instruction, while 717 students indicated that their teachers used English as the medium of instruction. Of these students who participated in the study, 196 students attended grade 12 at a private school, 110 students attended grade 12 at a township secondary school, 14 students attended grade 12 at a farm secondary school, and 208 students attended grade 12 at a secondary school in rural areas, while 454 students attended grade 12 at a secondary school in a town or city. A detailed demographic background of the students who participated in the study is given as Appendix E.

5.3. Conceptual Understanding

The performance in Section B of the test was calculated by allocating a score of one (1) for the correct option and a score of zero (0) for the incorrect option chosen for an item by a student. The scores for the individual students were added to obtain an average performance score for each cohort. There were twenty items in Section B, which gives a potential maximum performance score of 20. For the purpose of this study, and in deciding whether a student's score is high or low, a threshold value of 10 was adopted. A total score above or below 10 is considered to be high or low, respectively. Raw scores indicating the performance of the individual students obtained in the test are shown in

Appendix C, for each of the eight groups. 36% of students from the eight groups have their performance scores above the threshold, while 64% of the students have performance scores below the threshold.

The confidence levels of the students were calculated by allocating a score of zero (0) for choosing option A (a totally guessed answer), a score of one (1) for option B (almost a guess), a score of two (2) for option C (almost certain), and a score of three (3) for option D (certain). A score for the confidence level of an individual student was obtained by calculating the average of the scores obtained by a student in all twenty items. For the purpose of this study, and in order to decide whether a student's confidence level is high or low, a threshold value of 1.5 was adopted. An average score above or below 1.5 is considered to be high or low, respectively. The average confidence levels of individual students are shown in Appendix C, for each of the eight groups. 87.5% of the students have an average confidence level which is above the threshold, and 12.5% of the students have an average confidence levels below the threshold.

The overall performance and confidence levels of students participating in the study are shown below in tabular form. From Table 5.1, one realizes that the test performances of students from the eight groups differ. Students from groups UPsc and UPmaj have a higher average test performance as compared to the rest of the students, their average test performances are above the threshold of 10, i.e. 10.1 and 10.9, respectively. The other six groups are regarded as having obtained low scores, because their average test performances are below the threshold of 10. Students from group ULfy have the lowest average test performance, 5.6. The students in all the eight groups have high confidence levels. The average confidence levels of students in the eight groups are above the threshold of 1.5.

Table 5.1 Average performance and average confidence levels of students from the eight student cohorts

Student groups	**Number of students**	**Average Test Performance** (Maximum 20)	**Average Confidence Level**	**Correlation coefficient**
UPteach	31	6.5	1.9	0.44
UPadp	68	7.6	2.0	0.30
UPsc	483	10.1	2.1	0.42
UPmaj	33	10.9	2.2	0.57
CTadp	143	7.5	1.9	0.25
ULfy	102	5.6	1.9	0.23
ULsc	79	6.9	2.0	0.07
ULmaj	43	7.3	2.0	0.05

The nature of the relationship between test performance and average confidence levels in the eight cohorts that took part in the study is shown in a tabular form. The test performance and average confidence levels of individual students, from the eight groups, were correlated and the results are given in the last column of Table 5.1, and also in the scatter plots shown in Appendix D. The correlation coefficient of 0.57 between performance and confidence levels for students from group UPmaj is fairly strong. This indicates that a high confidence level is usually associated with a high score in performance. The correlations between performance and confidence levels for UPteach and UPsc are both weak and the correlation for UPadp, CTadp and ULfy are all very weak. In the case of groups ULsc and ULmaj there is virtually no correlation between performance and confidence levels. The correlation coefficient in the region of 0.06 that was obtained for these groups implies that a high (or low) confidence level is equally likely to be associated with a high or low test performance. This lack of correlation is also shown in the scatter plots of performance versus confidence level for the two groups of students, shown in Appendix D ((g) and (h)).

According to Hasan *et al.* (1999) model, the students were divided into four groups according to their performance and confidence levels. Table 5.2 reports the population of the four groups.

Table 5.2 Overall performance matrix of all the students and for all the test items (N = 982).

	Low Confidence Level ($CL^b < 1.5$)	High Confidence Level ($CL^b > 1.5$)
High Test Performance ($TP^a > 10$)	19 (1.9%) Lack of knowledge (lucky guess)	335 (34.1%) Knowledge of correct concepts
Low Test Performance ($TP^a < 10$)	104 (10.6%) Lack of knowledge	524 (53.4%) Misconceptions

[a] TP represents test performance; [b] CL represents confidence level.

From Table 5.2 above, 19 (1.9%) of the students had high performance and low average confidence levels. According to Hasan *et al.* (1999) these students are regarded as having made lucky guesses. Low average confidence levels indicate that the students have reported that they have guessed or almost guessed the answer. 104 (10.6%) of the students scored low on the test and had low average confidence levels. These students are classified as having lack of knowledge and understanding of the concepts. They have performed poorly and they were aware that their knowledge and understanding were inadequate. 524 (53.4%) of the students scored low on the test and have high average confidence levels. According to Hasan *et al.* (1999) this is an indication that these students have strong alternative conceptions about concepts in mechanics. The students are confident about the choices they are making, even though their choices are incorrect. 335(34.1%) of the students scored high on the test and have high confidence levels. These students are classified as having acceptable knowledge and understanding of concepts, which are associated with justified confidence.

5.4. Item by Item Analysis

Item analysis is one of the important activities in test development. Gall *et al.* (1996) describe item analysis as a set of procedures that is used to determine the difficulty, the validity and reliability of each item in the test. One can also use item analysis to find out whether distractors for a particular item are good or bad. The specific procedures are determined by the purpose of the test. In this study item analysis was carried out in order to determine the performance and confidence levels of the different groups of students, and to judge item difficulty in terms of the number and percentage of students answering an item correctly.

Hasan *et al.* (1999) used test performance and the certainty of response index (CRI) to determine the presence of alternative conceptions among students. Planinic *et al.* (2006) used linear measures of item difficulty and student confidence to asses the strength of known alternative conceptions. They documented that poor performance in the test (low scores) coupled with high confidence indicate that the student has alternative conceptions for a particular concept. This instrument has been designed so that one can pick up alternative conceptions not just indirectly from specific distractors included in the multiple-choice component of each item, but also from the written explanations that the students provided. Chase (1999) documented that multiple-choice tests can be used to assess factual levels of learning, but they are poor at assessing higher order of cognition.

Item analysis was done with respect to the general performance of the whole student population who sat for the test. Item by item analysis in this case was carried out in two ways, i.e. analysis of the multiple-choice section and analysis of the student's written responses. The analysis of the multiple-choice was carried out for all the students who participated in the study, and analysis of the written responses was carried out for a selected sample of the students who participated in the study. The students from UL were selected for the analysis of the written responses because of their geographical location, which was convenient for the researcher. The UPmaj cohort was used as a benchmark in this analysis for two reasons: (i) This group of students achieved the best performance in the test and (ii) was able to judge their answers more accurately than any of the other groups, as reflected by the correlation coefficient of 0.57 between average performance and average confidence level.

5.5. Analysis of the Multiple-Choice Section

This analysis was carried out by comparing and interpreting the percentage of students choosing the different options for each item. The analysis was carried out for all eight groups of students involved in the study. The analysis of each item is given in a table form as well as in a narrative form below. The table indicates the percentage of students choosing each of the five options for each item, and the average confidence levels, for each group. The correct option in each item is given in brackets and underlined. Refer to Appendix B for the items in the test instrument.

There are three average confidence levels in each of Tables 5.3(a – t) below. The average confidence levels marked "All" indicates the average confidence levels of all the students in a group. This value is calculated by dividing the sum of the confidence levels for all the students by the number of students. The average confidence level marked "Correct Option" indicates the average confidence levels of the students who answered the item correctly. This value is calculated by dividing the sum of the confidence levels for the students who answered the item correctly by the number of students who chose the correct option. The average confidence level marked "Incorrect Option" indicates the average confidence level of the students who answered the item incorrectly. This average confidence level is calculated by dividing the sum of confidence levels of students who answered the item incorrectly by the number of students choosing the incorrect options.

The analysis is done this way in order to compare the confidence levels of the students choosing the correct option and those choosing the incorrect option.

A comparison of the average confidence levels associated with correct and incorrect answers, respectively, provides an indication of the quality of judgment made within a specific cohort about the correctness of answers provided for a specific test item.

5.5.1. Item 6

This item deals with two metal balls, of different masses, dropped simultaneously from the top of a two-storey building. Students were to indicate which ball would reach the ground first. The item is found in the conceptual dimension of Gravitation (Table 4.1), and addresses the conception that acceleration of falling objects is independent of the weight of objects. Distractors A and D, the most prevalent alternative conception documented in literature, reflect the idea that "Heavier objects fall faster than lighter objects" (Gunstone & White, 1981; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992). The less prevalent distractors B and E reflect the alternative conception that lighter objects fall faster than heavier objects. Table 5.3(a) below indicates the percentage of students, for each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(a) Performance and Confidence levels of all students for item 6

Student Group	Number of Students	Options (%)							Average Confidence Level		
		A	B	(C)	D	E	A+D	B+E	All	Correct Option	Incorrect Options
UPteach	31	19.4	3.2	45.2	19.4	12.9	39.8	16.1	2.2	2.2	2.1
UPadp	68	5.9	13.2	63.2	13.2	4.4	19.1	17.6	2.3	2.4	2.2
UPsc	483	5.4	6.0	74.2	9.4	5.0	14.8	20.8	2.4	2.5	2.0
UPmaj	33	15.2	6.1	78.8	0.0	0.0	15.2	6.1	2.6	2.7	2.0
CTadp	143	13.3	7.7	51.7	22.4	4.9	35.7	12.6	2.1	2.3	1.9
ULfy	102	13.7	21.6	34.3	18.6	11.8	32.3	33.4	2.4	2.6	2.3
ULsc	79	15.2	12.7	35.4	19.0	17.7	34.2	30.4	2.3	2.4	2.3
ULmaj	43	18.6	11.6	48.8	14.0	7.0	32.6	18.6	2.4	2.4	2.5

The correct option in this item was option C, that the two metal balls will reach the ground simultaneously. More than 50% of the students from UPadp, UPsc, UPmaj and CTadp have chosen the correct option; while less than 50% of the students from UPteach, ULfy, ULSC and ULmaj have chosen the correct option. However, a number of students have the belief that the heavier metal ball will reach the ground first. This is indicated by the high percentage of students in all the eight groups choosing options A and D. The responses obtained for ULfy are randomly distributed between the options C (34%), A + D (32.3%) and B + E (33.4%). Distractors A and D are similar in the sense that they reflect the conception that a heavier ball will reach the ground significantly faster than the lighter ball. In the same way distractors B and E reflect the conception that the lighter ball will reach the ground significantly faster than the heavier ball.

The average confidence levels for the students in all the eight groups are found to be high, ranging from 2.1 to 2.6, indicating that the students are very confident about their choices. The students who chose the correct option are confident about their answers; this is indicated by the confidence levels ranging from 2.2 to 2.7, and the students who chose the incorrect options are also confident about their choice, with their confidence levels ranging from 1.9 to 2.5 (shown in Table 5.3(a) above). The difference between the average confidence values associated with a correct answer and with the combination of wrong answers for a specific group is indicative of the quality of judgment about the correctness of the answer provided that the students of that group are capable of. Students in cohorts UPsc and UPmaj showed both the highest performance and the best quality of judgment on this item.

5.5.2. Item 7

The item deals with a head-on collision between a large truck and a small car. The students were to indicate the forces involved during this interaction between the two vehicles. The item is located in the conceptual dimension of Newton's third law (Table 4.1) for impulsive forces. The alternative conceptions documented in the literature are: Distractors A and D, that "a greater mass implies a greater force", and distractor C, that "obstacles exert no force" (Halloun *et al.*, 1985b; Maloney, 1984). Table 5.3(b) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(b) Performance and Confidence levels of all students for item 7

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	D	(E)	All	Correct Option	Incorrect Options
UPteach	31	64.5	6.5	3.2	0.0	25.8	2.4	2.4	2.4
UPadp	68	58.8	1.5	0.0	1.5	38.2	2.2	2.2	2.2
UPsc	483	40.3	1.0	0.8	0.4	57.4	2.4	2.5	2.3
UPmaj	33	39.4	3.0	0.0	0.0	57.6	2.5	2.7	2.2
CTadp	143	42.7	4.2	0.0	1.4	51.7	2.3	2.3	2.2
ULfy	102	66.7	3.9	1.0	2.0	26.5	2.4	2.4	2.3
ULsc	79	59.5	2.5	6.3	3.8	27.8	2.4	2.5	2.4
ULmaj	43	51.2	2.3	0.0	2.3	44.2	2.4	2.5	2.3

The correct answer for this item was option E, i.e. both vehicles exert equal force on each other. The table above indicates that, in general the performance on this item was poor, more than 50% of the students from UPsc, UPmaj and CTadp have chosen the correct option, while less than 50% of the students from UPteach, UPadp, ULfy, ULsc and ULmaj have chosen the correct option. The concept assessed in this item is clearly more difficult to grasp. Option A was the only meaningful distractor for all of the eight cohorts, i.e. the bigger vehicle exerts a greater amount of force on the smaller vehicle, while the smaller vehicle exerts a smaller amount of force on the bigger vehicle. Distractors B, C and D were very weak and attracted less than 10% of the responses in seven of the eight groups.

The students in all eight groups were very confident about their chosen options. This is evident from the table above, which reflects average confidence levels ranging from 2.3 to 2.7. The table also reflects that the students who chose the correct option and those students, who chose the incorrect options, are both confident about their choice. The students who chose the correct option have confidence levels ranging from 2.2 to 2.7, while those who have chosen the incorrect options have confidence levels ranging from 2.2 to 2.4. The only exception to this trend is UPmaj where the majority of students either knew that their answers were correct or realized that they may be incorrect.

5.5.3. Item 8

This item deals with a steel ball being thrown vertically upwards, with the effect of air resistance being ignored. Students had to identify the force(s) exerted on the ball during the course of its flight. The item is found in the conceptual dimension of gravitation (from Table 4.1). The most common alternative conceptions found in physics education literature are, distractor A "impetus dissipation", distractor B "gravity increases as object falls, gravity acts after impetus wears down", distractor C "delayed impetus build-up" and distractor E "gravity is intrinsic to mass" (Gunstone *et al.*, 1981; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1985). Table 5.3(c) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(c) Performance and Confidence levels of all students for item 8

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	6.5	35.5	45.2	12.9	0.0	1.9	2.0	1.9
UPadp	68	5.9	27.9	50.0	14.7	1.5	2.2	2.3	2.2
UPsc	483	3.5	8.1	58.2	29.9	0.2	2.4	2.6	2.3
UPmaj	33	3.0	9.1	51.5	36.4	0.0	2.4	2.7	2.2
CTadp	143	4.2	21.8	56.3	16.9	0.7	2.2	2.4	2.1
ULfy	102	14.7	28.4	44.1	11.8	1.0	2.2	2.3	2.2
ULsc	79	13.9	19.0	35.4	27.8	3.8	2.2	2.2	2.2
ULmaj	43	9.3	11.6	48.8	27.9	2.3	2.2	2.3	2.2

The correct answer for the item was option D, that is only a constant gravitational force is acting on the ball until it returns to the ground. From the table above it is evident that less than 50% of students in all eight groups have chosen the correct option D, while a higher percentage (ranging from 35.4% to 58.2%) of students in all eight groups have chosen option C, i.e. the forces acting on the ball until it returns to the ground are a constant gravitational force together with an upward force that decreases as the ball goes up. The alternative conception reflected by distractor B is important for all cohorts, except UPsc and UPmaj. Distractor E is too weak to contribute to the analysis. Distractor A is weak for all groups except for the UL groups. According to Halloun & Hestenes

(1985a) the students believe that as the ball goes up, the upward force wears down. This misconception is more prevalent within UL cohorts than in the other cohorts.

The students in all the groups were confident about their chosen options. This is evident from the table above, which reflects average confidence levels from 1.9 to 2.4. Table 5.3(c) also reflects that the students who have chosen the correct option and those students, who have chosen the incorrect options, were confident about their choice. The confidence levels of students choosing the correct option ranges from 2.0 to 2.7, while those students who have chosen the incorrect options have their confidence levels ranging from 1.9 to 2.3. Significantly, the largest difference between average confidence associated with correct answers and average confidence associated with incorrect answers was observed in the cohort UPmaj, a group that also achieved the highest performance. This result is interpreted to mean that the better performing students were able to make better quality judgments about the correctness of their answers.

5.5.4. Item 9

This item deals with a bowling ball accidentally falling from the cargo of an airliner which is flying in a horizontal direction. Students had to identify the path that will most likely be followed by the ball, as seen by an observer on the ground. The item is found in the conceptual dimensions of kinematics and gravitation (Table 4.1), and addresses the conception that "constant acceleration entails parabolic trajectory". The most common alternative conceptions documented in the literature are: Distractors A and B that "mass makes objects stop", distractor C that "force compromise determines motion" and distractor E that "gravity acts after impetus wears down, impetus dissipation" (Halloun & Hestenes, 1985b; Jimoyiannis *et al.*, 2001). Table 5.3(d) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(d) Performance and Confidence levels of all students for item 9

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	35.5	29.0	6.5	25.8	3.2	2.0	2.0	2.0
UPadp	68	33.8	8.8	16.2	36.8	4.4	2.3	2.5	2.1
UPsc	483	27.4	13.9	10.8	45.3	2.5	2.2	2.4	2.0
UPmaj	33	27.3	0.0	15.2	57.6	0.0	2.2	2.4	2.0
CTadp	143	42.1	15.0	10.0	27.1	5.7	2.0	2.1	1.9
ULfy	102	52.9	15.7	9.8	14.7	6.9	2.0	2.5	2.0
ULsc	79	16.5	19.0	10.1	49.4	5.1	2.4	2.6	2.2
ULmaj	43	14.0	4.7	16.3	58.1	7.0	2.2	2.2	2.3

The correct option was D, that as seen from the ground the bowling ball will follow a parabolic path forward while falling down. The two mainstream cohorts, UPmaj and ULmaj, have shown the best average performance on this item, i.e. 57.6% and 58.1%, respectively, while less than 50% of the students from UPteach, UPadp, UPsc, CTadp, ULfy and ULsc have chosen the correct option. Distractors A – C feature with varying prominence for the eight groups and distractor E is too weak to be significant for the analysis. As compared to distractors B and C, a higher percentage of students in six of the eight groups have chosen the incorrect option A, that as seen from the ground the bowling ball will follow a parabolic path backward while falling down.

Students from all the eight groups are very confident about their chosen options; the table above indicates that the confidence levels of the students ranges from 2.0 to 2.4. Table 5.3(d) also reflects that the students who have chosen the correct option and those students, who have chosen the incorrect options, are confident about their choice. The confidence levels of students choosing the correct option ranges from 2.0 to 2.6, while those students who have chosen the incorrect options have their confidence levels ranging from 1.9 to 2.3. A comparison of the difference between average confidence values for correct and incorrect answers indicates that four groups showed reasonable accuracy of judgment. Significantly poorer accuracy of judgment is observed for UPteach and ULmaj.

5.5.5. Item 10

The item deals with two blocks of equal masses hanging from the ceiling of an elevator by means of two strings. Students were to determine the magnitude of the force exerted by rope 1 on block I when the elevator goes upwards at constant velocity. The item is found in the conceptual dimensions of Newton's first law and superposition principle (Table 4.1). Distractor A includes a common alternative conception that "$F = m \times v$" (Clement J., 1982; Hestenes *et al.*, 1992). The mistake that students make arises from confusing speed and acceleration, which they use interchangeably. Distractor C, D and E are about the direction of motion and the magnitude of the force. Table 5.3(e) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(e) Performance and Confidence levels of all students for item 10

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	32.3	45.2	12.9	9.7	0.0	1.9	2.2	1.8
UPadp	68	20.6	42.6	7.4	27.9	1.5	1.8	2.1	1.6
UPsc	483	14.6	54.3	12.7	16.7	1.7	2.0	2.2	1.6
UPmaj	33	15.2	63.6	9.1	12.1	0.0	2.0	2.2	1.8
CTadp	143	18.3	59.2	8.5	12.0	2.1	1.8	1.8	1.7
ULfy	102	52.0	35.3	2.0	10.8	0.0	2.0	2.1	1.8
ULsc	79	25.6	50.0	10.3	14.1	0.0	2.2	2.3	2.2
ULmaj	43	20.9	72.1	4.7	2.3	0.0	2.1	2.2	1.9

More than 50% of the students in each of UPsc, UPmaj, CTadp, ULsc and ULmaj have chosen the correct option, option B, that the force exerted by rope 1 on block I has a magnitude of 10 N. Significantly the best performance is observed for the two mainstream cohorts, UPmaj and ULmaj. Distractor A is most prominent, that the forces exerted by rope 1 on block I has a magnitude of 2 N. This is a common alternative conception where students use acceleration and speed interchangeably. Distractors C, D and E, are about motion being in the direction of bigger force. Students have this conception that motion is always in the direction of a bigger force (Maloney, 1984). Since the downward force is 10 N, the students therefore make a mistake that the force causing the object to go up must be greater than 10 N. Distractor D was more prominent than distractor A for UPadp and UPsc. However, distractors C and D vary in prominence for the different groups and distractor E is too weak to be meaningful.

Students from each of the eight groups are confident about their chosen options, their confidence levels range from 1.8 to 2.2. Table 5.3(e) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. All students are confident about their correct option, (confidence levels ranging from 1.9 to 2.3). Students choosing the incorrect options are also confident about their choices; this is indicated by the confidence levels ranging from 1.6 to 2.2 in all the groups. Noteworthy is the fact that a higher quality of judgment is observed for all UP groups compared to the others. The students were clearly more accurate with their judgment about the correctness of their answers to this item.

5.5.6. Item 11

The item deals with two blocks of equal masses hanging from the ceiling of an elevator by means of two strings. Students were to determine the magnitude of the force exerted by rope 1 on block II when the elevator is stationary. The item is found in the conceptual dimensions of Newton's first law and superposition principle (Table 4.1). Table 5.3(f) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

that they reflect the conception that a heavier ball will reach the ground significantly faster than the lighter ball. In the same way distractors B and E reflect the conception that the lighter ball will reach the ground significantly faster than the heavier ball.

The average confidence levels for the students in all the eight groups are found to be high, ranging from 2.1 to 2.6, indicating that the students are very confident about their choices. The students who chose the correct option are confident about their answers; this is indicated by the confidence levels ranging from 2.2 to 2.7, and the students who chose the incorrect options are also confident about their choice, with their confidence levels ranging from 1.9 to 2.5 (shown in Table 5.3(a) above). The difference between the average confidence values associated with a correct answer and with the combination of wrong answers for a specific group is indicative of the quality of judgment about the correctness of the answer provided that the students of that group are capable of. Students in cohorts UPsc and UPmaj showed both the highest performance and the best quality of judgment on this item.

5.5.2. Item 7

The item deals with a head-on collision between a large truck and a small car. The students were to indicate the forces involved during this interaction between the two vehicles. The item is located in the conceptual dimension of Newton's third law (Table 4.1) for impulsive forces. The alternative conceptions documented in the literature are: Distractors A and D, that "a greater mass implies a greater force", and distractor C, that "obstacles exert no force" (Halloun *et al.*, 1985b; Maloney, 1984). Table 5.3(b) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(b) Performance and Confidence levels of all students for item 7

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	D	(E)	All	Correct Option	Incorrect Options
UPteach	31	64.5	6.5	3.2	0.0	25.8	2.4	2.4	2.4
UPadp	68	58.8	1.5	0.0	1.5	38.2	2.2	2.2	2.2
UPsc	483	40.3	1.0	0.8	0.4	57.4	2.4	2.5	2.3
UPmaj	33	39.4	3.0	0.0	0.0	57.6	2.5	2.7	2.2
CTadp	143	42.7	4.2	0.0	1.4	51.7	2.3	2.3	2.2
ULfy	102	66.7	3.9	1.0	2.0	26.5	2.4	2.4	2.3
ULsc	79	59.5	2.5	6.3	3.8	27.8	2.4	2.5	2.4
ULmaj	43	51.2	2.3	0.0	2.3	44.2	2.4	2.5	2.3

The correct answer for this item was option E, i.e. both vehicles exert equal force on each other. The table above indicates that, in general the performance on this item was poor, more than 50% of the students from UPsc, UPmaj and CTadp have chosen the correct option, while less than 50% of the students from UPteach, UPadp, ULfy, ULsc and ULmaj have chosen the correct option. The concept assessed in this item is clearly more difficult to grasp. Option A was the only meaningful distractor for all of the eight cohorts, i.e. the bigger vehicle exerts a greater amount of force on the smaller vehicle, while the smaller vehicle exerts a smaller amount of force on the bigger vehicle. Distractors B, C and D were very weak and attracted less than 10% of the responses in seven of the eight groups.

The students in all eight groups were very confident about their chosen options. This is evident from the table above, which reflects average confidence levels ranging from 2.3 to 2.7. The table also reflects that the students who chose the correct option and those students, who chose the incorrect options, are both confident about their choice. The students who chose the correct option have confidence levels ranging from 2.2 to 2.7, while those who have chosen the incorrect options have confidence levels ranging from 2.2 to 2.4. The only exception to this trend is UPmaj where the majority of students either knew that their answers were correct or realized that they may be incorrect.

5.5.3. Item 8

This item deals with a steel ball being thrown vertically upwards, with the effect of air resistance being ignored. Students had to identify the force(s) exerted on the ball during the course of its flight. The item is found in the conceptual dimension of gravitation (from Table 4.1). The most common alternative conceptions found in physics education literature are, distractor A "impetus dissipation", distractor B "gravity increases as object falls, gravity acts after impetus wears down", distractor C "delayed impetus build-up" and distractor E "gravity is intrinsic to mass" (Gunstone *et al.*, 1981; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1985). Table 5.3(c) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(c) Performance and Confidence levels of all students for item 8

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	6.5	35.5	45.2	12.9	0.0	1.9	2.0	1.9
UPadp	68	5.9	27.9	50.0	14.7	1.5	2.2	2.3	2.2
UPsc	483	3.5	8.1	58.2	29.9	0.2	2.4	2.6	2.3
UPmaj	33	3.0	9.1	51.5	36.4	0.0	2.4	2.7	2.2
CTadp	143	4.2	21.8	56.3	16.9	0.7	2.2	2.4	2.1
ULfy	102	14.7	28.4	44.1	11.8	1.0	2.2	2.3	2.2
ULsc	79	13.9	19.0	35.4	27.8	3.8	2.2	2.2	2.2
ULmaj	43	9.3	11.6	48.8	27.9	2.3	2.2	2.3	2.2

The correct answer for the item was option D, that is only a constant gravitational force is acting on the ball until it returns to the ground. From the table above it is evident that less than 50% of students in all eight groups have chosen the correct option D, while a higher percentage (ranging from 35.4% to 58.2%) of students in all eight groups have chosen option C, i.e. the forces acting on the ball until it returns to the ground are a constant gravitational force together with an upward force that decreases as the ball goes up. The alternative conception reflected by distractor B is important for all cohorts, except UPsc and UPmaj. Distractor E is too weak to contribute to the analysis. Distractor A is weak for all groups except for the UL groups. According to Halloun & Hestenes

(1985a) the students believe that as the ball goes up, the upward force wears down. This misconception is more prevalent within UL cohorts than in the other cohorts.

The students in all the groups were confident about their chosen options. This is evident from the table above, which reflects average confidence levels from 1.9 to 2.4. Table 5.3(c) also reflects that the students who have chosen the correct option and those students, who have chosen the incorrect options, were confident about their choice. The confidence levels of students choosing the correct option ranges from 2.0 to 2.7, while those students who have chosen the incorrect options have their confidence levels ranging from 1.9 to 2.3. Significantly, the largest difference between average confidence associated with correct answers and average confidence associated with incorrect answers was observed in the cohort UPmaj, a group that also achieved the highest performance. This result is interpreted to mean that the better performing students were able to make better quality judgments about the correctness of their answers.

5.5.4. Item 9

This item deals with a bowling ball accidentally falling from the cargo of an airliner which is flying in a horizontal direction. Students had to identify the path that will most likely be followed by the ball, as seen by an observer on the ground. The item is found in the conceptual dimensions of kinematics and gravitation (Table 4.1), and addresses the conception that "constant acceleration entails parabolic trajectory". The most common alternative conceptions documented in the literature are: Distractors A and B that "mass makes objects stop", distractor C that "force compromise determines motion" and distractor E that "gravity acts after impetus wears down, impetus dissipation" (Halloun & Hestenes, 1985b; Jimoyiannis *et al.*, 2001). Table 5.3(d) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(d) Performance and Confidence levels of all students for item 9

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	35.5	29.0	6.5	25.8	3.2	2.0	2.0	2.0
UPadp	68	33.8	8.8	16.2	36.8	4.4	2.3	2.5	2.1
UPsc	483	27.4	13.9	10.8	45.3	2.5	2.2	2.4	2.0
UPmaj	33	27.3	0.0	15.2	57.6	0.0	2.2	2.4	2.0
CTadp	143	42.1	15.0	10.0	27.1	5.7	2.0	2.1	1.9
ULfy	102	52.9	15.7	9.8	14.7	6.9	2.0	2.5	2.0
ULsc	79	16.5	19.0	10.1	49.4	5.1	2.4	2.6	2.2
ULmaj	43	14.0	4.7	16.3	58.1	7.0	2.2	2.2	2.3

The correct option was D, that as seen from the ground the bowling ball will follow a parabolic path forward while falling down. The two mainstream cohorts, UPmaj and ULmaj, have shown the best average performance on this item, i.e. 57.6% and 58.1%, respectively, while less than 50% of the students from UPteach, UPadp, UPsc, CTadp, ULfy and ULsc have chosen the correct option. Distractors A – C feature with varying prominence for the eight groups and distractor E is too weak to be significant for the analysis. As compared to distractors B and C, a higher percentage of students in six of the eight groups have chosen the incorrect option A, that as seen from the ground the bowling ball will follow a parabolic path backward while falling down.

Students from all the eight groups are very confident about their chosen options; the table above indicates that the confidence levels of the students ranges from 2.0 to 2.4. Table 5.3(d) also reflects that the students who have chosen the correct option and those students, who have chosen the incorrect options, are confident about their choice. The confidence levels of students choosing the correct option ranges from 2.0 to 2.6, while those students who have chosen the incorrect options have their confidence levels ranging from 1.9 to 2.3. A comparison of the difference between average confidence values for correct and incorrect answers indicates that four groups showed reasonable accuracy of judgment. Significantly poorer accuracy of judgment is observed for UPteach and ULmaj.

5.5.5. Item 10

The item deals with two blocks of equal masses hanging from the ceiling of an elevator by means of two strings. Students were to determine the magnitude of the force exerted by rope 1 on block I when the elevator goes upwards at constant velocity. The item is found in the conceptual dimensions of Newton's first law and superposition principle (Table 4.1). Distractor A includes a common alternative conception that "$F = m \times v$" (Clement J., 1982; Hestenes *et al.*, 1992). The mistake that students make arises from confusing speed and acceleration, which they use interchangeably. Distractor C, D and E are about the direction of motion and the magnitude of the force. Table 5.3(e) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(e) Performance and Confidence levels of all students for item 10

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	32.3	45.2	12.9	9.7	0.0	1.9	2.2	1.8
UPadp	68	20.6	42.6	7.4	27.9	1.5	1.8	2.1	1.6
UPsc	483	14.6	54.3	12.7	16.7	1.7	2.0	2.2	1.6
UPmaj	33	15.2	63.6	9.1	12.1	0.0	2.0	2.2	1.8
CTadp	143	18.3	59.2	8.5	12.0	2.1	1.8	1.8	1.7
ULfy	102	52.0	35.3	2.0	10.8	0.0	2.0	2.1	1.8
ULsc	79	25.6	50.0	10.3	14.1	0.0	2.2	2.3	2.2
ULmaj	43	20.9	72.1	4.7	2.3	0.0	2.1	2.2	1.9

More than 50% of the students in each of UPsc, UPmaj, CTadp, ULsc and ULmaj have chosen the correct option, option B, that the force exerted by rope 1 on block I has a magnitude of 10 N. Significantly the best performance is observed for the two mainstream cohorts, UPmaj and ULmaj. Distractor A is most prominent, that the forces exerted by rope 1 on block I has a magnitude of 2 N. This is a common alternative conception where students use acceleration and speed interchangeably. Distractors C, D and E, are about motion being in the direction of bigger force. Students have this conception that motion is always in the direction of a bigger force (Maloney, 1984). Since the downward force is 10 N, the students therefore make a mistake that the force causing the object to go up must be greater than 10 N. Distractor D was more prominent than distractor A for UPadp and UPsc. However, distractors C and D vary in prominence for the different groups and distractor E is too weak to be meaningful.

Students from each of the eight groups are confident about their chosen options, their confidence levels range from 1.8 to 2.2. Table 5.3(e) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. All students are confident about their correct option, (confidence levels ranging from 1.9 to 2.3). Students choosing the incorrect options are also confident about their choices; this is indicated by the confidence levels ranging from 1.6 to 2.2 in all the groups. Noteworthy is the fact that a higher quality of judgment is observed for all UP groups compared to the others. The students were clearly more accurate with their judgment about the correctness of their answers to this item.

5.5.6. Item 11

The item deals with two blocks of equal masses hanging from the ceiling of an elevator by means of two strings. Students were to determine the magnitude of the force exerted by rope 1 on block II when the elevator is stationary. The item is found in the conceptual dimensions of Newton's first law and superposition principle (Table 4.1). Table 5.3(f) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(f) Performance and Confidence levels of all students for item 11

Module Code	Number of Students	Options (%)					Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	20.0	63.3	0.0	13.3	3.3	1.9	2.1	1.7
UPadp	68	10.3	75.0	4.4	10.3	0.0	1.8	2.0	1.4
UPsc	483	9.0	79.7	2.3	8.8	0.2	1.9	2.1	1.2
UPmaj	33	12.5	75.5	6.3	6.3	0.0	2.0	2.2	1.5
CTadp	143	12.3	73.9	2.2	10.9	0.7	1.8	1.9	1.3
ULfy	102	39.2	47.1	2.9	8.8	2.0	1.6	1.8	1.4
ULsc	79	26.2	55.7	10.1	6.3	1.3	2.0	2.0	2.0
ULmaj	43	18.6	53.5	2.3	25.6	0.0	2.1	2.0	2.1

More than 50% of the students in each of the eight groups, except for ULfy, have chosen the correct option, which is option B, that the force exerted by rope 1 on block II has a magnitude of 10 N. 47.1% of the students from ULfy have chosen the correct option. A high percentage (ranging from 9.0% to 39.2%) of students from each of the eight groups have chosen option A, that the forces exerted by rope 1 on block II has a magnitude of 2 N. Despite this being an easy item, the best performance is not observed in the two major course cohorts (UPmaj and ULmaj). At both institutions (UP and UL) the service course cohorts marginally outperformed the major course cohorts. The academic development groups at UCT and UP also performed well on this item. Options A and D are the most important distractors, with distractor A featuring more prominently than distractor D for almost all the cohorts. Options C and E are weak distractors for all cohorts, with ULsc being the only exception.

Students from all eight groups were confident about their chosen options; this is indicated by their average confidence levels ranging from 1.6 to 2.1. Table 5.3(f) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from all eight groups were confident about their correct option (confidence levels ranging from 1.8 to 2.2. Students from UPadp, UPsc, CTadp and ULfy were not confident about their incorrect options; this is indicated by the confidence levels ranging from 1.2 to 1.4, while students from UPteach, UPmaj, ULsc and ULmaj have shown higher confidence levels, 1.5 and 2.1, respectively. The largest difference between the average confidence associated with the correct answers and the average confidence associated with the incorrect answers was observed in the UP mainstream cohorts, UPmaj and UPsc. In general, students were clearly more accurate in their judgments about the correctness of their answers in this item, with the exceptions being students from ULsc and ULmaj.

5.5.7. Item 12

This item deals with a car having a maximum acceleration of 3.0 m/s^2. The students were to determine what the maximum acceleration of the car would be when it tows a second car twice its mass. The item is found in the conceptual dimension of Newton's second law (from Table 4.1), and addresses the conception of the inverse proportion between mass and acceleration of objects at constant forces, i.e. when the mass of an object increases the acceleration decreases proportionally. All of the distractors reflect the conception that when mass increases the acceleration decreases. Table 5.3(g) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(g) Performance and Confidence levels of all students for item 12

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	0.0	6.5	67.7	19.4	6.5	1.9	2.2	1.8
UPadp	68	1.5	1.5	61.2	32.8	3.0	1.6	1.7	1.6
UPsc	483	0.6	2.5	45.1	49.5	2.3	1.8	1.9	1.7
UPmaj	33	3.0	0.0	57.6	36.4	3.0	2.2	2.3	2.2
CTadp	143	0.7	1.4	71.1	21.1	5.6	1.9	1.8	1.9
ULfy	102	0.0	1.0	85.3	8.8	4.9	1.8	2.3	1.8
ULsc	79	8.9	7.6	57.0	24.1	2.5	2.0	2.1	2.0
ULmaj	43	0.0	0.0	86.0	7.0	7.0	1.8	2.3	1.8

Less than 50% of the students in each of the eight groups have chosen the correct option, option D. If a car is pulling a second car twice its mass, its new acceleration will be one-third (⅓) of the initial acceleration, because the combined mass of the two cars is three times that of the first car. A higher percentage (ranging from 45.1% to 86.0%) of students in each of the eight groups have chosen option C, that if the car is now pulling a second car twice its mass then the new acceleration will be half (½) of the initial acceleration, clearly forgetting that the mass of the car pulling the second car has to be taken into consideration. Options A, B and E are very weak distractors for all cohorts, which can be interpreted to mean that the students understood the question well, but that flawed reasoning resulted in poor performance. The item, however, can be viewed as being difficult, because even the mainstream cohorts performed poorly.

Students from all eight groups were confident about their chosen options; this is shown by their average confidence levels which range from 1.6 and 2.2. Table 5.3(g) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from all eight groups were confident about their correct option; this is indicated by the confidence levels, in the above table, ranging from 1.7 to 2.3. Students, from all eight groups, choosing the incorrect options are confident about their choices (confidence levels of 1.6 to 2.2). However, a small difference between the average confidence levels for correct answers and the average confidence levels for incorrect answers can be observed in the majority of cohorts, except for UPteach, ULfy and ULmaj. The small percentage of correct answers obtained for these three groups should be noted.

The poor accuracy of judgment shown by all groups, but especially by the benchmark group, UPmaj, is a reason for concern. It may indicate that this item does not assess depth of conceptual understanding. Respondents may have thoroughly understood the concepts involved, but made a simple error due to inaccurate analysis of the problem situation as described.

5.5.8. Item 13

This item deals with an elevator that is being lifted up an elevator shaft by means of a cable. The students were to compare the magnitudes of the forces acting on the elevator, while moving up at constant velocity. The item is found in the conceptual dimensions of Newton's first law and superposition principle (Table 4.1), and addresses the conception of "canceling forces". The alternative conceptions documented in the literature are: distractor A that "largest force determines motion", distractor D which is "only active agents exert forces", and distractor E "air pressure assisted gravity" (Gunstone, 1981; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992). Table 5.3(h) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

56.5% and 63.6% of the students from UPsc and UPmaj, respectively, have chosen the correct option, option B, while from 27.5% to 45.1% of the students from UPteach, UPadp, CTadp, ULfy, ULsc and ULmaj have also chosen the correct option, that the force by the cable on the elevator is equal in magnitude to the downward force by gravity on the elevator. A high percentage (ranging from 33.3% to 52.0%) of students from each of the eight groups have chosen A, the strongest distractor, that the upward force by the cable on the elevator is greater than the downward force by gravity on the elevator. This is a common alternative conception, as noted from above. Significantly, options C, D and E are weak distractors, except for ULsc and ULmaj, where distractors C and E feature slightly more prominently.

Table 5.3(h) Performance and Confidence levels of all students for item 13

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	45.2	38.7	3.2	3.2	9.7	2.3	2.4	2.3
UPadp	68	50.0	41.2	2.9	1.5	4.4	2.0	2.1	2.0
UPsc	483	38.9	56.5	2.3	2.1	0.2	2.3	2.5	2.1
UPmaj	33	33.3	63.6	0.0	0.0	3.0	2.4	2.6	2.1
CTadp	143	42.3	45.1	7.0	2.1	3.5	2.2	2.3	2.1
ULfy	102	52.0	27.5	9.8	5.9	4.9	2.0	1.8	2.1
ULsc	79	34.2	35.4	13.9	5.1	11.4	2.1	2.2	2.0
ULmaj	43	34.9	34.9	11.6	2.3	16.3	2.1	2.5	1.9

The average confidence levels in each of the eight groups is high (from 2.0 to 2.4), indicating that the students were confident about their chosen options. Table 5.3(h) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students choosing the correct option were confident about their correct option, their confidence levels ranging from 1.8 to 2.6. Students, from all the eight groups, choosing the incorrect options were also quite confident about their choice. This is indicated by confidence levels ranging from 1.9 to 2.3. There is a large difference between the average confidence levels for the correct answer and the average confidence levels for incorrect answers for students in UPsc, UPmaj and ULmaj. Interesting to note is the fact that the accuracy of judgment of ULmaj, a poorly performing cohort, was on par with those of UPsc and UPmaj, the two best performing cohorts in this item. The accuracy of judgment from ULfy, the lowest performing cohort, was observed to be very poor, as the students choosing the incorrect options displayed higher confidence levels than those choosing the correct option.

5.5.9. Item 14

This item deals with a large man and a boy pulling as hard as possible on two ropes attached to a crate. The students were to identify the path that will be followed by the crate as the two people pull it along. The item is found in the conceptual dimension of the superposition principle (Table 4.1), and addresses the conception about the vector sum of forces. The alternative conceptions documented in the physics education literature are: distractor A which is that "the largest force determines the motion", distractors C and D that "force compromise determines motion" (Clement, 1982; Halloun & Hestenes, 1985b; Hestenes *et al.*, 1992). Table 5.3(i) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(i) Performance and Confidence levels of all students for item 14

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	9.7	22.6	64.5	3.2	0.0	2.1	2.4	2.0
UPadp	68	2.9	39.7	55.9	1.5	0.0	2.2	2.1	2.1
UPsc	483	1.0	62.1	35.8	0.8	0.2	2.3	2.3	2.2
UPmaj	33	3.0	57.6	39.4	0.0	0.0	2.3	2.3	2.2
CTadp	143	9.2	39.4	49.3	0.7	1.4	1.9	2.1	1.8
ULfy	102	11.8	35.3	50.0	2.0	1.0	2.1	2.4	2.0
ULsc	79	15.2	30.4	48.1	3.8	2.5	2.0	2.0	2.0
ULmaj	43	18.6	44.2	32.6	4.7	0.0	2.1	2.0	2.1

62.1% and 57.6% of students from UPsc and UPmaj, respectively, have chosen the correct option, while less than 50% (from 22.6% to 44.2%) of the students from the other six groups have also chosen the correct option, which is option B, that if both the man and the boy are pulling the crate, then the crate will follow a path closer to the man's pulling path than that of the boy. Option C, the strongest distractor, has attracted some attention from all the cohorts, with the percentage frequency ranging from 32.6% to 64.5%. This option says if both the man and the boy are pulling the crate, the crate will follow a path midway between the man's and the boy's pulling paths. Distractor A displays the thinking that "the winner takes all" and is more prevalent in the UL cohorts, than in the rest of the cohorts. Options D and E are weak distractors.

The table above indicates that all the students were confident about their chosen options (the average confidence levels ranging from 1.9 to 2.3). Table 5.3(i) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students in each of the eight groups were very confident about their correct option (their confidence levels ranging from 2.0 to 2.4). Students from all eight groups were also confident about their chosen incorrect options, their confidence levels range from 1.8 to 2.2. Noticeable is that there is very little difference between the average confidence levels for correct answers and average confidence levels for incorrect answers. Students therefore showed poor accuracy of judgment about their answers to this item in almost all cohorts, which seems to point to the presence of firm alternative conceptions amongst all cohorts.

5.5.10. Item 15

This item deals with two blocks moving to the right, and the positions of the two blocks represented by numbered squares at successive 0.20-second time intervals. The students were to indicate whether the two blocks ever had the same speed. If they choose a "yes" they had to indicate the instant at which the two blocks had the same speed. The item is found in the conceptual dimension of kinematics (Table 4.1), and addresses the conception about the differentiation between velocity and position. Distractors B, C and D address an alternative conception which is documented in the literature that "position and velocity are undiscriminated" (Clement, 1982; Halloun & Hestenes, 1985b). Table 5.3(j) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(j) Performance and Confidence levels of all students for item 15

Student Group	Number of Students	Options (%)						Average Confidence Level		
		A	B	C	D	(E)	B+C+D	All	Correct Option	Incorrect Options
UPteach	31	25.8	12.9	9.7	41.9	9.7	64.5	2.0	2.3	1.9
UPadp	68	40.3	4.5	16.4	28.4	10.4	49.3	2.2	2.6	2.1
UPsc	483	25.4	3.7	8.5	25.2	37.2	37.8	2.0	2.3	1.9
UPmaj	33	21.2	3.0	3.0	15.2	57.6	21.2	2.1	2.5	1.5
CTadp	143	44.8	5.6	9.8	21.7	18.2	37.1	1.9	1.8	1.9
ULfy	102	36.0	2.0	10.0	35.0	17.0	47.0	2.0	2.2	1.9
ULsc	79	38.0	7.6	13.9	26.6	13.9	48.1	2.2	1.9	2.2
ULmaj	43	46.5	4.7	4.7	32.6	11.6	42.0	2.1	2.6	2.1

57.6% of the students from UPmaj have chosen the correct option, and less than 50% of the students from each of remaining seven groups have chosen the correct option, which is option E, that the two blocks will have the same speed, at some time during the interval between 3 and 4. Options A and D are the most important distractors, with A featuring more prominently for almost all the cohorts. Distractor A states that the two blocks will never have the same speed. Distractors B, C and D state that the blocks are at the same position at instances 2 and/or 5. The students therefore make the mistake that the same position represents the same speed, a common alternative conception of being unable to discriminate between speed and position (Clement, 1982; Halloun & Hestenes, 1985b; Hestenes *et al.*, 1992). The prevalence of this alternative conception is reflected by the sum of the responses B+C+D in Table 5.3(j).

The students were confident about their chosen options. The average confidence levels of students from all the eight groups are high (ranging from 1.9 to 2.2. Table 5.3(j) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Confidence levels ranging from 1.8 to 2.6 for the correct option indicate that the students from all eight groups were confident about their correct options. Students from all eight groups were also confident about their incorrect options, their confidence levels range from 1.5 to 2.2. This item displays a reasonable difference between the average confidences associated with correct answers as compared to the average confidence associated with the incorrect answers. This is evident from all the cohorts except for CTadp and ULsc cohorts, where the average confidence levels of the incorrect answers was higher than the average confidence levels for the correct answers. This is an excellent conceptual question. Despite its difficulty students who understood the concept and the graphical representation, analysed and answered it with confidence.

5.5.11. Item 16

The item deals with the positions of blocks "a" and "b", at successive time intervals. The time intervals were represented by means of numbered squares. The students were to interpret the visual representation in order to compare the acceleration of the two blocks. The item is found in the conceptual dimension of kinematics (Table 4.1), and addresses the conception that acceleration is discriminated from velocity. Distractors A, B and C reflect the alternative conception that "velocity and acceleration are indiscriminate" (Clement, 1982; Hestenes *et al.*, 1992). Students were expected to realize that the numbered squares for blocks a and b are an equal distance apart, which is an indication of constant velocity. Table 5.3(k) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(k) Performance and Confidence levels of all students for item 16

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	35.5	0.0	19.4	29.0	16.1	2.2	2.3	2.1
UPadp	68	17.6	1.5	36.8	38.2	5.9	2.2	2.5	2.1
UPsc	483	10.0	2.5	25.2	56.1	6.2	2.4	2.8	2.0
UPmaj	33	12.1	0.0	21.2	66.7	0.0	2.2	2.7	1.2
CTadp	143	15.4	5.6	29.4	31.5	18.2	2.1	2.5	1.8
ULfy	102	24.0	7.0	43.0	15.0	11.0	1.8	2.1	1.8
ULsc	79	25.3	11.4	30.4	20.3	12.7	2.2	2.4	2.2
ULmaj	43	25.6	11.6	20.9	30.2	11.6	2.1	2.2	2.0

56.1% and 66.7% of the students from UPsc and UPmaj, respectively have chosen the correct option, while 15.0% to 38.2% of the students from UPteach, UPadp, CTadp, ULfy, ULsc and ULmaj have also chosen the correct option, option D, that the acceleration of both blocks is equal to zero. Options A and C are the strongest distractors, with distractor C featuring more prominently in almost all the cohorts. Distractor C is about the acceleration of block "b" being greater than the acceleration of block "a", an answer that may be based on the larger distance between the squares for block b. Distractor A is about the acceleration of block "a" being greater than the acceleration of block "b". Distractors B and E were less prominent for all the cohorts as compared to distractors A and C. The graphical representation in this item is similar to the one used in item 15. Similar conceptual thinking and graphical interpretation are required. However, the performance is generally higher in this item than item 15.

The students were confident about their chosen options, with the average confidence levels of students from all the groups ranging from 1.8 to 2.4. Table 5.3(k) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students choosing the correct option, in all eight groups, were confident about their option, this was indicated by the confidence levels ranging from 2.1 to 2.8. These average confidence values are amongst the highest observed in this test. Similar values were only observed for items 6, 7 and 8. Students, from UPteach, UPadp, UPsc, CTadp, ULfy, ULsc and ULmaj, choosing incorrect options were confident about their choices. Their confidence levels range from 1.8 to 2.2. Students from groups UPmaj were not confident about their incorrect options, their average confidence level 1.2. The difference between the average confidence levels for correct answers as compared to the average confidence levels for incorrect answers is larger than in item 15, especially in the UPsc, UPmaj and CTadp cohorts. Accuracy of judgment for UPmaj, the best performing cohort, is exceptionally high, the highest observed for any of the test items. According to the reasoning of Hasan *et al.* (1999) this could be interpreted to mean that the relatively poor performance in almost all of the cohorts can be ascribed to a lack of knowledge rather than to the presence of strong alternative conceptions.

5.5.12. Item 17

This item deals with two pucks of different masses on a frictionless table. The two pucks were pushed simultaneously across the table by means of equal forces. The students were to choose the puck that would reach the finish line first. The item is found in the conceptual dimension of Newton's second law (Table 4.1), and addresses the conception of the inverse proportion between mass and acceleration of objects upon application of constant forces. The strongest distractor is option C which is based on the alternative conception that "same amount of forces implies equal acceleration" (Clement, 1982). Distractors B and D reflect alternative conceptions that are less common among students. Distractor B states that the heavier puck will reach the finish line first, while distractor D is implying that additional information is required to enable one to provide an answer. Table 5.3(l) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(l) Performance and Confidence levels of all students for item 17

Student Group	Number of Students	Options (%)					Average Confidence Level		
		(A)	B	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	67.7	9.7	22.6	0.0	0.0	2.2	2.4	1.7
UPadp	68	72.1	7.4	20.6	0.0	0.0	2.3	2.3	2.1
UPsc	483	68.4	10.8	17.0	3.7	0.0	2.2	2.3	1.9
UPmaj	33	87.9	3.0	6.1	3.0	0.0	2.3	2.4	2.0
CTadp	143	68.3	6.3	18.3	7.0	0.0	2.2	2.3	1.8
ULfy	102	71.6	5.9	19.6	2.9	0.0	2.4	2.5	2.1
ULsc	79	64.6	5.1	12.7	13.9	3.8	2.1	2.3	1.6
ULmaj	43	65.1	9.3	16.3	9.3	0.0	2.2	2.2	2.2

More than 50% of the students in each of the eight groups have chosen the correct option, which is option A, saying that the puck having a smaller mass will reach the finish line first. Option C has attracted some attention from students. The percentage of students choosing this option ranges from 12.7% to 22.6%. Option C says that the two pucks will reach the finish line at the same time, since they received the same amount of force. Students make the mistake of ignoring the effect of mass on the acceleration of an object, for constant force. Distractors B and D are weak. The students probably realized that option D is an unlikely answer.

Students in each of the eight groups were confident about their chosen options; the table above shows the average confidence levels ranging from 2.1 to 2.4. Table 5.3(l) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students who chose the correct option were confident about their option, their confidence levels range from 2.2 to 2.5. Students from groups all the eight groups, who chose the incorrect options, were also confident about their incorrect options, their confidence levels range from 1.6 to 2.2. The difference in the average confidence levels of the correct answers and the average confidence levels for incorrect answers is large in almost all the cohorts, except for ULmaj and UPadp.

5.5.13. Item 18

This item is about a large box being pushed across the floor at constant speed. The students were to compare the magnitude of the forces acting on the box. The item is found in the conceptual dimensions of Newton's first law and superposition principle (Table 4.1), and addresses conception of "canceling forces." Distractor A address the alternative conception "speed is proportional to the applied force", distractors B and D address the alternative conception "motion when force overcomes resistance" and distractor E addresses the alternative conception "resistance opposes force" (Clement, 1982; Hestenes *et al.*, 1992; Minstrell, 1982). Table 5.3(m) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(m) Performance and Confidence levels of all students for item 18

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	(C)	D	E	All	Correct Option	Incorrect Options
UPteach	31	16.1	9.7	22.6	41.9	9.7	1.9	1.8	1.9
UPadp	68	13.2	5.9	16.2	60.3	4.4	2.0	2.3	2.0
UPsc	483	5.4	6.0	45.9	39.7	2.9	2.1	2.4	1.8
UPmaj	33	3.0	12.1	54.5	27.3	3.0	2.2	2.4	2.0
CTadp	143	7.0	8.4	30.1	48.3	6.3	1.9	2.1	1.8
ULfy	102	23.8	17.8	14.9	29.7	13.9	1.8	1.8	1.9
ULsc	79	20.3	13.9	30.4	27.8	7.6	1.9	1.8	1.9
ULmaj	43	30.2	7.0	25.6	30.2	7.0	2.1	2.5	1.9

The relatively poor performance on this item indicates that students found this to be a difficult question. 54.5% of the students in UPmaj have chosen the correct option, while less than 50% (ranging from 14.9%to 45.9%) of the students in each of the other seven groups have also chosen the correct option, which is option C. Option C states that the amount of force applied to move the box at a constant speed is equal to the amount of the frictional forces that resist the box's motion. Higher percentages (from 27.3% to 60.3%) of students in each of the groups have chosen D. Options B and D reflect a common alternative conception that the amount of force applied to move the box at a constant speed must be more than the frictional forces that resist the box's motion. The students make the mistake that the applied force must overcome the weight or the frictional force for the box to actually move. Option E is relatively a weak distractor for all the cohorts, and is about the alternative conception that "resistance opposes force". According to Hestness *et al.* (1992); Hestenes & Wells (1992) and Minstrell (1982) the students do not regard friction as a "real" force; they take it that friction is just there to resist motion. However, this alternative conception is rare within the respondents in this study. Distractor A assumes that the speed is dependent on the applied force. Students make the mistake that increasing the force applied on the box would result in the speed of the box also increasing.

Students from all eight groups were confident about their chosen options, their average confidence levels range from 1.8 to 2.2. Table 5.3(m) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from all the eight groups, who have chosen the correct option, were confident about their choice. Their confidence levels range from 1.8 to 2.5. Students, from all the eight groups, who have chosen the incorrect options, also have high confidence levels ranging from 1.8 to 2.0. There is significantly poor accuracy of judgment for the UPteach, ULfy and ULsc. The best judgment on this item is recorded for UPsc and ULmaj.

5.5.14. Item 19

This item deals with a diagram representing a multiflash of an object moving to the right along a horizontal surface. The students were to identify the graph that best represented the object's velocity as a function of time. The item is located in the conceptual dimension of kinematics (from Table 4.1). The interpretation of a diagram of multiflash, and transforming the multiflash into a graphical representation are assessed in this item. Table 5.3(n) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(n) Performance and Confidence levels of all students for item 19

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	26.7	43.3	13.3	13.3	3.3	2.0	1.9	2.1
UPadp	68	36.8	55.9	4.4	2.9	0.0	2.0	2.0	1.9
UPsc	483	26.2	63.2	4.6	2.5	3.5	2.1	2.2	1.9
UPmaj	33	24.2	66.7	9.1	0.0	0.0	2.3	2.5	1.9
CTadp	143	30.3	38.7	12.0	9.9	9.2	1.7	2.0	1.5
ULfy	102	28.7	28.7	14.9	4.0	23.8	1.4	1.4	1.4
ULsc	79	20.3	44.3	10.1	13.9	11.4	1.9	2.3	1.6
ULmaj	43	18.6	30.2	25.6	9.3	16.3	2.0	2.1	1.9

55.9%, 63.2% and 66.7% of the students from UPadp, UPsc and UPmaj, respectively, have chosen the correct option, and less than 50% of the students from UPteach, CTadp, ULfy, ULsc and ULmaj have also chosen the correct option, option B, that the speed of the object increases constantly for a longer period of time, the speed remains constant, and then the speed decreases constantly for a short period of time. Option A has also received some attention, the percentage frequency of students choosing this option ranges from 18.6% to 36.8% in the eight groups. Option A shows the speed of the object to increase constantly for a short period of time, the speed remains constant, and then the speed decreases constantly for a longer period of time. Options C, D and E were weak distractors for UPadp, UPsc and UPmaj. Options C to E show a distinct break in the velocity of the object. It suggests that the UL groups, CTadp and UPteach may have confused the concepts of velocity and acceleration.

The table above indicates the average confidence levels of students for all the eight groups. Students from all the groups, except for students from ULfy, are confident about their chosen options; this is shown by their average confidence levels ranging from 1.7 to 2.3. Students from ULfy were not confident about their chosen options; their average confidence level is 1.4. Table 5.3(n) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from the seven groups (UPteach, UPadp, UPsc, UPmaj, CTadp, ULsc and ULmaj) are confident about their correct option, their confidence levels range from 1.9 to 2.5, while students from ULfy are not confident about their correct options, their confidents level is 1.4. Students from the seven groups, except for ULfy, have shown confidence levels ranging from 1.5 to 2.1, which indicate that they are fairly confident about their incorrect options. Students from ULfy are not confident about their incorrect options, their confidence level is 1.4. There is a moderately strong difference between the accuracy of judgment between students choosing the correct answers and those choosing the incorrect answers, especially in the UPmaj and ULsc. However the accuracy of judgment for the UPteach cohort is poor, the students answering the item incorrectly are more confident than those providing the correct answer.

5.5.15. Item 20

This item deals with the diagram representing a multiflash of an object moving to the right along a horizontal surface that was shown in item 19. Unfortunately the description of the problem did not contain any direct reference to item 19. The students were to identify the graph that best represented the object's acceleration as a function of time. The item is located in the conceptual dimension of kinematics (from Table 4.1). The graphical representation in this item is similar to the one used in item 19. Similar conceptual thinking and graphical interpretation is required, except that students were required to interpret the multiflash diagram in terms of acceleration rather than velocity. Table 5.3(o) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

More than 50% of the students from UPteach, UPadp, UPsc and UPmaj and less than 50% of the students from CTadp, ULfy, ULsc and ULmaj have chosen the correct option, option D. Option D is about the object accelerating constantly for a longer period of time, it maintains constant speed, and then decelerates constantly for a short period of time. Option E has also attracted some attention from students. The option is about the object accelerating constantly for a short period of time, maintaining a constant speed, and then accelerating for a longer period of time.

Table 5.3(o) Performance and Confidence levels of all students for item 20

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	3.3	10.0	3.3	60.0	23.3	1.3	1.2	1.5
UPadp	68	10.3	2.9	10.3	51.5	25.0	1.9	2.2	1.5
UPsc	483	5.8	3.3	7.9	62.0	21.0	2.2	2.3	2.0
UPmaj	33	6.1	3.0	6.1	69.7	15.2	2.2	2.3	1.9
CTadp	143	5.0	6.4	15.0	48.6	25.0	1.5	1.7	1.3
ULfy	102	8.8	17.6	23.5	35.3	14.7	1.1	1.3	0.9
ULsc	79	13.9	20.3	8.9	43.0	13.9	1.7	2.0	1.5
ULmaj	43	9.3	14.0	16.3	48.8	11.6	1.8	2.0	1.6

Students seem to be less confident about their answers to this item than about answers to other items. The average confidence levels of 1.1 and 1.3, respectively, for students from UPteach and ULfy, indicate that the students are not confident about their chosen options, while students from UPadp, UPsc, UPmaj, CTadp, ULsc and ULmaj are more confident about their chosen options, the average confidence levels range from 1.5 to 2.2. Table 5.3(o) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from UPadp, UPsc, UPmaj, CTadp, ULsc and ULmaj are confident about their correct option, their confidence levels range from 1.7 to 2.3, while students from UPteach and ULfy are not confident about their correct options, their confidence levels are 1.2 and 1.3, respectively.

Students from UPteach, UPadp, UPsc, ULsc and ULmaj have average confidence levels ranging from 1.5 to 2.0, this indicates that they are confident about their incorrect options, while students from CTadp and ULfy, have confidence levels of 1.3 and 0.9, respectively, this indicates that they are not confident about their incorrect options. A moderately large difference between average confidence associated with the correct answer and the average confidence associated with the incorrect answers was observed in almost all cohorts, except for UPteach whose accuracy of judgment was poor.

5.5.16. Item 21

This item deals with ticker tape trace which represents the motion of a car, moving to the right. The students were to study the tape and indicate the direction of the acceleration as well as the direction of the net force on the car. The item is located in the conceptual dimension of Newton's second law (Table 4.1), and addresses the conception that the directions of the acceleration and the net force are the same. Distractors B and C include the alternative conception that motion is in the direction of force (Clement, 1982; Halloun & Hestenes, 1985a). Table 5.3(p) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

The frequency distribution for this item could not be interpreted because of flaws in the problem presentation. It was not mentioned in the statement, for this item, where the first dot was made, a fact that was not picked up during the analysis of the pilot study. If one studies the tape carefully, there are two possible correct options. It is possible that the motion of the car could have been accelerated, and it is also possible that the motion could have been decelerated. In the case of the car accelerating, the acceleration and the net force could both be directed to the right, and hence option A could be the correct one. For a decelerated motion, the acceleration and the net force could both be directed to the left, and hence option D could be the correct option.

Table 5.3(p) Performance and Confidence levels of all students for item 21

Student Group	Number of Students	Options (%)					Average Confidence Level		
		(A)	B	C	(D)	E	All	Correct Option	Incorrect Options
UPteach	31	22.6	29.0	29.0	6.5	12.9	1.7	3.0	1.6
UPadp	68	23.5	26.5	29.4	14.7	5.9	1.8	2.1	1.7
UPsc	483	23.3	11.0	41.4	20.8	3.5	2.0	2.3	1.9
UPmaj	33	27.3	3.0	30.3	36.4	3.0	2.4	2.4	2.4
CTadp	143	34.0	19.1	22.7	13.5	10.6	1.7	2.0	1.7
ULfy	102	30.4	42.2	15.7	4.9	6.9	1.8	2.6	1.7
ULsc	79	39.2	19.0	17.7	10.1	13.9	2.0	2.1	2.0
ULmaj	43	39.5	34.9	14.0	4.7	7.0	1.8	3.0	1.8

5.5.17. Item 22

This item deals with a person pulling a block across a rough horizontal surface. The person pulls the block at constant speed by applying a force F. The directions of the forces acting on the block were indicated on the diagram. The students were to choose the correct relationship of the magnitudes of the various forces acting on the block. The item is located in the conceptual dimension of superposition principle (Table 4.1), and addresses the conception "canceling forces" (Clement, 1982; Halloun & Hestenes, 1985a; Maloney, 1984; Minstrell, 1982). Table 5.3(q) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(q) Performance and Confidence levels of all students for item 22

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	(C)	D	E	All	Correct Option	Incorrect Options
UPteach	31	12.9	3.2	9.7	61.3	12.9	2.1	1.7	2.1
UPadp	68	5.9	0.0	8.8	80.9	4.4	2.3	2.3	2.3
UPsc	483	16.7	1.5	11.9	65.1	4.8	2.3	2.5	2.3
UPmaj	33	15.2	3.0	6.1	75.8	0.0	2.6	3.0	2.6
CTadp	143	11.9	0.7	7.0	79.0	1.4	2.2	1.5	2.2
ULfy	102	4.9	5.9	13.7	63.7	11.8	1.9	2.1	1.9
ULsc	79	21.5	10.1	13.9	44.3	10.1	2.0	2.2	2.0
ULmaj	43	14.0	9.3	16.3	53.5	7.0	1.9	2.0	1.9

The performance of students in all groups on this item was exceptionally poor. Less than 17% of the students in each of the eight groups have chosen the correct option, which is option C. Option C is about the forces acting on the crate that is being pulled at constant speed, the normal force is less than the weight, and the applied force is greater than the frictional force. A high percentage (ranging from 44.3% to 80.9%) of students from each of the eight groups have chosen option D. Option D is about the normal force being equal in magnitude to the weight and the pulling force being greater than the frictional force.

The students from all eight groups were confident about their chosen options, their average confidence levels range from 1.9 to 2.6. Table 5.3(q) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from all the eight groups were confident about their correct options, their confidence levels range from 1.5 to 2.5. Students, from all eight groups, choosing the incorrect options were also confident about their choices. Their confidence levels range from 1.9 to 2.6. Accuracy of judgment for the UPteach and CTadp is observed to be very poor as compared to the other cohorts. Their average confidence levels were higher for incorrect answers than for correct answers. This item seems to be associated with strong alternative conceptions as judged by the generally poor accuracy of judgment.

5.5.18. Item 23

This item deals with a rocket drifting sideways in outer space, with no outside force subjected to it. At position "b" the engine of the rocket produces a constant thrust at right angles to its original direction, and the engine is later switched off on reaching a certain point "c". The students were to select the path that best represented the movement of the rocket between "b" and "c". The item is found in the conceptual dimensions of kinematics and Newton's second law (Table 4.1), and addresses the conception "constant acceleration entails parabolic trajectory". Distractor A includes the alternative conception "loss of original force", distractor B includes the alternative conception "last force to act determines motion", distractor C includes the alternative conception "force compromise determines motion" and distractor D includes the alternative conception "delayed impetus build-up" (Clement, 1982; Hestenes *et al.*, 1992; Jimoyiannis *et al.*, 2001;). Table 5.3(r) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(r) Performance and Confidence levels of all students for item 23

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	B	C	D	(E)	All	Correct Option	Incorrect Options
UPteach	31	9.7	41.9	32.3	3.2	12.9	1.3	1.3	1.3
UPadp	68	11.8	30.9	25.0	14.7	17.6	1.8	1.9	1.7
UPsc	483	10.4	23.6	26.5	14.6	24.8	1.7	1.8	1.6
UPmaj	33	3.0	21.2	27.3	18.2	30.3	1.8	2.2	1.7
CTadp	143	14.8	35.9	20.4	14.1	14.8	1.5	1.6	1.4
ULfy	102	10.8	41.2	21.6	7.8	18.6	1.6	1.2	1.6
ULsc	79	13.9	22.8	35.4	12.7	15.2	1.6	1.9	1.6
ULmaj	43	23.3	27.9	23.3	14.0	11.6	1.3	0.8	1.4

This appears to have been a difficult item, even the best performing cohort, UPmaj, performed poorly here. 30% or less of the students from each of the eight groups has chosen the correct option, which is option E. The two most prominent distractors are options B and C, with the percentage of students from the eight groups, ranging from

21.2% to 41.9% for option B and from 20.4% to 35.4% for option C. It is possible that the word "thrust" in the problem statement may not have been understood correctly. The relatively low confidence levels associated with most responses to this item is either an indication of a poor conceptual understanding or of a lack of clarity of the problem statement.

Students from UPadp, UPsc, UPmaj, CTadp, ULfy and ULsc, were marginally confident about their chosen options, their average confidence levels range from 1.5 to 1.8. The average confidence level, of 1.3, of the students from UPteach and ULmaj indicates that the students are not confident about their chosen options. Students from UPadp, UPsc, UPmaj, CTadp and ULsc, who have chosen the correct option, are confident about their chosen option. Their average confidence levels range from 1.6 to 2.2. The students who have chosen the correct options, from UPteach, ULfy and ULmaj are not confident about their choices. Their confidence levels range from 0.8 to 1.3. The average confidence of ULmaj is so low that it may indicate a lucky guess for most of the 11.6% correct responses. Students choosing the incorrect options, from UPadp, UPsc, UPmaj, ULfy and ULsc, were marginally confident about their incorrect choices. Their average confidence levels range from 1.6 to 1.7. Students from UPteach, CTadp and ULmaj were not confident about their incorrect choices. Their confidence levels range from 1.3 to 1.4. The largest difference between average confidence associated with the correct answers and the average confidence associated with the incorrect answers is observed for UPmaj. For the cohorts ULfy and ULmaj the accuracy of judgment is poor because average confidence associated with the correct answers is lower than average confidence associated with the incorrect answers.

5.5.19. Item 24

This item is about a heavy ball, attached to a string, and swung in a circular path in a horizontal plane. At a certain point the string breaks at the ball. The students were to predict the path the ball would follow as viewed from directly above the plane. The item is found in the conceptual dimension of Newton's first law (Table 4.1). Distractors A and D include the alternative conception "circular impetus", distractor C and E include the alternative conception "centrifugal force" (Clement, 1982; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992). The correct answer is option B which shows the ball to be flying along the tangent of the circle at the time of separation. Table 5.3(s) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(s) Performance and Confidence levels of all students for item 24

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	25.8	35.5	16.1	6.5	16.1	1.6	1.8	1.5
UPadp	68	35.3	30.9	7.4	5.9	20.6	1.9	2.0	1.8
UPsc	483	28.5	46.3	7.7	8.8	8.8	1.8	1.9	1.7
UPmaj	33	30.3	42.4	12.1	6.1	9.1	1.8	2.1	1.6
CTadp	143	44.1	30.1	7.0	4.2	14.7	1.6	1.7	1.6
ULfy	102	34.3	28.4	11.8	5.9	19.6	1.7	1.8	1.6
ULsc	79	29.1	35.4	12.7	7.6	15.2	1.8	1.9	1.7
ULmaj	43	27.9	27.9	20.9	9.3	14.0	1.8	1.7	1.9

Less than 50% of the students from each of the eight groups have chosen the correct option, which is option B. Option A was a good distracter, because it has attracted some attention from students, the percentage ranges from 25.8% to 44.1%. Options C and E (centrifugal force) accounted for most of the remaining answers in all of the cohorts.

Students from each of the eight groups have shown that they were reasonably confident about their chosen options, their average confidence levels range from 1.6 to 1.9. Table 5.3(s) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from each of the eight groups have shown that they were confident about their correct option; their confidence levels are between 1.7 and 2.1. Students who have chosen the incorrect options in each of the eight groups have shown that they were also confident about their incorrect options. Their confidence levels range from 1.5 to 1.9.

5.5.20. Item 25

This item deals with the movement of the ball on a semicircular channel fixed to a table top. The ball entered and left the channel at the indicated points. The students were to select the path that would most nearly correspond to the path of the ball as it exited the channel and rolled across the tabletop. The item is found in the conceptual dimension of Newton's first law (Table 4.1), and addresses the conception of "with no force" (Clement, 1982; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992). Distractor A includes the alternative conception "circular impetus", distractors C and E includes the alternative conception "centrifugal force" and distractor D includes the alternative conception "force compromise determines motion" (Clement, 1982; Halloun & Hestenes, 1985a). Table 5.3(t) below indicates the percentage of students, in each of the eight groups, choosing an option and their average confidence levels.

Table 5.3(t) Performance and Confidence levels of all students for item 25

Student Group	Number of Students	Options (%)					Average Confidence Level		
		A	(B)	C	D	E	All	Correct Option	Incorrect Options
UPteach	31	35.5	51.6	9.7	0.0	3.2	1.6	1.7	1.5
UPadp	68	33.8	57.4	4.4	2.9	1.5	1.8	1.8	1.7
UPsc	483	25.6	66.0	7.5	0.6	0.2	1.8	1.9	1.6
UPmaj	33	36.4	57.6	3.0	3.0	0.0	2.1	2.4	1.8
CTadp	143	30.3	53.5	14.8	0.0	1.4	1.7	1.8	1.6
ULfy	102	17.6	49.0	26.5	3.9	2.9	1.8	2.0	1.6
ULsc	79	12.7	29.1	27.8	10.1	20.3	1.6	1.5	1.6
ULmaj	43	20.9	34.9	27.9	11.6	4.7	1.6	1.7	1.6

More than 50% of the students from UPteach, UPadp, UPsc, UPmaj and CTadp, and less than 50% of the students from ULfy, ULsc and ULmaj, have chosen the correct option, option B. Option A has received some attention from students, the percentage of students choosing this option ranges from 12.7% to 36.4%. The conceptual content of this item is essentially the same as that of item 24, but students performed up to 23% better than in item 24 as judged by the percentage correct answers per group. The only exception is ULsc.

Students from the eight groups have shown that they were confident about their chosen options, their average confidence levels range from 1.6 to 2.1. Table 5.3(t) also indicates the confidence levels of students who have chosen the correct option and those choosing the incorrect options. Students from all eight groups have shown that they were confident about their correct option. Their confidence levels range from 1.5 to 2.4. Students, from the eight groups, who have chosen the incorrect options, have indicated that they were also confident about their incorrect options, and the confidence levels of the students in all the eight groups range from 1.5 to 1.8.

5.6. Summary

The difference in the confidence levels associated with correct and incorrect answers for each item will be analyzed in this section. The difference between the average confidence levels associated with a correct answer and with the combination of incorrect answers is indicative of the quality of judgment about the correctness of the answer provided that cohorts are capable of. The summary of the analysis of the multiple-choice component of the results is based on the performance by the UPmaj cohort. The UPmaj cohort was chosen as a benchmark, because this cohort was the best performing group of all. Table 5.4 below indicates the ability of students to make accurate judgment in terms of the difference in the confidence levels. Item difficulty in Table 5.4 represents the percentage of UPmaj students who have chosen the correct answer.

Table 5.4 Summary of differences between average confidence levels for correct and incorrect responses, for all cohorts and item difficulty for the UPmaj cohort.

Item	Conceptual Dimension	Item Difficulty	Difference in the average confidence levels associated with correct and incorrect answers							
			UPteach	UPadp	UPsc	UPmaj	CTadp	ULfy	ULsc	ULmaj
6	Gravitation	Easy (78.8%)	0.1	0.2	0.5	0.7	0.4	0.3	0.1	-0.1
7	Newton's third law	Moderate (57.6%)	0.0	0.0	0.2	0.5	0.1	0.1	0.1	0.2
8	Gravitation	Difficult (36.4%)	0.1	0.1	0.3	0.5	0.3	0.1	0.0	0.1
9	Kinematics and Gravitation	Moderate (57.6%)	0.0	0.4	0.4	0.4	0.2	0.5	0.4	-0.1
10	Superposition principle and Newton's first law	Moderate (63.6%)	0.4	0.5	0.6	0.4	0.1	0.3	0.1	0.3
11	Newton's first and third laws and superposition principle	Easy (75.5%)	0.4	0.6	0.9	0.7	0.6	0.4	0.0	-0.1
12	Newton's second law	Difficult (36.4%)	0.4	0.1	0.2	0.1	-0.1	0.5	0.1	0.5
13	Newton's first law and superposition principle	Moderate (63.6%)	0.1	0.1	0.4	0.5	0.2	-0.3	0.2	0.6
14	Superposition principle	Moderate (57.6%)	0.4	0.0	0.1	0.1	0.3	0.4	0.0	-0.1
15	Kinematics	Moderate (57.6%)	0.4	0.5	0.4	1.0	-0.1	0.3	-0.3	0.5
16	Kinematics	Moderate (66.7%)	0.2	0.4	0.8	1.5	0.7	0.3	0.2	0.2
17	Newton's second law	Easy (87.9%)	0.7	0.2	0.4	0.4	0.5	0.4	0.7	0.0
18	Newton's first law and superposition principle	Moderate (54.5%)	-0.1	0.3	0.6	0.4	0.3	-0.1	-0.1	0.6
19	Kinematics	Moderate (63.7%)	-0.2	0.1	0.3	0.6	0.5	0.0	0.7	0.2
20	Kinematics and Newton's first law	Moderate (69.7%)	-0.3	0.7	0.3	0.4	0.4	0.4	0.5	0.4

Item	Conceptual Dimension	Item Difficulty	Difference in the average confidence levels associated with correct and incorrect answers							
			UPteach	UPadp	UPsc	UPmaj	CTadp	ULfy	ULsc	ULmaj
21	Newton's second law	Moderate (63.7%)	1.4	0.4	0.4	0.0	0.3	0.9	0.1	1.2
22	Superposition principle	Difficult (6.1%)	0.4	0.0	0.2	0.4	-0.7	0.2	0.2	0.1
23	Kinematics and Newton's second law	Difficult (30.3%)	0.0	0.2	0.2	0.5	0.2	-0.4	0.3	-0.6
24	Newton's first law	Moderate (42.2%)	0.3	0.2	0.2	0.5	0.1	0.2	0.2	-0.2
25	Newton's first law	Moderate (57.6%)	0.2	0.1	0.3	0.6	0.2	0.4	-0.1	0.1

The performance of the UPmaj cohort will be used in determining the difficulty of an item. The UPmaj cohort is used in this analysis because this cohort has shown to be the best overall performance amoung the eight cohorts chosen in the study. For the purpose of the study, an item is regarded as being easy if 70% and above of the students were able to answer it correctly; an item is regarded as being moderate if between 40% and 69% of the students were able to answer it correctly; and an item is said to be difficult if between 0% and 39% of the students answered it correctly.

The analysis of Table 5.4 above indicates that there are three groups of items. The first group is made up of items that are classified as being easy, and those are items 6, 11 and 17. The second group consists of items that have been classified as being moderately difficult, and these are items 7, 9, 10, 13, 14, 15, 16, 18, 19, 20, 21, 24 and 25. The third group is made up of items that are regarded as being difficult, and these are items 8, 12, 22 and 23.

The difference in the average confidence levels associated with correct and incorrect answers, for each cohort, is calculated by subtracting the average confidence levels associated with incorrect answers from the average confidence levels associated with correct answers. A positive difference between the average confidence levels of students choosing the correct answer and those choosing the incorrect answers can be interpreted to mean that the majority of students in that cohort were making a correct judgment about their knowledge. However the degree to which this is true would depend on how big the difference between average confidence levels is. In Table 5.4 above, negative differences can be observed. This indicates the poor accuracy of judgment among the students, meaning that those that are getting answers wrong are more confident about their incorrect answers than those who answered correctly.

From Table 5.4, two sets of unique items can be identified. Items 12, 14 and 21 for UPmaj are flagged by their small values for differences in average confidence, despite the difference in their difficulty levels. The other uniqueness is observed in items 15 and 16 which have exceptionally large differences between average confidences while having comparable difficulties. At this stage it is not clear why these sets of items are unique, however an attempt will be made in order to find out what this means in the next chapter where an analysis of the written responses will be made.

CHAPTER 6 ANALYSIS OF WRITTEN RESPONSES

6.1. Introduction

This analysis was carried out in order to obtain insight into the students' understanding of concepts, instead of just relaying on the multiple-choice responses. Chase (1999) documented that multiple-choice questions are good at assessing learning at face value, but are lacking at assessing creative thinking and reasoning as well as higher order process skills. Analysis of the written responses was not done for all the cohorts of students, participating in the study. Instead, all the UL cohorts and one UP cohort were chosen for the analysis. The students from UL were selected for this analysis because of their geographical location, which was convenient for the researcher and because the results would enrich the teaching practice of the researcher at that institution. The UPmaj was chosen as a benchmark, because this cohort showed best overall performance in the test. A total of 257 students' written responses were used in the analysis, i.e. 224 students from the combined UL cohorts (ULfy, ULsc and ULmaj) and 33 students from UPmaj.

6.2. Coding and Analysis of Written Explanations

Analysis of the written responses, for each item, was carried out using a coding system. Each code corresponds to a particular group of responses supplied by students. The code for the scientifically acceptable explanation(s) for each item is given in brackets and is underlined. The response distribution is given as the number of students who provided a particular explanation for their multiple-choice answer to the item, and as a percentage of the total number of responses to that item. In each of the tables (Tables 6.1(a) to 6.1(t)) the percentage of students (frequency %) responding according to a particular code, was calculated by using the following formula

$$Frequency(\%) = \frac{n}{N} \times 100$$

where n represents the number of students, whose explanations belong to the same code, N represents the total number of students in a group.

6.2.1. Item 6 – Coding of written explanations

A01: No response

A02: Uncodable response

A03: The force of gravity acting on the two balls is the same, because they are of the same size. The two balls will therefore reach the ground at the same time.

A04: The frictional force acting on the lighter ball is smaller than the frictional force acting on the heavier ball. The lighter ball will thus travel at a higher velocity than the heavier ball, and hence reaches the ground first.

(A05): The acceleration due to gravity experienced by the two balls is the same, since it is independent of the mass of the object. The rate of change of velocity of the two balls will be the same, and thus they will reach the ground at the same time. The two balls will reach the ground at the same time, because they both experience free-fall.

A06: The force of gravity depends on the mass of the object; a heavier ball will therefore be pulled down with a bigger force, than the lighter ball. Therefore the heavier ball will reach the ground first.

Table 6.1(a) Frequency of written responses for item 6 for the combined UL cohorts and UPmaj cohort.

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
A01	3	1.3	0	0.0
A02	4	1.8	0	0.0
A03	31	13.8	5	15.2
A04	66	29.5	0	0.0
(A05)	52	23.2	22	66.7
A06	74	33.0	6	18.2

Explanation A05 corresponds to the correct answer to the multiple-choice component of this item. Explanation A03 indicates the inadequate level of understanding of students. The students have an idea that the two balls would reach the ground at the same time, but lack the understanding of the reasoning involved. Explanation A06 represents a classical alternative conception associated with gravity that heavier objects fall faster than lighter objects (Gunstone *et al.*, 1981; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992). This alternative conception is almost twice more prevalent in the

UL cohorts than in the UPmaj cohort. Alternative conception A04, that lighter objects fall faster than heavier objects, is less prominent among UL students and non-existent in the UP cohorts.

From Tables 5.3(a) and 6.1(a) it can be deduced that students have some idea that the two balls, having different masses, would reach the ground at the same time. There are those students who believe that the two metal balls will reach the ground at the same time because they experience the same gravitational acceleration downwards. However, some of the reasons for the two balls to reach the ground at the same time are not scientifically correct. Some students believe that the two balls reach the ground at the same time because they are both acted upon by the same amount of gravitational force. Even though the masses are different, the students believe that they (the two metal balls) experience the same pulling force downwards. It would seem that the students confuse gravitational force and gravitational acceleration. It is true that falling objects of different masses would experience the same gravitational acceleration; that is their velocity while falling down would increase at the same rate. The gravitational force acting on them depends on (among others) the masses of the objects involved. Therefore different objects would not experience the same gravitational force, while falling down. There are those students who believe that a heavy metal ball would reach the ground first. A heavier object would fall faster, a belief that was documented by Planinic *et al.* (2006) and Halloun *et al.* (1985a), as a common alternative conception among the physics students.

6.2.2. Item 7 – Coding of written responses

B01: No response

B02: Uncodable response

(B03): They all exert the same amount of force on each other. According to Newton's Third Law of motion, the force exerted by the truck on the compact car is equal but opposite to the force exerted by the compact car on the truck.

B04: The force exerted by the truck on the compact car is bigger, because the truck has a bigger mass, so it will exert a bigger force.

B05: The compact car was traveling at a higher velocity compared to the truck. The compact car will thus exert a bigger force on the truck.

B06: The compact car does not exert a force on the truck, because during collision the car will bounce back and the truck will move forward until it stops.

B07: The two vehicles are moving towards each other, so they exert equal forces on each other.

(B08): The momentum of both the compact car and the truck before collision will be equal to their momentum after the collision. Thus two vehicles will exert equal forces on each other.

Table 6.1(b) Frequency of the written explanations for item 7 for the combined UL cohorts and UPmaj cohorts.

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
B01	6	2.7	1	3.0
B02	0	0.0	0	0.0
(<u>B03</u>)	40	17.9	18	54.4
B04	137	61.2	12	36.4
B05	7	3.1	1	3.0
B06	6	2.7	0	0.0
B07	11	4.9	0	0.0
(<u>B08</u>)	17	7.6	1	3.0

Explanations B03 and B08 are acceptable scientific explanations for the item. The frequency for explanations B03 and B08, in Table 6.1(b) and that for option E from Table 5.3(b), are almost the same for the UPmaj cohort, and similar for the UL cohorts. In explanation B07 the students have an idea that the forces exerted by the two vehicles on each other will be of the same magnitude, but lack the knowledge and understanding in this regard. This alternative explanation is only present in the UL cohorts. Explanations B05 and B06 are less prominent among the students. Explanation B04 is a classical alternative conception, which is documented in physics education research. This conception is that if two objects of different masses interact with each other, the massive object will exert a bigger force on the smaller object as compared to the force exerted by the smaller object on the massive object (Halloun & Hestenes, 1985a; Maloney, 1984). This alternative conception, which corresponds to distractors A and D from the multiple-choice part, is almost twice as strong in the UL cohorts as in the UPmaj cohort.

The analysis of the students' responses in this item (Tables 5.3(b) and 6.1(b)) suggests that about 57.4% of the UPmaj students and only 25.5% of the UL students have an understanding that the two vehicles would exert forces of equal magnitudes on each other, in accordance with Newton's Third Law of motion. However, the majority of the rest of the students of the two cohorts believe that the large truck would exert a greater amount of force on the small compact car, while the small compact car exerts a smaller amount of force on the large truck. These students believe that the amount of force depends on the mass of the object exerting it, and therefore make a conclusion that the truck exerts a greater amount of force since it has a bigger mass.

6.2.3. Item 8 – Coding of written responses

C01: No response

C02: Uncodable response

C03: There are two forces acting on the ball. The upward force exerted by the hand, which keeps the ball going up, and the downward force of gravity, which is bigger.

(C04): The only force acting on the ball, during its flight, is the force of gravity, since the ball left the hand some time ago and there is no frictional force acting on the ball.

C05: As the steel ball goes up, its velocity decreases. This means that the upward force by the hand decreases as the ball goes up. The velocity of the ball increases as the ball goes down, because the downward force acting on it increases.

C06: The force of gravity only acts when the ball goes down. There is no gravitational force when the ball goes up.

C07: The gravitational force for upward motion is negative and decreases, while for the downward motion it is positive and increasing.

Table 6.1(c) Frequency of written responses to item 8 for the combined UL cohorts and UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
C01	4	1.8	2	6.1
C02	6	2.7	1	3.0
C03	66	29.5	2	6.1
(<u>C04</u>)	39	17.4	13	39.4
C05	80	35.7	15	45.5
C06	17	7.6	0	0.0
C07	13	5.8	0	0.0

The scientifically acceptable explanation for this item is C04. This explanation corresponds to option D on the multiple-choice part of this item. Explanation C03 is based on the reasoning that the force by the hand is able to act on the ball while it is not in contact with the ball. It is well known to the researcher from personal experience that students regard this force as the "force of motion". The students reason that the ball is able to move upwards because there is a "force of motion" exerted on the ball by the hand. This is also a well-known alternative conception that has been documented by Gunstone *et al.* (1981), Halloun & Hestenes (1985a) and Hestenes *et al.* (1992). In fact, the only force that is able to act at a distance is the gravitational force. Unlike the gravitational force, the force by the hand can not act at a distance. For this force to act the hand and the ball have to be in contact with each other. This alternative conception is much more prominent in the UL cohorts than in the UPmaj cohort. Explanation C05 involves the increase in the magnitude of the force due to gravity, as the ball goes down, and the decrease in magnitude by the upward force. This alternative conception is more prominent in the UPmaj than in the UL cohorts. Explanations C06 and C07 are less prominent among students in the UL cohorts and non-existent in the UPmaj cohort.

From Tables 5.3(c) and 6.1(c), it can be deduced that the majority of the students in all the cohorts believe that, other than the force of gravity acting on the ball, there is upward force acting on the ball as it goes up. Some of the reasons they provide is that there is a force by the hand acting on the ball as it goes up. The force by the hand on the ball ended when the ball left the hand, however students believe that the ball goes up because that force is still in action. The students have this understanding that "motion requires force", and believe that "active force wears out" (Hestenes *et al.*, 1992), because the velocity of the ball decreases as it goes up. Both "motion requires force" and "active force wears out" are regarded as common alternative conceptions in mechanics. Of course, there are some students who are able to identify the force acting on the ball correctly as the gravitational force only, when the frictional force is ignored.

6.2.4. Item 9 – Coding of written responses

D01: No response

D02: Uncodable response

D03: There is gravitational force acting on the bowling ball. Since the gravitational force is acting vertically downwards, the bowling ball will fall straight down.

D04: The bowling ball is moved forward by the force of the airliner. While moving forward its velocity decreases, the ball then fall straight downwards because of the gravitational force acting on it.

(D05): Even though there is gravitational force pulling the bowling ball downwards, it will fall forward at an angle because of inertia.

D06: When the bowling ball falls from the airliner, there is gravitational force acting downwards (on the ball) causing it to fall down. There is also frictional force acting in the direction opposite to the direction of the airliner. This force pushes the ball backwards. The combination of the frictional force and the gravitational force thus results in the ball falling backwards at an angle.

Table 6.1(d) Frequency of the written responses to item 9 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
D01	5	2.2	2	6.1
D02	3	1.3	1	3.0
D03	36	16.1	1	3.0
D04	29	12.9	3	9.1
(D05)	78	34.8	19	57.6
D06	73	32.6	7	21.2

The scientifically acceptable explanation is D05, which states that the bowling ball will fall forward at an angle because of its inertia and the gravitational force acting on it. This explanation corresponds to option D in the multiple-choice component of this item. In explanation D03 students seem to ignore both the effect of air friction on the ball and the fact that the bowling ball possesses inertia. This alternative conception is more prominent in the UL cohorts than in the UPmaj. Explanation D04 is also more prominent in the UL cohorts than in the UPmaj. The reasoning seems to imply that one force acts on the bowling ball, and the other forces start acting after the first force has ended. This therefore seems to imply that the airliner exerts a force on the bowling ball and then later on gravity starts acting. This is a well known alternative conception that "gravity acts after impetus wears down" (Halloun & Hestenes, 1985b; Jimoyiannis *et al.*, 2001). The frequency from Table 6.1(d) indicates that the alternative conception D06 is most prominent in both the UL and UPmaj cohorts.

From the analysis of Tables 5.3(d) and 6.1(d), it can be realized that the majority of the students in the UP cohorts indicated that the ball would follow a parabolic path forward, because of its inertia. Some students believe that the bowling ball would move forward because of the force of the airliner. The students have this belief that the airliner exerts a force on the ball as it falls, and this force decreases with time. The gravitational force starts acting on the ball once the force by the airliner has stopped. Others believe that the frictional force is the only force acting horizontally on the ball when it falls, and therefore the ball will be pushed backwards. This explanation may be an attempt to explain the backward motion of the bowling ball that would be observed by a person sitting in the airliner. The students may associate this with experiences of passengers in moving vehicles when objects are dropped from windows.

6.2.5. Item 10 – Coding of written responses

E01: No response

E02: Uncodable response

E03: The rope is exerting an upward force on the block. This force must be slightly bigger than the weight of the block; hence the elevator travels upward at constant speed.

E04: According to Newton's Second Law of motion, the force exerted on the block, making the elevator to travel upwards, is given by F = ma. The acceleration of the block upwards is 2 m/s and the mass of the block is 1.0 kg, therefore the force exerted on the block by the rope will be 2 N.

E05: Block II together with the rope are exerting forces on block I, and the collective force by the rope and block II is twice as much as the weight of block I, the elevator travels upwards at constant speed.

(E06): For the block to travel upwards at constant speed, the resultant force on it must be zero. The forces acting on block I, are the force of gravity on the block and the force by the rope on the block. Since the weight of the block is 10 N, then rope I exerts an equal but opposite force on block I.

Table 6.1(e) Frequency of written responses to item 10 for the combined UL and the UPmaj cohorts.

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
E01	16	7.1	4	12.1
E02	4	1.8	0	0.0
E03	8	3.6	2	6.1
E04	77	34.4	3	9.1
E05	18	8.0	3	9.1
(E06)	101	45.1	21	63.6

Newton's First law of motion implies that for an object to be at rest or move at constant velocity, the forces acting on it must balance each other. Explanation E06 seems to concur with Newton's first law of motion, and corresponds to option B from the multiple-choice part of this item, in Table 5.3(e) from the previous chapter. Explanation E04 is more prominent in the UL cohorts than in the UPmaj cohort. This is a well documented alternative conception in which the students use acceleration and velocity interchangeably, instead of using the correct formula $F = m \times a$, the students use the incorrect formula $F = m \times v$ (Clement, 1982; Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992). Explanations E03 and E05 imply that motion is always in the direction of the bigger force. This is regarded as an alternative conception according to Halloun & Hestenes (1985a), Hestenes *et al.* (1992) and Maloney (1984) but does not feature prominently in both the UL and the UPmaj cohorts.

A high percentage of students in this item were able to indicate correctly that for the block to travel at constant velocity upwards, the forces acting on it must balance each other. The students were able to identify the forces acting on the block as the gravitational force directed down, with a magnitude of 10 N, and the force exerted by rope 1 directed upwards. According to Newton's first law of motion, for the state of motion of the block not to change, the forces acting on the block must balance each other. Therefore the force by the rope must have a magnitude of 10 N for the block to travel at constant speed, or remain at rest. However, there are those students who believe that a constant resultant force produces a constant velocity, and the expression given as: $F = m \times v = 2$ N, where $v = 2$ m/s and $m = 1$ kg (Clement, 1982). These students were unable to differentiate between velocity and acceleration (Halloun & Hestenes, 1985a; Hestenes *et al.*, 1992).

6.2.6. Item 11 – Coding of written responses

F01: No response

F02: Uncodable response

F03: Force on block II is equal to the tension in rope I minus the weight of block II, i.e. F = T – W.

F04: The force by rope I on block II is given by F = m x g

F05: According to Newton's Second law of motion, when a block is stationary there are no other forces acting on it, except the gravitational force.

(F06): As the blocks are in equilibrium, the tension in rope 1 must be equal to the weight of block I, therefore rope 1 exerts 10 N downwards on block II.

F07: The gravitational force acting on block II is equal to 10N, and the gravitational force on block I is also 10 N. The tension in the rope is thus the sum of gravitational forces on the two blocks, hence T = 20 N.

Table 6.1(f) Frequency of written responses to item 11 for the UL and UPmaj cohorts

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
F01	7	3.1	5	15.2
F02	1	0.5	0	0.0
F03	10	4.5	2	6.1
F04	61	27.2	1	3.0
F05	11	4.9	2	6.1
(F06)	112	50.0	21	63.6
F07	22	9.8	2	6.2

F06 is the scientifically acceptable explanation as the blocks are in equilibrium. The explanation corresponds to option B in the multiple-choice part of this item in Table 5.3(f). Explanation F03 is less prominent in all the UL and UPmaj cohorts. This explanation is not common among students. Explanations F04 and F05 assume that the resultant force is the force due to gravity on the block. Explanation F04 is the most prominent alternative conception in the UL cohorts, but it is almost absent amongst UPmaj students. This conception, F07, is less prominent in both the UL and UPmaj cohorts. The implication of these results for teaching is that the misconception evident in explanation F04 requires serious attention in groups of weaker students.

6.2.7. Item 12 – Coding of written responses

G01: No response

G02: Uncodable response

(G03): The car is now towing a car twice its mass, the implication is that the mass of the car is increased three times. According to Newton's Second law of motion the mass of an object is inversely proportional to the acceleration produced, provided the same amount of force is applied. If the mass of an object is increased three times, then its acceleration will be ⅓ its original values.

G04: The mass of the car is doubled. If the mass of the car is doubled, then its acceleration will be halved.

G05: According to Newton's Second Law, the acceleration of the car is inversely proportional to the mass of the car. If the mass of the car is increased, then its acceleration decreases.

Table 6.1(g) Frequency for the written responses to item 12 for UL and UPmaj cohorts

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
G01	10	4.5	2	6.1
G02	6	2.8	2	6.1
(G03)	27	12.1	10	30.3
G04	157	70.1	16	48.5
G05	24	10.7	3	9.1

This item challenges students to use their analytical thinking skills for the interpretation of the relationship between the mass and the acceleration of a car. Explanations G03, G04 and G05 are all about the dependence of acceleration on mass. These explanations assume an inverse relationship between mass and acceleration of the car. The students have some idea that as the mass of the car increases, its acceleration decreases. The question seems to have been properly understood by the students, but they ignored the influence of the mass of the first car. The flaw in the reasoning lead to explanations G04 and G05, which were more prominent in the UL cohorts than in the UPmaj cohort.

The students were able to realize that there exists an inverse relationship between acceleration and mass, i.e. if the mass of a car is increased the acceleration of the car will decrease, on condition that we still have the same applied force. However, students seem to forget that the changes between mass and acceleration have to be inversely proportional, if the mass is increased three times, then the acceleration will decrease and become ⅓ of its original value. Otherwise the relationship will no longer be inversely proportional, a fact that would violate Newton's second law of motion. Alternatively, students may not have analysed the problem carefully and neglected to take the mass of the first car into consideration because of oversight.

6.2.8. Item 13 – Coding of written responses

H01: No response

H02: Uncodable response

H03: The gravitational force is greater than the upward force by the cable, because the cable is thin and has less mass and will thus exert less force.

H04: Motion is always in the direction of the bigger force. The upward force by the cable is greater than the gravitational force, thus the upward motion.

H05: As the cable is shortened, the elevator automatically goes up. The cable does not exert a force on the elevator.

(H06): According to the first law of Newton, if the elevator travels at constant speed, then the forces acting on it must balance each other.

Table 6.1(h) Frequency for the written responses to item 13 for the UL and UPmaj cohorts.

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
H01	8	3.6	1	3.0
H02	4	1.8	1	3.0
H03	22	9.8	0	0.0
H04	112	50.0	11	33.3
H05	10	4.5	0	0.0
(H06)	68	30.4	20	60.6

H06 is the scientifically acceptable explanation for this item, explaining that a constant velocity implies balanced forces acting on the object. Explanation H03 and H05 correspond to the alternative conception that the cable exerts less or no force at all; the cable is thin or automatically shortens as the elevator goes up. This alternative conception is only present in the UL cohorts. Explanation H04 corresponds to the alternative conception that motion is always in the direction of the bigger force, therefore for the elevator to move upwards the force upward, by the cable, must be greater than the downward force, by gravity. This is the most prominent alternative conception which is evident from the written responses of both cohorts, but it is more prominent for the UL cohorts than the UPmaj cohorts.

The majority of the students responded to this item by indicating that if the elevator goes up then the upward force on the elevator must be greater than the gravitational force on the elevator. They reasoned that "otherwise the elevator will not move up". The implication is that motion is always in the direction of the bigger force. There were some of the students who believed that since the cable is less massive and thin, it applied a smaller amount of force on the elevator as compared to gravity.

6.2.9. Item 14 – Coding of written responses

I01: No response

I02: Uncodable response

I03: The man and the boy are pulling the crate at the same time and at the same angle, the resultant path will be the path midway the two of them.

(I04): The man is pulling with a greater force as compared to the boy; the crate will thus follow a path closer to the man's pull.

I05: The man is much stronger than the boy. The man is pulling the crate with a greater force while the force by the boy is negligibly small. The crate will thus move in the direction of the man's pull.

I06: The boy is younger and has more strength than the man, who is old. The boy will thus pull with a greater force than the man, and the resultant path will be closer to the boy's pull.

Table 6.1(i) Frequency for the written responses to item 14 for the UL and the UPmaj cohort.

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
I01	7	3.1	2	6.1
I02	3	1.3	0	0.0
I03	101	45.1	12	36.4
(I04)	78	34.8	19	57.6
I05	29	13.0	0	0.0
I06	6	2.7	0	0.0

The scientifically accepted explanation for this item is I04, that the force by the man is greater than the force by the boy. Explanation I03 is prominent in both cohorts.

The students reason that since both the man and the boy are pulling at the same time and at the same angle, the crate will follow a path midway the man's and the boy's pull. The length of the strings in the diagram could have lead to this flaw in the reasoning, because students may have interpreted the drawing to be a vector diagram. Explanations I05 and I06 are less prominent in the UL cohorts and do not exist in the UPmaj cohort. The frequencies for the multiple-choice options D and E in Table 5.3(i) corresponds to explanations I05 and I06 of the written responses in Table 6.1(i).

From the analysis of Tables 5.3(i) and 6.1(i), it can be deduced that some of the students were able to recognize that a large man will be able to exert a greater amount of force on the crate than the boy, and that the resultant force on the crate would be in the direction closer to the man's pulling path than the boy's. However, there are those students who believe that, since the man and the boy are pulling simultaneously on the crate, therefore they are pulling the crate with forces of equal magnitudes. The crate would therefore move in the path that is directed midway the man's and the boy's pulling paths.

6.2.10. Item 15 – Coding of written responses

J01: No response

J02: Uncodable response

J03: The two blocks are placed directly opposite/parallel to each other at point 2 and point 5, indicating that they have the same speed at these points.

J04: The intervals between the points are not equal; one block moves at constant speed while the other block is accelerating. They will thus never have the same speed.

(J05): The spaces between points 3 and 4 are equal. During this interval they cover the same distance in the same period of time. Therefore somewhere between point 3 and 4 the two blocks will have the same speed.

Table 6.1(j) Frequency of the written responses to item 15 for the UL and UPmaj cohorts

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
J01	10	4.5	4	12.1
J02	5	2.2	2	6.1
J03	101	45.1	3	9.1
J04	82	36.6	6	18.2
(J05)	26	11.6	18	54.5

Explanation J05 is scientifically accepted for this item. This explanation often accompanied option E, from Table 5.3(j) in the multiple-choice component of the item. Explanation J03 corresponds to the alternative conception of same position implying same speed (Clement, 1982; Halloun & Hestenes, 1985b; Hestenes *et al.*, 1992). This alternative conception is more prominent in the UL cohorts than in the UPmaj cohort. Explanation J04 corresponds to option A in Table 5.3(j). It states that the two blocks will never have the same speed, because the spaces between the successive dots are different for the different blocks. This explanation represents a higher level of conceptual thinking than J03, because students were able to interpret the position of the blocks in terms of constant speed versus acceleration. This alternative conception is more prominent in the UL cohorts than in the UPmaj cohort.

The prevalence of explanation J03 for the weak or under prepared UL students as compared to its near absence for the benchmark group should be noted. The UL students were unable to realise the difference between the rate of change of position and position itself. The students' responses implied that if the two moving objects are at the same position at a particular moment in time, then they are traveling at the same speed. The students are unable to differentiate between position and velocity. Objects that are at the same position at a moment in time are regarded as having the same velocity (Hestenes *et al.*, 1992), according to the students.

6.2.11. Item 16 – Coding of written responses

K01: No response

K02: Uncodable response

K03: The spaces between the numbered squares are larger for block "b" and smaller for block "a". The acceleration of block "b" is thus greater than the acceleration of block "a".

K04: Block "a" is ahead of block "b", because there are more time intervals at the top than at the bottom. This indicates that block "a" is moving faster than block "b". Therefore the acceleration of block "a" is greater than the acceleration of block "b'.

(K05): The spaces between the numbered squares at the top are smaller and equal, while those at the bottom are bigger and also equal. This indicates that both blocks are moving at different but constant speeds. The two blocks thus have zero acceleration.

K06: The two blocks are accelerating at the same rate. The acceleration of block "a" is equal to the acceleration of block "b".

Table 6.1(k) Frequency of the written responses for item 16 for the UL and UPmaj cohorts

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
K01	16	7.1	2	6.1
K02	7	3.1	2	6.1
K03	76	33.9	5	15.2
K04	55	24.6	2	6.1
(<u>K05</u>)	44	19.6	22	66.7
K06	26	11.6	0	0.0

K05 is the scientifically acceptable explanation for this item. This explanation often accompanied option D in Table 5.3(k). The frequency for option D in Table 5.3(k) is almost the same as the frequency for explanation K05 in Table 6.1(k). The students were expected to realize that the numbered squares for both blocks are equal distances apart, an indication that the two blocks are both traveling at constant velocities. The majority of UL students and a small percentage of UP students failed to interpret the visual representation correctly in order to compare the acceleration of the two blocks. Explanations K03, K04 and K06 represent an alternative conception in which velocity and acceleration are indiscriminated. Explanations K04 and K06 are more prominent in the UL cohorts than in the UPmaj cohort. Explanations K03, K04 and K06 reveal a serious lack of understanding and inability to interpret the diagrams. This corresponds to the results obtained in the multiple-choice section of item (Table 5.3(k)) where large differences in the confidence levels associated with correct and incorrect answers were recorded.

The spaces between the numbered squares are equal, for both blocks "a" and "b". The space between the numbered squares is larger for block "b" than for block "a". However some of the students were unable to recognize the equal intervals between the numbered squares in each set. Therefore they failed to realize that equal intervals would mean constant velocity and hence zero acceleration. Students used the fact that the spaces between the numbered squares are larger for block "b" than block "a", to conclude that the acceleration of block "b" must be greater than the acceleration of block "a". They associated the spaces between the numbered squares with acceleration. This implies that larger intervals would represent a higher acceleration, while narrow intervals would therefore represent lower acceleration. This reflects a failure to distinguish between velocity and acceleration as documented by Hestenes *et al.* (1992) and Clement (1982).

6.2.12. Item 17 – Coding of written responses

L01: No response

L02: Uncodable response

L03: The same amount of force is applied simultaneously on the two pucks. The pucks will have the same acceleration, and will thus reach the finish line at the same time.

(L04): Puck I has a smaller mass as compared to puck II. Even though the same amount of force is applied on both pucks, the lighter puck will accelerate more than the heavier puck. Thus puck I will reach the finish line first.

L05: Puck II has more mass than puck I. If the same amount of force is applied on both of them, the heavier puck will reach the finish line first.

Table 6.1(l) Frequency for the written responses to item 17 for the UL and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
L01	9	4.0	0	0.0
L02	5	2.2	1	3.0
L03	44	19.6	2	6.1
(L04)	152	67.9	29	87.9
L05	14	6.3	1	3.0

The scientifically acceptable explanation is L04, which corresponds to option A from Table 5.3(l) in the multiple-choice part of this item. Similar frequencies were obtained for option A in Table 5.3(l) and for explanation L04 in Table 6.1(l). Explanation L03 represents a classical alternative conception that equal forces applied simultaneously produce equal accelerations (Clement, 1982). The effect of mass on acceleration seems to be ignored by students. This alternative conception is more prominent in the UL cohorts than in the UPmaj cohort. Explanation L05 reflects an alternative conception which is less common among the students.

The majority of students in all the cohorts were able to realise that puck I would reach the finish line first, because of its smaller mass as compared to puck II. The students were able to apply the second law of Newton. However, there were also those students who believe that the pucks would reach the finish line at the same time. Their reason was that the pucks were pushed simultaneously with the same amount of force; they would therefore have the same acceleration. These students seemed to ignore the fact that the pucks are of different masses.

6.2.13. Item 18 – Coding of written responses

M01: No response

M02: Uncodable response

M03: The force applied is directly proportional to the speed at which the box is being moved across the floor. If the force is doubled then the speed also doubles.

M04: The applied force must be more than the frictional force between the floor and the box, otherwise the box will not move. Since the applied force is bigger, then the motion is in the direction of the bigger force.

(M05): For the box to move at constant speed the forces exerted on the box must balance each other. The applied force must be equal in magnitude to the frictional force on the box.

M06: The magnitude of the applied force must be greater than the magnitude of the gravitational force on the box, otherwise the box will not move.

M07: The external forces acting on the box are very weak forces. The applied force must be greater than the external forces for the box to move.

Table 6.1(m) Frequency of the written responses for item 18 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
M01	8	3.6	5	15.2
M02	2	0.9	1	3.0
M03	52	23.2	1	3.0
M04	64	28.6	6	18.2
(M05)	49	21.9	16	48.5
M06	31	13.8	3	9.1
M07	18	8.0	1	3.0

The scientifically acceptable explanation is M05, which corresponds to option C in Table 5.3(m) in the multiple-choice component of this item. However, not all students who chose option C gave the acceptable explanation. Explanation M03 is a classical alternative conception, in which students mistook force and velocity as being proportional to each other (Hestenes *et al.*, 1992). A higher velocity is taken as a result of a bigger applied force on an object. The alternative conception is more prominent in the UL cohorts than in the UPmaj cohorts. Explanations M04 and M07 represent the alternative conception which states that motion occurs when force overcomes friction (Clement, 1982; Hestenes & Wells, 1992; Minstrell, 1982). The alternative conception seems to be more prominent in the UL cohorts than in the UPmaj cohort. Explanation M06 is a known alternative conception that "a force cannot move an object unless it is greater than the object's weight (Gunstone *et al.*, 1981). Explanation M06 corresponds to option B in Table 5.3(m) and similar frequencies are reported for them.

The students were able to recognize the forces acting on the box as the applied force and the frictional force. However, some of the students believe that for a box to move at constant speed over a rough surface the applied force must be greater than the frictional force, otherwise the box will not move. The applied force must be greater so as to overcome the frictional force. Other students believe that for an object to move at constant speed the applied force must be constant as well, i.e. constant force produces constant speed, expressed as $F = m \times v$ (Hestenes *et al.*, 1992). Almost half of UPmaj students and only about 22% of the UL students correctly believe that the box move at constant speed because the frictional force has the same magnitude as the applied force, but is directed opposite.

6.2.14. Item 19 – Coding of written responses

N01: No response

N02: Uncodable response

N03: The velocity of the object increases, and then the object stops, after which its velocity decreases and later on the objects stops at a different position.

(N04): The object accelerates uniformly from rest for a longer period of time, moves at constant velocity for some time, and then decelerates for a short period of time, in the same direction.

N05: The object accelerates for a short period of time, moves at constant velocity and then decelerates for a longer period of time, in the same direction.

N06: The object starts from rest, moves at a certain speed, and later stops, change direction and decelerates to a stop.

N07: The object accelerates slowly, then moves at constant speed, and then accelerates faster.

Table 6.1(n) Frequency of the written responses to item 19 for the UL and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
N01	11	4.9	3	9.1
N02	7	3.1	1	3.0
N03	39	17.4	5	15.2
(N04)	76	33.9	15	45.5
N05	52	23.2	5	15.2
N06	19	8.5	3	9.1
N07	33	14.7	1	3.0

N04 is the scientifically acceptable explanation for this item. This explanation corresponds to option B from Table 5.3(n) in the multiple-choice component of this item. However, the frequency for option B in Table 5.3(n) is different to the frequency for explanation N04 for the UPmaj cohort. The students were expected to match the multiflash, for the motion of an object, and the velocity-time graphs. The object had undergone three different types of motion. First the object accelerated from rest, moved at constant velocity, and then decelerated. However, they failed to realize that the first part of motion took place for a longer period of time and the last part of motion took a shorter period of time, and that all three different types of motion took place in the same direction. A more subtle interpretation of the diagram is required to distinguish between options A and B in the multiple-choice component of the answer and between explanations N04 and N05. Explanations N03, N06 and N07 are a clear indication of serious flaws in the reasoning and interpretation of the representation of the motion of an object by a multiflash diagram.

The students were unable to recognise, that unlike the speed the velocity is a vector quantity, and thus the direction of motion also plays a role in the representation of velocity. The students failed to realize that the acceleration of an object depends on the rate of change in velocity, and not on the velocity itself. A higher velocity does not mean a higher acceleration, but rather a higher rate of change of velocity implies a higher acceleration. The other problem in this item is that students were unable to interpret the diagrammatical representation of motion.

6.2.15. Item 20 – Coding of written responses

O01: No response

O02: Uncodable response

(O03): The object accelerates for a longer period, moves at constant motion, and then decelerates for a short period of time. The acceleration is positive, then zero, and later on becomes negative.

O04: The object accelerates uniformly but slowly, moves at constant velocity, and then accelerates uniformly and faster.

O05: The object accelerates faster, moves at constant velocity, and then accelerates slowly.

O06: the object accelerates for a short period of time, moves at constant velocity, and then decelerates for a longer period of time.

O07: The object accelerates slowly, decelerates, and then accelerates faster.

Table 6.1(o) Frequency of the written responses to item 20 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
O01	7	3.1	4	12.1
O02	3	1.3	2	6.1
(O03)	89	39.7	18	54.6
O04	38	17.0	1	3.0
O05	22	9.8	2	6.1
O06	29	13.0	5	15.2
O07	36	16.1	1	3.0

Item 19 and 20 require the students to interpret the motion of an object using graphs. In Item 19 the students were supposed to interpret the motion using the velocity-time graph. In item 20 they are to interpret the same motion using the acceleration-time graph. The correct explanation in this item is O03, which corresponds to explanation N04 from the previous item (in Table 6.1(n)), and also corresponds to option D in Table 5.3(o) in the multiple-choice component of this item. Explanation O06 is similar to explanation

O03. It suggests a proper understanding of the principles involved, except that the distance between dots was not interpreted accurately. However, the frequency of the correct explanation in item 19 is lower than the frequency of the correct explanation in item 20.

6.2.16. Item 21 – Coding of written responses

P01: No response

P02: Uncodable response

P03: The intervals get shorter from left to right. This indicates that the speed of the car decreases. The motion is thus a decelerated motion. The acceleration is directed to the left. The car is still moving to the right, therefore the net force is in the direction of motion.

(P04): The intervals get shorter from left to right. This indicates that the speed of the car decreases. The motion is thus decelerated. Therefore the acceleration is directed to the left. The net force, which is the frictional force and opposes motion, is also directed to the left.

(P05): The car is pulling the tape as it moves to the right. The intervals get bigger as motion proceeds. The motion is thus an accelerated motion to the right. For an accelerated motion the direction of acceleration and the direction of the net force are the same as the direction of motion. Therefore the acceleration and the net force are both directed to the right.

P06: The car is moving to the right, this means that the speed of the car is to the right. Therefore the acceleration is also directed to the right. However, the frictional force acting on the car is directed opposite to the direction of motion of the car. Therefore the direction of the net force is directed to the left.

Table 6.1(p) Frequency of the written responses to item 21 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
P01	15	6.7	3	9.1
P02	8	3.6	2	6.1
P03	57	25.5	9	27.3
(P04)	15	6.7	11	33.3
(P05)	79	35.3	8	24.2
P06	50	22.32	0	0.00

The frequency distribution for this item could not be interpreted because of flaws in the item presentation. If one studies the tape carefully, it is possible that the motion of the car could have been accelerated, and it is also possible that the motion could have been decelerated. If the tape was attached to the car with the ticker stationary, then the motion would be accelerated. In this case the direction of the net force and the direction of the acceleration would be to the right. In the case where the ticker was attached to the car, with the tape stationary, the motion would be decelerated. Therefore the direction of the net force and the direction of the acceleration would be to the left.

In this item the majority of students were able to realize that the net force and the acceleration have the same direction. The problem with this item was that the problem statement did not specify where the first dot was made. Therefore it is possible that both the acceleration and the net force could be directed to the left, in this case the motion would be decelerated. It is also possible that the net force and the acceleration could be directed to the right, and the motion would be accelerated.

6.2.17. Item 22 – Coding of written responses

Q01: No response

Q02: Uncodable response

Q03: The block does not accelerate up or down, therefore N = W. The horizontal component of force F must be equal to force k; therefore force F must be greater than force k.

(Q04): When the box moves at constant speed, it means that all forces acting on it balance each other.

Q05: The applied force must be greater than the frictional force, since motion is in the direction of a bigger force. The weight of an object is always greater than the upward force by the surface on an object.

Table 6.1(q) Frequency of the written responses to item 22 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
Q01	19	8.5	1	3.0
Q02	6	2.7	2	6.1
Q03	118	52.7	25	75.8
(Q04)	36	16.1	4	12.1
Q05	45	20.1	2	6.1

Explanation Q04 corresponds to option C in Table 5.3(q) in the multiple-choice component of this item. This can be seen from a comparison of the frequency obtained for Q04 in Table 6.1(q) with the frequency obtained for option C in Table 5.3(q). This indicates the mistake that the students are making in the interpretation of the forces acting on the box. Balanced forces in the students' reasoning, would mean equal magnitude and opposite directions. However, in this item the components of forces have to be taken into account when a balance of forces is considered. Therefore force N plus the component of force F (in the vertical direction) must be equal in magnitude to force W, while force k equals the magnitude of the component of force F (in the horizontal direction). Explanation Q03 is the most prevalent alternative conception of "canceling forces" (Clement, 1982; Halloun & Hestenes, 1985a; Maloney, 1984; Minstrell, 1982).

Students believe that a crate can move at constant speed only when the forces acting on it are of equal magnitudes, and are directed opposite each other, this is corresponds to option A from the multiple-choice component of this item. There are also cases when the forces are directed oppositely and have equal magnitudes that the object moves at constant speed. There are also cases where the forces have equal magnitudes but are directed at angles to each other; in this situation the object would not move at constant speed. In such a situation the components of forces are the ones to balance each other, and not the forces themselves.

6.2.18. Item 23 – Coding of written responses

R01: No response

R02: Uncodable response

R03: The rocket will go straight up at right angles, because there are no forces acting on it.

R04: There are no forces acting on the rocket, and the rocket possesses inertia. Therefore the horizontal component of its motion will remain the same.

(R05): Even though the rocket engine is turned off, the rocket possesses inertia, and will follow path "E" until it reaches c.

Table 6.1(r) Frequency of the written responses to item 23 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
R01	16	7.1	11	33.3
R02	8	3.6	3	9.1
R03	72	32.1	4	12.1
R04	92	41.1	4	12.1
(R05)	36	16.1	11	33.3

The correct explanation is R05, which often accompanied option E from the multiple-choice component of this item. This appears to have been a difficult item, even the best performing cohort performed poorly here. A third of the UPmaj students did not provide any explanation for their multiple-choice answer. The item required higher order thinking and imagination for the interpretation of the problem. The setting of the rocket in outer space seems to be an unfamiliar situation to the students. From the explanations given by the students, one would realize that the two disconnected diagrams in the problem statement also lead to difficulty in the understanding of the problem.

In this item the students were unable to visualize the situation in the first place, and were therefore unable to imagine what would happen from point b to point c. This is the item that most of the students admitted to guessing their answers. However, some of the students indicated that because the rocket possesses inertia it will follow a parabolic path since the engine would be switched off.

6.2.19. Item 24 – Coding of written responses

S01: No response

S02: Uncodable response

(S03): The centripetal force that was originally exerted on the ball is removed when the string breaks. The ball moves because it possesses momentum, and therefore will proceed in the same direction it was moving when the string breaks. The ball will thus follow path "B".

S04: The original motion of the ball was circular in shape. Even when the string breaks the ball would still maintain its original circular motion, because of inertia.

S05: The ball will follow path "C" because of the momentum it possesses, and also because the centripetal force is removed when the string breaks.

S06: When the string breaks, the ball looses balance and heads straight downwards because gravity is the only force exerted on it.

Table 6.1(s) Frequency of the written responses to item 24 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
S01	21	9.4	7	21.2
S02	7	3.1	3	9.1
(S03)	60	26.8	11	33.3
S04	65	29.2	7	21.2
S05	24	10.7	3	9.1
S06	47	21.0	2	6.1

The correct explanation is S03, which corresponds to the correct option B in the multiple-choice component of this item. The majority of students were able to recognize that once the ball exits the track or the string breaks, the ball would want to continue in the same direction, because it possesses momentum. However, the frequency of explanation S03 obtained for UPmaj, in Table 6.1(s), is lower than the frequency obtained for option B, in Table 5.3(s). The larger percentage of "no responses" to this item recorded for UPmaj may be the reason for the discrepancy. Explanation S04 indicates that the students believe that even if the string breaks the ball will continue motion in the same circular path because it possesses momentum. The students believe that the ball will continue to do what it was doing before, that is continue to move in a circular path. This is the most prominent alternative conception for both groups of students. Explanations S05 and S06 is based on the thinking that there is no longer a centripetal force exerted by the string, and the only force acting on the ball is the force of gravity, therefore the ball will fall down. This alternative conception is only prominent in the UL cohorts.

6.2.20. Item 25 – Coding of written responses

T01: No response

T02: Uncodable response

(T03): According to Newton's First Law of motion, the ball will continue to move with the same speed in the same direction, unless an external unbalanced force is exerted on it. The direction of the ball's speed when it leaves the channel is path "B", and it will continue in the same direction.

T04: Originally the ball moved in a circular path; because of its inertia it would still follow a circular path even after leaving the channel.

T05: When the ball leaves the channel, the only force acting on it is the gravitational force directed downwards. Therefore the ball will move straight downwards when it leaves the channel.

Table 6.1(t) Frequency of the written responses to item 25 for the combined UL cohorts and the UPmaj cohort

Code	UL		UP	
	Number of Students	Number of Students (%)	Number of Students	Number of Students (%)
T01	12	5.4	5	15.2
T02	5	2.2	2	6.1
(T03)	88	39.3	16	48.5
T04	37	16.5	9	27.3
T05	82	36.6	1	3.0

The conceptual content in this item is the same as that of item 24, but students have shown a better performance in this item. The scientifically acceptable explanation for item 25 is T03, which frequently accompanied option B in the multiple-choice component of this item. Explanation T04 is about the ball possessing inertia, and because of its inertia it continues moving in the same circular path even if the force by the string has ended. It is similar to explanation S04 in the previous item. This is the strongest alternative conception in the UPmaj cohort. Explanation T05 is based on the thinking that gravitational force is the only one acting on the ball, thus making the ball to go straight downwards, even if it possesses inertia. This alternative conception is also present in item 24 as explanation S06. It is almost completely absent in the UPmaj cohort, but it is very prominent in the UL cohorts.

6.3. Summary

The analysis of the written responses for the strongest cohort (UPmaj) and the combined UL cohorts, which include some of the weakest students, allows the identification of the most important alternative conceptions and the relative difficulty of addressing these conceptions. The UPmaj cohort has had the benefit of better quality teaching in physics than the UL cohorts, as observed from Appendix E. The prevalent alternative conceptions, which were recorded for UPmaj, can therefore be viewed as resistant to change. This result has important implications for teaching as will be discussed in the next chapter.

The next table (Table 6.2) provides a summary of the prevalence of the most important alternative conceptions observed for the two groups, UPmaj and the combined UL cohorts. A number of faulty explanations with frequencies above 10% listed in Tables 6.1(a) to 6.1(t) above are not included in Table 6.2. These faulty explanations are interpreted to reflect lack of analytical accuracy or inadequacy in the accurate interpretation of diagrams. These are the incorrect explanations for items 12, 14, 19 and 20. The deficiencies in the problem statement for item 21 and the unfamiliar setting for item 23 prevented meaningful interpretation of written responses, and are therefore also not reflected in Table 6.2.

Table 6.2 Alternative Conceptions and Incorrect Explanations Revealed by the written responses

			UL cohort	UP cohort
Alternative conception/Incorrect explanation	Item number	Code	Frequency (%)	Frequency (%)
Less friction acting on lighter ball than on heavier ball	6	A04	29.5	0.0
A heavy object falls faster than a light object	6	A06	33.0	18.2
A bigger mass exerts a bigger force	7	B04	61.2	36.4
Continuing action of an applied force after contact stops	8	C03	29.5	6.1
Impetus dissipation followed by increasing gravity as the object falls	8	C05	35.7	45.4
A compromise between the downwards gravitational force and the backwards frictional force determines the direction of motion.	9	D06	32.6	21.2
The applied force is directly proportional to the velocity of the object	10	E04	34.4	9.1
Misapplication of the formula $F = m \times g$	11	F04	27.2	3.0
Motion is in the direction of the bigger force	13	H04	50.0	33.3
Velocity and position undiscriminated	15	J03	45.1	9.1
Acceleration and velocity undiscriminated	16	K03	33.9	15.2

			UL cohort	UP cohort
Alternative conception/Incorrect explanation	Item number	Code	Frequency (%)	Frequency (%)
Equal forces produce equal accelerations	17	L03	19.6	6.1
Motion when force overcomes friction	18	M04	28.6	18.2
Lack of/Incorrect application of components of forces	22	Q03	52.7	75.8
The object moved in a circular path. When the string breaks or when the object leaves the circular channel it would continue on its circular path	24	S04	29.2	21.2
	25	T04	16.5	27.3
When the string breaks or the ball leaves the circular channel the only force acting on the ball is the gravitational force which pulls it down	24	S06	21.0	6.1
	25	T05	36.6	3.0

The results in Table 6.2 indicate that the alternative conceptions A04, C03, E04, F04, J03, L03 and S06/T05 are more easily uprooted than the others, because they are present to a large extent in the UL cohorts, but almost completely absent in the UPmaj cohort. The prevalence of the alternative conceptions A06, B04, D06, H04, K03, M04 and S04 in the UPmaj cohort is between 15.2% and 36.4%, and between 29.2% and 61.2% in the UL cohorts. This result can be interpreted to indicate that with better quality teaching in physics these alternative conceptions can be addressed, but that they may be more difficult to uproot than in the previous group. However, in the case of alternative conceptions C05, Q03 and T04 their prevalence is higher in the UPmaj cohort than in the UL cohorts. This can be interpreted that these are the most difficult alternative concepts to uproot, because they are much more strongly held by the students, as compared to the other two previous groups of misconceptions.

Faulty explanations G04, I03, N05, O06, P03 and R04, which were also associated with frequencies above 10%, are not reflected in Table 6.2, because they can be interpreted as showing lack of higher order analytical skills or inaccurate interpretation of diagrammatical representations of motion.

CHAPTER 7 DISCUSSION AND CONCLUSION

7.1 Introduction

This study explored the baseline knowledge and understanding of mechanics concepts upon entry to tertiary education of eight cohorts of students enrolled at three universities in South Africa. In this regard the following three research questions were formulated:

1. What are the performance and associated confidence levels of first entering physics students registered at selected South African universities?
2. Is there a correlation between the confidence and performance of students in mechanics?
3. Can the relationship between confidence and performance be used to reliably identify the presence of misconceptions in mechanics?

This chapter will present answers to these questions as revealed in the research report in this dissertation and discuss their implications to teaching physics at tertiary level.

7.2 Discussion

Generally one would expect to find that students showing high confidence levels, in a certain concept, will show evidence of having the necessary skills and understanding of that particular concept, by obtaining high scores in a test that is intended for assessing skills and understanding of the said concept. It is expected that students answering an item correctly would show high levels of confidence, while students responding incorrectly to an item, would show lower levels of confidence. However, that was not necessarily revealed in this study. Students made incorrect judgments about their skills, knowledge and understanding of basic mechanics concepts. Students having high confidence levels do not necessarily score high on the test, and students having low confidence levels do not necessarily score low on the test. From Table 5.2, it is evident that 34.1% of the students having high performance in the test, show high confidence levels. A small percentage, 1.9% of the students scored high on the test but were not confident about their choices, 10.6% of the students scored low on the test and showed low levels of confidence, while 53.4% of the students have scored low on the test but show high confidence levels. According to Hasan *et al.* (1999), 34.1% of the students would be classified as having correct knowledge of concepts, 1.9% of the students classified as having lack of knowledge and understanding of the concepts and happen to have guessed correctly, 10.6% of the students definitely having lack of knowledge of the concepts, while 53.4% of the students have strongly held alternative conceptions. More than 50% of the students are making false judgments about their knowledge and understanding of basics concepts in mechanics. This is in agreement with the study by Ochse (2003), who indicated that students (enrolled for Psychology third year) were unable to make a prediction of their performance. There are those students who are confident that they will obtain high scores, and as it turns out they obtained low scores, and there are those who obtain above average scores but had indicated earlier that they expect to obtain lower scores. The students made inaccurate judgments about their performance. The students' excessively high levels of confidence in their performance in mechanics is in agreement with the findings of Pallier *et al.* (2002), that students tend to be overconfident when assessing themselves on tasks that require higher order analytical skills.

Appendix C indicates the performance of the individual students and their confidence levels. When test performance and confidence levels for the individual students from the eight cohorts were correlated (Research question 1), different degrees of relationships were obtained. A moderate relationship between test performance and confidence level was obtained for the UPmaj cohort, this is indicated by a correlation coefficient of 0.57 (shown in Table 5.1). The trend line in the scatter plot, of Appendix D(d), starts from the bottom left and goes to the top right. This is indicative of the fact that students scoring high on the test are confident about their choices, while students scoring low on the test are less confident about their performance. The students therefore made fairly accurate judgments about their performance. There is, therefore, a relationship between performance and confidence level. Trend lines in the scatter plots of Appendices D(a)-(f) indicate that positive correlations between performance and confidence exist, with the degrees of relationships varying from 0.23 to 0.57 for six of the eight cohorts. Correlation coefficients of 0.23 and 0.25 (for ULfy and CTadp) indicate that the relationship is positive but rather weak as compared to that of 0.57. However, correlation coefficients of 0.07 and 0.05 as found for students from ULsc and ULmaj, respectively, indicate that there exist very little or no relationship between test performance and confidence levels for these cohorts. This is indicated by the almost horizontal trend lines on the scatter plots of Appendix D(g) and Appendix D(h), respectively. For these cohorts, students who scored low on the test did not necessarily show low levels of confidence, while student who scored high on the test did not necessarily show high levels of confidence. This confirms the incorrect judgment students made about their knowledge and understanding of basic concepts in mechanics.

7.2.1 Conceptual Dimensions

The studies by Hasan *et al.* (1999) and Planinic *et al.* (2006) both indicated the presence of alternative conceptions among students. It is also observed in this study that majority of the students do have alternative ideas about certain concepts, they believe that these ideas are correct and they are confident about them. The question then becomes in which of these concepts do student make incorrect judgments and what alternative conceptions do these students have? In order to answer these questions, the performance of the students in the different conceptual dimensions is discussed below. (Refer to Table 4.1, for the different conceptual dimensions, Table 6.2 for the alternative conceptions documented in this study, and Appendix B for the items in the test instrument.)

7.2.1.1 Kinematics

Items in this dimension require the students to differentiate between position, velocity and acceleration. The students were also required to recognize the vector nature of velocity and acceleration. Items 9, 15, 16, 19, 20 and 23 are found in this conceptual dimension. The performance of students in this dimension is, on average, poor, in almost all the cohorts, except for UPmaj. The average confidence levels of students choosing the correct options are above the threshold of 1.5, while the average confidence levels of students choosing the incorrect answers in this dimension are also above the threshold of

1.5. The low item performance coupled with high levels of confidence is an indication of students having either inadequate knowledge or alternative conceptions and being confident about these conceptions. Alternative conceptions D06 and K03 were considered moderately difficult to uproot, whereas alternative conception J03 was almost completely absent in the cohort with better school background. Inadequacy in the interpretation of ticker tape diagrams lead to the problem encountered with items 19 and 20, and item 23 challenged students due to its unfamiliar setting.

It can therefore be deduced that students have inadequate knowledge and understanding of the concepts associated with kinematics. For example students are unable to differentiate between velocity and position. Students regard objects that are at the same position at a particular moment in time as having the same velocity. Students also used the length of the space between successive blocks on a ticker tape, as an indication of the magnitude of acceleration instead of the magnitude of velocity. According to the students, a wider interval between the blocks would represent a higher acceleration, while a narrow interval between the blocks would represent a lower acceleration.

Acceleration is defined as the rate at which the velocity changes, but students regard an object having a high velocity as having a higher acceleration and the one having a lower velocity as having lower acceleration. This therefore indicates the confusion the students have between acceleration and velocity. However, the UPmaj cohort has displayed high average performance and high levels of confidence in almost all the items within this dimension. Unlike the other cohorts, the UPmaj cohort made a fairly accurate judgment about their performance.

7.2.1.2 Newton's First Law of Motion

Items 10, 11, 13, 18, 20, 24 and 25 are located in this conceptual dimension. The average performance of students in this conceptual dimension is poor, but better than the average performance in the kinematics conceptual dimension. Even though the average performance is poor, the average confidence levels of all cohorts in this dimension are above the threshold. In this category students have low average test performance and high average confidence levels. The students were unable to make accurate judgments about their performances. This was found to be an indication of the prevalence of alternative conceptions among students, in the dimension of Newton's first law of motion. The alternative conceptions documented for this conceptual dimension are E04 for item 10 (moderately strong), F04 for item 11 (moderately weak), H04 for item 13 (moderately strong), M04 for item 18 (moderately strong), S04/T04 and S06/T05 for items 24 and 25. The alternative conception associated with items 10 (E04) is present to a limited extend in the UL cohorts and almost absent in the UPmaj, see Table 6.2, which suggests that this alternative conception can be easily uprooted with proper teaching.

Students have this belief that for an object to move there must be a force to cause that motion. Students do not take into consideration the fact that the motion is uniform, i.e. the elevator is moving at constant velocity, and thus are unable to apply the rule of "canceling forces". The belief that objects move because of unbalanced forces, irrespective of the type of motion, is contradictory to Newton's first law of motion, an indication that the first law is not well understood by students. The items in this dimension are associated with smaller differences between average confidence levels associated with correct and incorrect answers, as shown in Table 5.4 in chapter 5. This was confirmed by the analysis of the written explanations, as presented in chapter 6.

7.2.1.3 Newton's Second Law of Motion

Items located in this conceptual dimension are 12, 17, 21 and 23. The performance of students in this conceptual dimension was found to be poor. On average the performance is the lowest as compared to all the other dimensions included in the test. This dimension had two problem items: item 21 (an ambiguous item) and item 23 (an item with an unfamiliar setting). Item 12 was plagued by lack of analytical accuracy while item 17 appeared to be easy and had one weak misconception, L03 (19.6% of UL cohorts in Table 6.2).

A small number of students have the belief that if the same amount of force is exerted on two objects of different masses, then the two objects would have the same acceleration. The concept of acceleration decreasing proportionally with increasing mass for the same applied force, seem to be unnoticed by many students. The students seemed to have difficulties in differentiating between acceleration and velocity. When velocity and acceleration are not differentiated in solving problems on moving objects, the result is the belief that the resultant force and velocity are directly proportional to each other, instead of the resultant force being directly proportional to the acceleration of a moving object. This therefore leads to the incorrect formula $F = m \times v$ instead of the correct formula $F = m \times a$.

The students' average confidence levels, in this dimension, are above the threshold. Therefore the students displayed low test performance and high average confidence levels, which according to Hasan *et al.* (1999) points to the presence of alternative conceptions among students. Noticeably, however, the best performing cohort, UPmaj, also obtained low average scores in this category. However, one can not conclude from this analysis that students have alternative conceptions as far as Newton's Second Law of motion is concerned. Only one item (item 17) seemed to give an indication as to whether alternative conceptions exist or not, while the other items points to the lack of higher order analytical skills. Items in this dimension are not unambiguous enough to allow application of the Hasan *et al.* (1999) model.

7.2.1.4 Newton's Third Law of Motion

Items found in this conceptual dimension are 7 and 11. The performance of students in this dimension is on average better than in all the other dimensions included in the study. The UPmaj cohort is performing well in this dimension and the confidence of these students were justified in this dimension. However, when looking at the other individual cohorts, the UL cohorts are scoring low on the items located in this dimension. Students have the belief that during an interaction between two objects of different masses, the object with a bigger mass will exert a bigger force (item 7), while the object with a smaller mass exerts a smaller force. In the case of the truck and a small compact car, the students believe that the truck will therefore exert a greater amount of force on the car, while the small compact car exerts a smaller amount of force on the truck during the collision. This is an alternative conception that can be corrected, because it is present to a large extent in the weaker cohorts and less so in the best performing cohort. The alternative conception associated with item 11 (F04) is present to a limited extend in the

UL cohorts and almost absent in the UPmaj, see Table 6.2, which suggests that it can be easily uprooted with proper teaching.

7.2.1.5 Superposition Principle

Items 10, 11, 13, 14, 18 and 22 are located in this conceptual dimension. The performance of students in this category is somewhat better than the performance in Newton's second law of motion category. However, the students have shown higher levels of confidence. The students from the best performing cohort have high performance in the test and have shown high levels of confidence. The students are making accurate judgment of their performance; they display the knowledge and understanding of correct concepts. However, the same cannot be said for the other cohorts; they show high levels of confidence but perform poorly, indicating the prevalence of alternative conceptions in the superposition principle category. The presence of weak alternative conceptions E04 and F04, and moderately strong alternative conceptions H04 and M04 were confirmed by the analysis of the students' written responses. For example, the belief that motion is determined by the bigger forces. When the block goes up, it is believed that the force pulling upwards is bigger than the pulling force downwards. The students reason that motion is always in the direction of the bigger force, implying that the upward force must be greater than the downward force by gravity, otherwise the block will not move. The fact that the block travels up at constant velocity, and the forces acting on it must be balanced, seems unnoticed by students, and thus rules out the fact that the resultant force on the block equals to zero. It is worth noting that alternative conception Q03 associated with item 22 had a significantly higher percentage in UPmaj than in the combined UL cohorts (75.8% of UPmaj students versus 52.7% of UL students). This item is rated difficult and also classified as requiring higher order analytical skills from the students. Its high prevalence amongst students from mainly privileged school backgrounds is alarming. Uprooting this alternative conception will be a challenge to even the most skillful physics teacher. In item 22 the block is being pulled by a force at an angle to the horizontal, the students believe that the forces balance each other. This indicates the mistake that the students made in the interpretation of the forces acting on the block. Balanced force in the students' reasoning, would mean equal magnitude and opposite directions. The students failed to consider the components of forces when a balance of forces is considered.

7.2.1.6 Gravitation

Items found in this conceptual dimension are 6, 8 and 9. The performance of students in this dimension is poor in almost all cohorts except UPmaj. However, the average confidence levels of all cohorts are above the threshold. According to Hasan *et al.* (1999), the students can thus be classified as having alternative conceptions as far as the gravitation category is concerned. This conclusion was confirmed by the analysis of the students' written explanations. Five different alternative conceptions were documented ranging from weak (A04 and C03 from items 6 and 8, respectively), moderately strong (D06 from item 9) to very strong (C05 from item 8). For example, students have the valid idea that the two balls, dropped simultaneously from the same height, and having different masses, would reach the ground at the same time. There are those students who believe that the two metal balls will reach the ground at the same time because they experience the same gravitational acceleration downwards. However, some of the reasons for the two balls to reach the ground at the same time are not scientifically correct. Some students believe that the two balls reach the ground at the same time because they are both acted upon the same amount of gravitational force. Even though the masses are different, the students believe that the same downwards pulling force acted upon the two metal balls. These groups of students confuse gravitational force and gravitational acceleration. There are those students who believe that a heavy metal ball would reach the ground first. The alternative conception prevalent in this category is that, heavy objects fall faster than lighter objects.

In the case of a ball that was thrown upwards, the students have the belief that, other than the force of gravity acting on the ball, there is an upward force acting on the ball as it goes. Some of the reasons they provide is that the hand is still acting on the ball as it goes up. The force by the hand on the ball ended when the ball left the hand, however students believe that the ball goes up because that force is still in action. The students have this understanding that there is a force of motion exerted by the hand on the ball, and this force decreases as the ball goes up. Their reason for the force by the hand to decrease was that the velocity decreased as the ball goes up. This is alternative conception C05, which is more prominent in the UPmaj than in the combined UL cohorts (45.4% of UPmaj students expressed this belief compared to 35.7% of UL students). This alternative conception seem to be difficult to uproot, it is more prominent despite better teaching. Of course, there are some students who are able to identify the force acting on the ball correctly as the gravitational force only, since the frictional force was ignored.

7.2.2 Confidence level

Students from each of the eight cohorts have shown that they are confident about their chosen options in all the items. They show high levels of confidence; this is evident from average confidence levels from Tables 5.3(a) to 5.3(t). The average confidence levels of those students who have chosen the correct options and those choosing the incorrect options are both high. In general the students who have chosen the correct options have shown high levels of confidence. This according to Hasan *et al.* (1999) is evident that the students have knowledge and understanding of concepts in basic mechanics. However, the students who have chosen the incorrect options have also shown high levels of confidence. It is only in item 23 that students admitted to guessing in the choices they made. It is in this item that on average the students, who have chosen the correct options and those choosing the incorrect options, are not confident about their choices. This was interpreted to be due to the unfamiliar setting of the item.

Hasan *et al.* (1999) used a certainty of response index to distinguish between students' strongly held alternative conceptions and the students' lack of knowledge, while Planinic *et al.* (2006) have postulated that the degree to which students are confident in their answers can be used to rank the students' alternative conceptions and identify those alternative conceptions that are significant, are firmly held by students and are therefore resistant to change. Hasan *et al.* (1999) has made the point that one can use the difference in confidences associated with correct and incorrect answers to distinguish between alternative conceptions and lack of knowledge. However, they did not have the means of checking their hypothesis. From the analysis of the results of the students' written explanations, it becomes evident that there are those alternative conceptions that are easy to uproot and there are those that difficult to uproot. Alternative conceptions that are difficult to uproot are present in all the groups including the UPmaj, while alternative conceptions that are easy to uproot are only prevalent in the weakest groups, all the UL, the UPteach and UPadp groups.

7.3 Alternative Conceptions or Lack of Knowledge

The study by Hasan *et al.* (1999) used the test performance and certainty of response to identify the presence of misconceptions. If test performance is low and the average confidence level is high, then it signifies the presence of misconceptions. From the analysis of the written responses done in chapter 6, it can be noted that low test performance coupled with high average confidence levels does not always signify the presence of alternative conceptions.

Items 12, 14, 19, 20, 21 and 22 are associated with low performance and high confidence levels among students. However one can not apply the Hasan *et al.* (1999) model and classify students as having alternative conceptions in these items. The analysis from the study has indicated that despite the difference in their difficulty levels, it is possible that the items did not assess the depth of the conceptual understanding. The students may have understood the concept but made simple errors due to lack of higher order analytical and interpretation skills. Item 12 has proved to be one such a case. In this item, students are to use the relationship between mass and acceleration as an application of Newton's second law of motion. The students were able to realize the inverse relationship, but failed in the analysis of the problem, thus end up ignoring the influence of the first car on the new acceleration. This could not be classified as misconception, but rather lack of critical analysis of the situation at hand. The same problem could also be observed in Item 19, where the students were able to recognize the three different types of motion. The students identified the motions as i) the first type to be accelerated motion starting from rest, ii) the second type to be motion with constant velocity, and lastly iii) the third type to be decelerated motion. However, the students failed to critically analyze how long each of these motions lasted, i.e. which one took longer than the others. The analysis of the responses indicated the lack of analytical skills in the interpretation of motion. The students have shown to be lacking in the interpretation of the diagrammatical representation of motion. This information could not be obtained while applying the four possible combinations in the Hasan *et al.* (1999) model, shown in Table 3.1. These limitations of the Hasan *et al.* (1999) model became evident during the analysis of the students' written explanations.

7.4 Conclusion

The study was aimed at investigating the presence of alternative conceptions, performance and confidence levels of students entering physics at the three universities (Research question 1). Students entering physics at the universities have different academic backgrounds. The students from UPsc and UPmaj have a higher average performance in the test than the rest of the groups. This then implies that the students from the latter six groups have limited knowledge and understanding of basic mechanics concept, hence their lower performance in the test. However, the results of the study indicate that all the students have high levels of confidence. The groups of student whose average performance is low and those having high average performance in the test all have high confidence levels. The analysis of the students' confidence levels in the test as a whole suggests that the students were confident about their knowledge and understanding of concepts in mechanics. The item-by-item analysis of students' confidence in incorrect responses suggests that they have alternative conceptions, which they acquired from past experiences, and are confident about these ideas they have. However, it also points to a lack of analytical accuracy and inadequacy in the interpretation of diagrams.

Some of the students' strongly held alternative conceptions found in this study are: (a) a heavier object falls faster than a lighter object; (b) motion take place because of a constant applied force, the students belief in the notion of "force implies motion" i.e. every motion has a cause. An object only moves because there exist an external force exerted on it; (c) acceleration and velocity are used interchangeably, i.e. the velocity of an object is directly proportional to the force applied, and this statement then leads to the conclusion that constant force implies constant velocity; (d) the students also believe that a bigger object exerts a bigger force, and hence the third law of Newton is violated, and (e) that moving objects at the same position in a given time have the same speed.

The study was also aimed at investigating whether a relationship exists between the students' confidence levels and test performance (Research question 2). Do students make accurate judgments about their knowledge and understanding of the basic mechanics concepts? The study has shown that in most cases the best performing students make quality judgment about their performance, while poor performing students always make inaccurate judgments about their performance. The study also investigated whether the relationship between confidence and performance can be used to reliably identify the presence of misconceptions in mechanics (Research question 3). The analysis of the students' written explanations and the item difficulty revealed that the Hasan *et al.* (1999) study is lacking in the differentiation between lack of analytical skills and the presence of alternative conceptions. Lack of analytical or interpretation skills cannot be classified as evidence of the presence of alternative conceptions. The respondent may be having knowledge of the necessary concepts, but lack higher order analytical skills to be able to interpret the situation presented.

Misinterpretation of diagrams was evident from the analysis of the students' written explanations. However, this is beyond the scope of the study, and probably may be revisited for future work.

7.5 Limitations to the Study

- The study is confined to the three South African universities for students registered for physics. The sample used therefore represents only a subset of the first entering physics student population at all South African universities.
- The students entering the universities have changing profiles based on the changing landscapes in the South African Education Systems. The results of the study might not be the same after maybe a decade or so from now.
- The interpretation of the students' written explanations is picking up on some lack of knowledge and understanding; however one could not ask follow-up questions on these explanations. An interview would have provided an opportunity to be able to ask follow-up questions and get clarity on some explanations given.

- There are interesting issues like gender, cultural background and language, but these were not investigated in this study.

7.6 Implications to Teaching

Every first entering physics student brings to class a system of belief about the physical process. These systems of belief are acquired through interactions with the environment and also from past personal experiences. Physics education research has, over a number of years, indicated that these systems of belief play an important role in introductory physics and thus form the basis for learning. The knowledge and understanding of concepts the students bring along to class impacts on teaching and learning. It is important for educators to know which alternative concepts students have in physics, and in particular about forces and motion. The laws of Newton may seem straightforward to understand, but students find difficulty in applying them to everyday situations. Knowledge of how the students think is important in the planning and structuring of lessons.

Three types of alternative conceptions exist among the students. There are those alternative conceptions that are easier to correct because they are present to a large extend in the weaker performing cohorts and are almost absent in the best performing cohorts. The alternative conceptions are: (a) Less friction acts on lighter than on heavier objects. (b) Force of motion continues even when contact has stopped. (c) The applied force is directly proportional to the velocity of the object. (d) The use of velocity and acceleration indiscriminately. (e) The use of velocity and position indiscriminately. (f) Equal forces produce equal accelerations. (g) When an object moves in a circular path it will continue to move in a circular path even when the centripetal force stops. There are those alternative conceptions that are present in the poor performing cohorts but moderately so in the best performing cohorts. This can be interpreted to indicate that with better quality teaching in physics these alternative conceptions can be addressed, but they may be more difficult to uproot than the previous group. The alternative conceptions are: a) A heavier object falls faster than a lighter object. b) A bigger mass exerts a bigger force. c) Motion is in the direction of a bigger force. d) Motion takes place when force overcomes friction. There are those alternative conceptions that are present in the best performing cohorts. This can be interpreted as the alternative conceptions that strongly held by the student and can be difficult to uproot despite better quality teaching in physics. The alternative conceptions are: a) Contact force by hand decreases as the ball goes vertically up followed by gravity increasing as objects fall down. b) Incorrect application of vector addition when dealing with components of forces in two dimensions.

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APPENDIX A

Consent Form

I understand that

* The purpose of this study is to investigate the conceptual understanding and confidence levels of physics first entering students at the university.

* Any personal information about me that is collected during the study will be held in the strictest confidence and will not form part of my permanent record at the university.

* I am not waiving any human or legal rights by agreeing to participate in this study.

* My participation in this study is voluntary.

I verify, by signing below, that I have read and understood the conditions listed above.

Signature: ______________________________

Date: ______________________________

Adapted from Witt-Rose, D.L. (2003)

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APPENDIX B

PHYSICS TEST INSTRUMENT

Surname and Name(s): ______________________________

Student Number: ______________________________

University: ______________________________

Name of School (Grade 12): ______________________________

PLEASE NOTE:

The results of this test are very important to inform lecturers about misconceptions and lack of understanding in physics. The results will be used for research purposes and also to track your progress during this year. Please work as accurately as possible and give your honest response. The results will, however, not count towards your semester or final marks for physics.

Thank you for your cooperation!

APPENDIX B

PHYSICS TEST INSTRUMENT

Surname and Name(s): ______________________________

Student Number: ______________________________

University: ______________________________

Name of School (Grade 12): ______________________________

PLEASE NOTE:

The results of this test are very important to inform lecturers about misconceptions and lack of understanding in physics. The results will be used for research purposes and also to track your progress during this year. Please work as accurately as possible and give your honest response. The results will, however, not count towards your semester or final marks for physics.

Thank you for your cooperation!

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INSTRUCTIONS

- Fill the top section of this booklet and the top of the pink answer sheet with your personal details.

- It is very important that you **READ**, **SIGN** and **FILL IN THE DATE** on the **CONSENT FORM**.

- The test consists of two sections. Section A focuses on your educational and demographic background. Section B focuses on your understanding of some physics concepts.

- Each question in Section B should be answered using the following steps:

  Step 1: Select the correct answer and draw a circle around the corresponding letter.

  Step 2: Write down an explanation for your answer.

  Step 3: How confident are you that the answer you have given is correct? Circle the letter, that best indicates how certain you are about your answer, in the box that follows every question. For example, if you have totally guessed the answer, draw a circle around A, as shown below

Totally guessed answer	Almost a guess	Almost certain	Certain
(A)	B	C	D

- **IMPORTANT: WRITE YOUR ANSWERS TO ALL QUESTIONS ON THE TEST PAPER FIRST.**

- You will be provided with a pink answer sheet for computerized marking. Complete the top section of **SIDE ONE** of the pink sheet with your personal details. Transfer the data (your answers to all questions) to the pink sheet. **USE ONLY A PENCIL TO COMPLETE THE PINK SHEET.**

- **CALCULATORS ARE NOT ALLOWED DURING THE TEST.**

Section A: Background

Answer this section by drawing a circle around a letter, in this test booklet, that best describes your background.

What gender are you?

1

A. Male
B. Female

What is your home language?

2

A. An African language (e.g. Sepedi, Tshivhenda, siSwati, IsiZulu, IsiXhosa, Xitsonga, IsiNdebele, etc.)
B. Afrikaans
C. English
D. Another European language (e.g. French, Portuguese or German)
E. Other

What was the language of instruction used at your high school?

3

A. An African language (e.g. Sepedi, Tshivhenda, siSwati, IsiZulu, IsiXhosa, Xhitsonga, IsiNdebele, etc.)
B. Afrikaans
C. English
D. Another European language (e.g. French, Portuguese or German)
E. Other

Which language did your physical science teacher, at grade 12, frequently use?

4

A. An African language (e.g. Sepedi, Tshivhenda, siSwati, IsiZulu, IsiXhosa, Xitsonga, IsiNdebele, etc.)
B. Afrikaans
C. English
D. Another European language (e.g. French, Portuguese or German)
E. Other

At what kind of school did you finish your grade 12?

5

A. Private school
B. Township school
C. High school on a farm
D. High school in a rural area
E. High school in a town/city

Section B: Conceptual Understanding

6 Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two-story building at the same instant of time. The time it takes the balls to reach the ground below will be:

A. About half as long for the heavier ball.
B. About half as long for the lighter ball.
C. About the same time for both balls.
D. Considerably less for the heavier ball, but not necessarily half as long.
E. Considerably less for the lighter ball, but not necessarily half as long.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

____

____

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Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	**Almost a guess**	**Almost certain**	**Certain**
A	B	C	D

[41]

7

Imagine a head-on collision between a large truck and a small compact car. During collision:

A. The truck exerts a greater amount of force on the car than the car exerts on the truck.
B. The car exerts a greater amount of force on the truck than the truck exerts on the car.
C. Neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
D. The truck exerts a force on the car, but the car doesn't exert a force on the truck.
E. The truck exerts the same amount of force on the car as the car exerts on the truck.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	**Almost a guess**	**Almost certain**	**Certain**
A	B	C	D

[42]

8

A boy throws a steel ball straight up. **Disregarding any effect of air resistance**, the force(s) acting on the ball until it returns to the ground is(are)

A. Its weight vertically downward along with a steady decreasing upward force.
B. A steady decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steady increasing downward force of gravity as the ball gets closer to the earth.
C. A constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
D. A constant downward force of gravity only.
E. None of the above, the ball falls back down to earth simply because that is its natural action.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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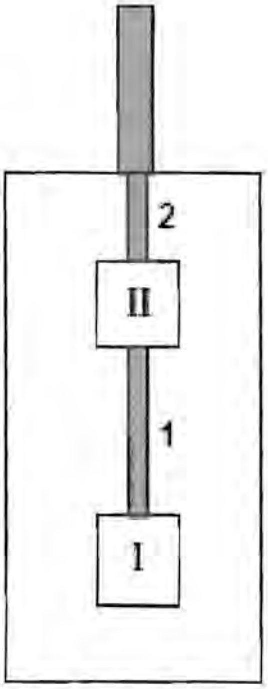
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[43]

Refer to the diagram below when answering questions 10 and 11.

Blocks I and II, each with a mass of 1.0 kg, are hung from the ceiling of an elevator by ropes 1 and 2.



10

What is the force exerted by rope 1 on block I when the elevator is traveling upwards at a constant speed of 2.0 m/s?

A. 2 N
B. 10 N
C. 12 N
D. 20 N
E. 22 N

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

____

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____

____

Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[45]

11 What is the force exerted by rope I on block II when the elevator is stationary?

A. 2 N
B. 10 N
C. 12 N
D. 20 N
E. 22 N

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

____

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____

____

Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[46]

12 A car has a maximum acceleration of 3.0 m/s^2. What would its maximum acceleration be while towing a second car twice its mass?

A. 2.5 m/s^2

B. 2.0 m/s^2

C. 1.5 m/s^2

D. 1.0 m/s^2

E. 0.5 m/s^2

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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____

____

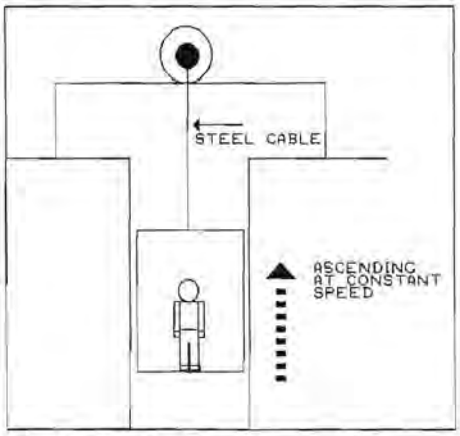
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[47]

When responding to the following question, assume that any <u>friction forces</u> due to air resistance are so small that they <u>can be ignored</u>.

13 An elevator, as illustrated, is being lifted up an elevator shaft by a steel cable. When the elevator is moving up the shaft at **<u>constant velocity;</u>**



A. The upward force on the elevator by the cable is greater than the downward force of gravity.
B. The amount of upward force on the elevator by the cable is equal to that of the downward force of gravity.
C. The upward force on the elevator by the cable is less than the downward force of gravity.
D. It goes up because the cable is being shortened, not because of the force being exerted on the elevator by the cable.
E. The upward force on the elevator by the cable is greater than the downward force due to the combined effects of air pressure and the force of gravity.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

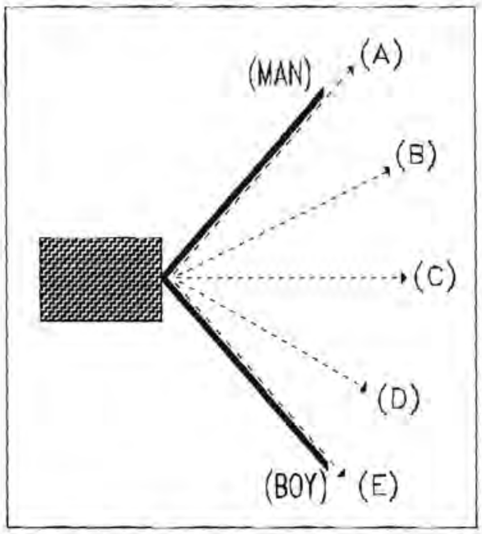
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	**Almost a guess**	**Almost certain**	**Certain**
A	B	C	D

[48]

14 Two people, a large man and a boy, are pulling as hard as they can on two ropes attached to a crate as illustrated in the figure below.

Which of the indicated paths (A to E) would most likely correspond to the path of the crate as they pull it along?



Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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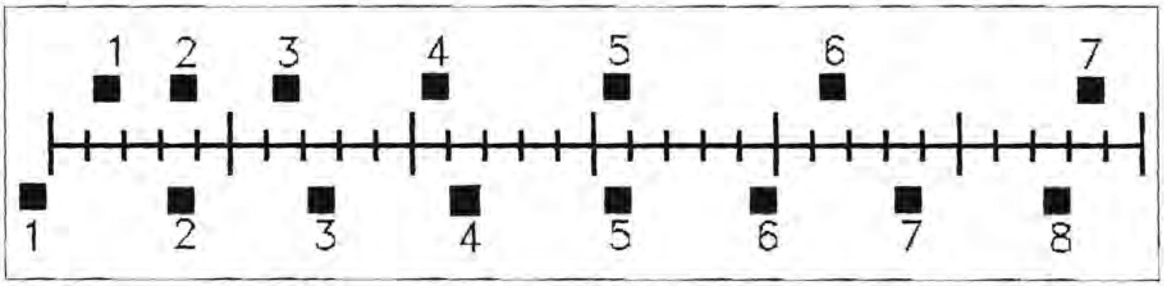
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[49]

The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the diagram below. The blocks are moving toward the right.



15 Do the blocks ever have the same speed?

A. No.
B. Yes, at instant 2.
C. Yes, at instant 5.
D. Yes, at instant 2 and 5.
E. Yes, at some time during interval 3 to 4.

Step 1. Select the correct option and draw a circle around it.

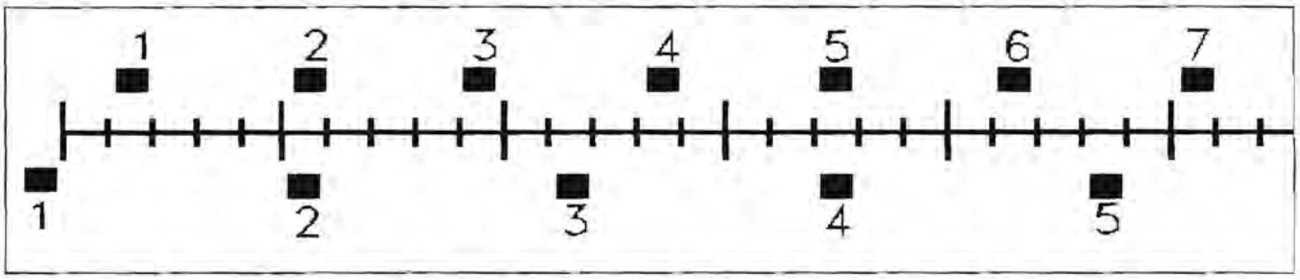
Step 2. Write down an explanation for your answer.

Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[50]

The positions of two blocks at successive equal time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right. The top block is "a" while the bottom block is "b".



16 The acceleration of the blocks are related as follows:

A. Acceleration of "a" > acceleration of "b".
B. Acceleration of "a" = acceleration of "b" > 0.
C. Acceleration of "b" > acceleration of "a".
D. Acceleration of "a" = acceleration of "b" = 0.
E. Not enough information to answer.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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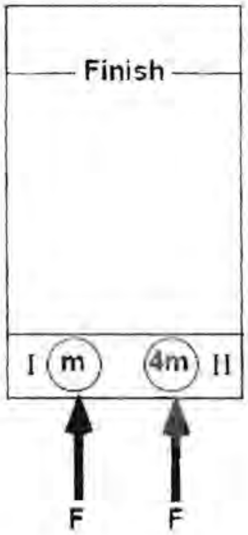
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[51]

The diagram depicts two pucks on a frictionless table. Puck II is four times as massive as puck I. Starting from rest, the pucks are pushed across the table by two **equal** forces.



17 Which puck will reach the finish line first?

A. I

B. II

C. They will both reach the finish line at the same time.

D. Too little information to answer.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[52]

18 A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box?

A. If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.

B. The amount of force applied to move the box at a constant speed must be more than its weight.

C. The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.

D. The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.

E. There is a force being applied to the box to make it move but the external forces such as friction are not 'real' forces, they just resist motion.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

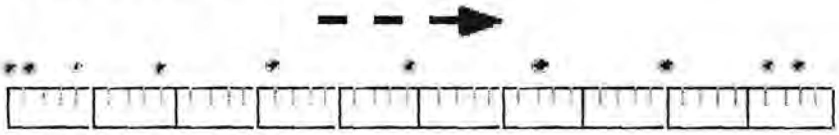
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

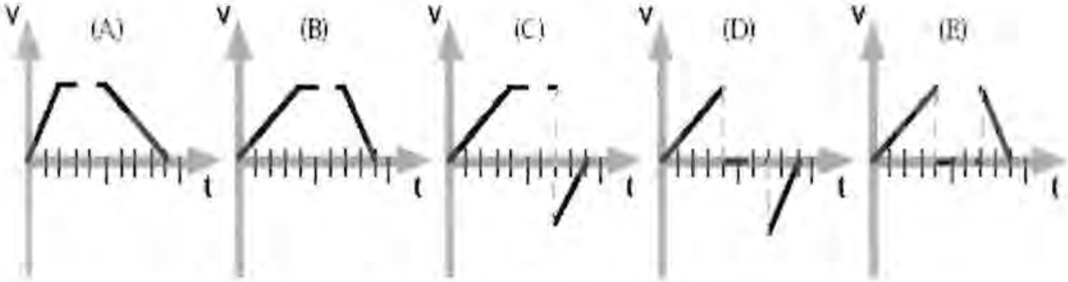
[53]

Refer to the diagram below when answering the next two questions (questions 19 & 20).

This diagram represents a multiflash of an object moving along a horizontal surface. The positions as indicated in the diagram are separated by equal time intervals. The first flash occurred just as the object started to move and the last flash just as it came to rest.



19 Which of the following graphs best represents the object's velocity as a function of time?



Step 1. Select the correct option and draw a circle around it.

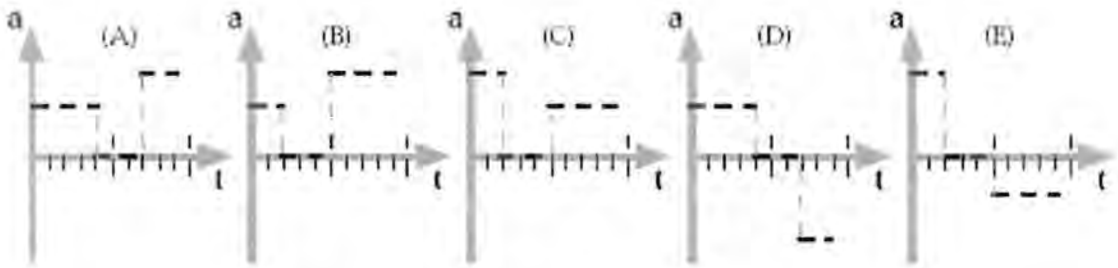
Step 2. Write down an explanation for your answer.

Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[54]

20 Which of the following graphs best represents the object's acceleration as a function of time?



Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[55]

21 Consider the ticker tape trace below, which represent the motion of a car. The car is moving to the right.

What is the direction of the acceleration and the net force on the car?

	Acceleration	Net force
A.	To the right	To the right
B.	To the right	To the left
C.	To the left	To the right
D.	To the left	To the left
E.	The information supplied is not enough.	

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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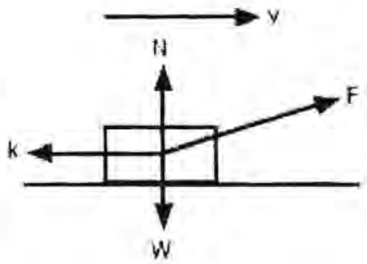
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[56]

22 A person pulls a block across a rough horizontal surface at a constant speed by applying a force F. The arrows in the diagram correctly indicate the directions, but not necessarily the magnitudes of the various forces on the block. Which of the following relations amoung the force magnitudes W, k, N and F must be true?



A. F = k and N = W

B. F = k and N > W

C. F > k and N < W

D. F > k and N = W

E. None of the above choices.

Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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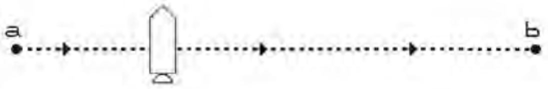
Step 3. Circle the option below that best describes how you arrived at your answer.

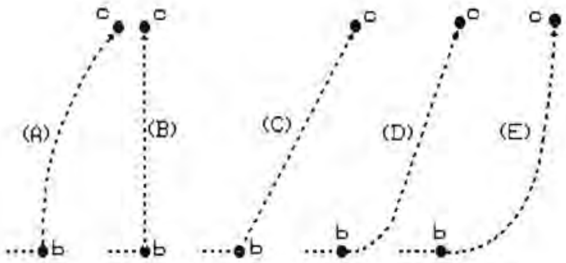
Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[57]

A rocket, drifting sideways in outer space from position "a" to position "b", is subjected to no outside forces. At "b" the rocket's engine starts to produce a constant thrust at right angles to line "ab". The engine turns off again as the rocket reaches point "c".



23 Which path below best represents the path of the rocket between "b" and "c"?



Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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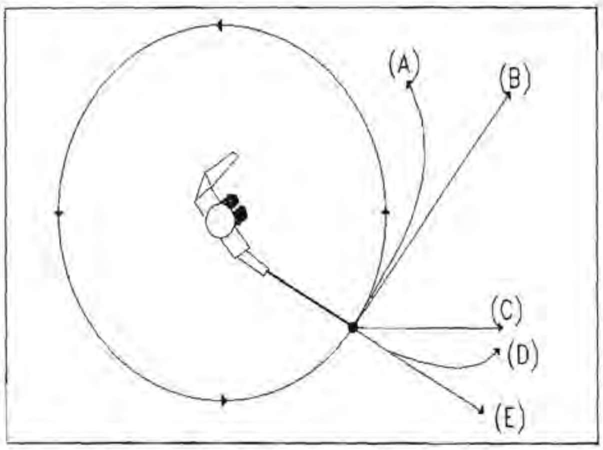
Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[58]

24 A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram below. At the point indicated in the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicates the path of the ball after the string breaks.



Step 1. Select the correct option and draw a circle around it.

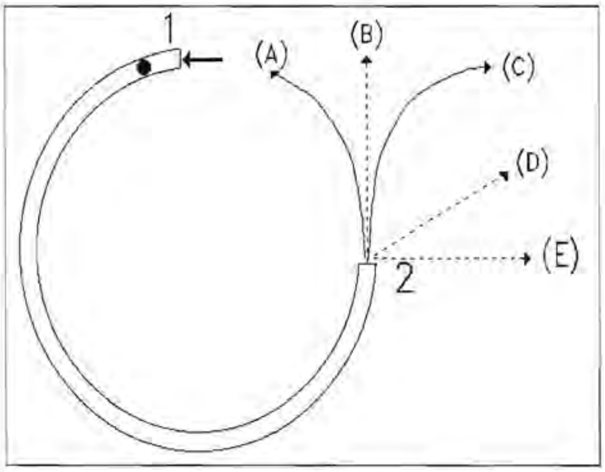
Step 2. Write down an explanation for your answer.

Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[59]

25 The accompanying diagram depicts a semicircular channel that has been securely attached, in a horizontal plane, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top?



Step 1. Select the correct option and draw a circle around it.

Step 2. Write down an explanation for your answer.

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Step 3. Circle the option below that best describes how you arrived at your answer.

Totally guessed answer	Almost a guess	Almost certain	Certain
A	B	C	D

[60]

APPENDIX C: Performance and Confidence of Students

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AA001	5	2.3	AB001	10	2.2	AB032	9	2.2
AA002	5	2.1	AB002	6	1.6	AB033	3	1.8
AA003	7	1.9	AB003	7	2.8	AB034	9	1.7
AA004	11	2.8	AB004	6	1.7	AB035	7	1.8
AA005	7	1.3	AB005	12	2.9	AB036	5	2.7
AA006	10	1.7	AB006	8	1.3	AB037	7	2.6
AA007	5	1.5	AB007	7	1.9	AB038	5	1.1
AA008	7	2.5	AB008	9	1.6	AB039	12	2.2
AA009	7	2.3	AB009	5	1.6	AB040	6	2.5
AA010	9	2.2	AB010	10	2.7	AB041	9	0.5
AA011	4	2.5	AB011	9	2.2	AB042	4	1.7
AA012	3	1.8	AB012	4	2.6	AB043	15	2.6
AA013	5	1.3	AB013	7	2.2	AB044	6	2.4
AA014	3	2.5	AB014	6	1.8	AB045	7	1.7
AA015	4	1.2	AB015	5	2.3	AB046	6	2.3
AA016	6	1.8	AB016	8	1.8	AB047	9	2.9
AA017	4	1.8	AB017	11	2.7	AB048	3	1.4
AA018	4	1.4	AB018	10	2.8	AB049	6	1.6
AA019	7	1.4	AB019	4	0.9	AB050	5	1.8
AA020	10	2.5	AB020	10	1.3	AB051	10	2.0
AA021	4	1.4	AB021	8	1.7	AB052	12	2.2
AA022	8	1.2	AB022	6	2.5	AB053	10	1.5
AA023	7	2.6	AB023	7	2.2	AB054	7	1.1
AA024	5	1.6	AB024	7	1.9	AB055	9	1.9
AA025	8	1.9	AB025	10	2.0	AB056	11	3.0
AA026	15	3.0	AB026	7	2.8	AB057	8	2.0
AA027	5	1.5	AB027	11	2.7	AB058	5	2.0
AA028	4	2.4	AB028	5	1.1	AB059	8	2.7
AA029	5	1.2	AB029	9	1.9	AB060	7	2.6
AA030	11	2.0	AB030	5	1.6	AB061	5	2.6
AA031	9	2.6	AB031	6	1.9	AB062	8	2.8

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AB063	8	2.2	AC026	10	2.5	AC057	11	2.2
AB064	6	1.6	AC027	8	1.8	AC058	6	3.0
AB065	12	2.8	AC028	10	2.1	AC059	10	2.7
AB066	4	1.8	AC029	17	2.0	AC060	8	2.0
AB067	10	1.6	AC030	5	2.5	AC061	4	1.9
AB068	10	1.4	AC031	11	2.8	AC062	9	1.9
AC001	6	2.4	AC032	7	2.5	AC063	8	2.5
AC002	15	2.9	AC033	16	3.0	AC064	15	2.1
AC003	9	2.4	AC034	6	2.1	AC065	10	1.2
AC004	13	2.7	AC035	16	2.7	AC066	8	1.5
AC005	8	1.8	AC036	8	1.9	AC067	12	2.5
AC006	13	2.4	AC037	4	2.0	AC068	6	1.9
AC007	7	1.9	AC038	8	2.6	AC069	8	1.9
AC008	13	2.0	AC039	11	1.7	AC070	14	2.4
AC009	13	1.8	AC040	17	2.3	AC071	11	2.3
AC010	11	2.8	AC041	10	1.9	AC072	13	2.9
AC011	13	2.9	AC042	7	1.6	AC073	13	2.2
AC012	10	2.2	AC043	10	2.2	AC074	9	2.7
AC013	11	1.5	AC044	9	2.7	AC075	11	2.2
AC014	14	2.4	AC045	6	1.6	AC076	6	2.1
AC015	13	2.6	AC046	13	2.6	AC077	13	2.1
AC016	9	1.9	AC047	7	2.4	AC078	12	2.1
AC017	9	1.4	AC048	9	1.8	AC079	11	2.0
AC018	5	2.1	AC049	5	1.3	AC080	6	1.6
AC019	8	1.2	AC050	12	2.4	AC081	3	1.0
AC020	13	2.1	AC051	13	2.7	AC082	9	1.7
AC021	10	1.5	AC052	2	1.7	AC083	13	2.7
AC022	9	1.6	AC053	8	1.7	AC084	10	1.9
AC023	8	2.2	AC054	15	1.9	AC085	10	2.1
AC024	14	2.6	AC055	10	1.6	AC086	5	1.4
AC025	7	0.9	AC056	9	2.1	AC087	14	2.9

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AC088	16	2.2	AC119	6	1.4	AC150	9	2.2
AC089	11	3.0	AC120	7	2.3	AC151	9	2.2
AC090	14	2.9	AC121	15	1.3	AC152	15	3.0
AC091	5	2.0	AC122	14	2.9	AC153	10	1.5
AC092	9	1.8	AC123	11	2.4	AC154	5	2.2
AC093	6	1.8	AC124	12	2.0	AC155	9	2.7
AC094	11	0.8	AC125	12	2.7	AC156	15	2.4
AC095	13	1.7	AC126	11	2.2	AC157	11	2.5
AC096	10	2.3	AC127	10	1.3	AC158	8	2.2
AC097	10	1.5	AC128	9	2.7	AC159	10	1.9
AC098	15	1.6	AC129	8	2.2	AC160	7	2.6
AC099	9	2.8	AC130	10	1.8	AC161	11	2.3
AC100	11	1.9	AC131	11	3.0	AC162	8	2.6
AC101	14	2.8	AC132	8	1.9	AC163	16	3.0
AC102	8	2.1	AC133	15	2.8	AC164	17	2.8
AC103	8	1.5	AC134	12	1.4	AC165	14	2.1
AC104	8	0.9	AC135	11	2.7	AC166	13	3.0
AC105	5	1.2	AC136	13	2.0	AC167	9	1.9
AC106	15	3.0	AC137	9	1.6	AC168	12	2.5
AC107	13	2.9	AC138	11	2.0	AC169	11	3.0
AC108	11	2.3	AC139	10	2.9	AC170	17	2.4
AC109	9	2.1	AC140	11	2.2	AC171	11	1.9
AC110	13	1.9	AC141	10	2.7	AC172	11	2.3
AC111	15	2.9	AC142	9	2.3	AC173	4	1.9
AC112	6	2.3	AC143	6	2.3	AC174	11	2.9
AC113	7	2.0	AC144	6	2.6	AC175	8	2.2
AC114	14	2.9	AC145	10	2.1	AC176	9	2.3
AC115	10	1.7	AC146	11	2.8	AC177	10	1.9
AC116	6	2.2	AC147	14	1.4	AC178	8	1.8
AC117	8	2.0	AC148	9	1.5	AC179	9	2.2
AC118	4	1.5	AC149	11	2.7	AC180	10	2.1

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AC181	12	2.1	AC212	13	2.6	AC243	13	1.9
AC182	8	0.9	AC213	7	2.2	AC244	12	2.3
AC183	9	2.1	AC214	9	2.0	AC245	9	2.1
AC184	14	2.8	AC215	12	1.9	AC246	10	1.5
AC185	10	2.1	AC216	5	1.7	AC247	16	3.0
AC186	9	2.4	AC217	9	1.9	AC248	10	2.7
AC187	13	2.1	AC218	10	1.9	AC249	11	2.5
AC188	14	1.8	AC219	8	2.1	AC250	12	2.6
AC189	7	1.7	AC220	8	1.5	AC251	9	2.4
AC190	13	1.6	AC221	9	2.2	AC252	16	3.0
AC191	8	2.0	AC222	11	2.4	AC253	9	2.3
AC192	7	1.8	AC223	12	2.4	AC254	6	1.7
AC193	11	2.3	AC224	12	1.6	AC255	10	1.8
AC194	10	2.4	AC225	9	2.3	AC256	16	2.9
AC195	5	2.0	AC226	11	1.4	AC257	8	1.5
AC196	17	2.2	AC227	12	2.7	AC258	12	2.7
AC197	6	1.8	AC228	8	2.5	AC259	12	1.6
AC198	8	2.1	AC229	8	1.8	AC260	7	2.1
AC199	8	2.0	AC230	10	2.3	AC261	10	2.3
AC200	5	1.6	AC231	9	2.1	AC262	11	1.8
AC201	10	2.6	AC232	8	1.9	AC263	6	2.1
AC202	15	2.5	AC233	7	2.4	AC264	5	2.5
AC203	12	3.0	AC234	13	2.4	AC265	6	2.3
AC204	13	2.2	AC235	7	2.2	AC266	13	2.7
AC205	4	0.7	AC236	11	2.1	AC267	12	1.8
AC206	9	3.0	AC237	9	2.3	AC268	9	1.3
AC207	11	1.8	AC238	9	2.5	AC269	6	2.8
AC208	13	2.0	AC239	11	1.4	AC270	13	2.5
AC209	11	1.6	AC240	6	1.4	AC271	17	2.4
AC210	6	1.8	AC241	11	1.4	AC272	12	2.2
AC211	16	2.6	AC242	8	1.9	AC273	11	2.9

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AC274	15	2.3	AC305	9	2.4	AC336	11	2.7
AC275	10	1.8	AC306	6	2.6	AC337	6	2.7
AC276	10	2.4	AC307	13	2.4	AC338	12	2.0
AC277	16	2.7	AC308	11	2.4	AC339	7	2.7
AC278	13	2.6	AC309	9	2.3	AC340	6	1.4
AC279	5	1.9	AC310	9	1.3	AC341	7	2.5
AC280	9	2.0	AC311	6	0.6	AC342	11	2.5
AC281	10	2.4	AC312	9	2.0	AC343	14	2.9
AC282	8	2.9	AC313	6	1.9	AC344	14	2.0
AC283	10	1.3	AC314	14	2.2	AC345	11	1.9
AC284	9	1.9	AC315	16	2.9	AC346	7	2.3
AC285	9	1.9	AC316	9	2.0	AC347	11	2.5
AC286	9	1.5	AC317	8	2.4	AC348	9	2.3
AC287	14	2.4	AC318	15	2.2	AC349	11	1.6
AC288	9	1.5	AC319	7	2.1	AC350	10	1.9
AC289	11	2.1	AC320	6	2.0	AC351	14	2.8
AC290	16	3.0	AC321	14	2.4	AC352	13	2.3
AC291	5	1.4	AC322	14	1.7	AC353	6	1.8
AC292	5	2.5	AC323	8	1.5	AC354	6	0.3
AC293	7	2.2	AC324	9	2.1	AC355	9	3.0
AC294	5	1.4	AC325	8	2.3	AC356	15	2.5
AC295	9	2.5	AC326	8	1.8	AC357	5	1.4
AC296	12	2.4	AC327	12	2.0	AC358	8	2.4
AC297	6	1.8	AC328	12	2.0	AC359	8	2.4
AC298	11	2.2	AC329	11	3.0	AC360	10	2.1
AC299	12	2.5	AC330	10	1.9	AC361	5	1.3
AC300	11	2.7	AC331	16	2.7	AC362	6	1.0
AC301	13	1.6	AC332	4	2.1	AC363	9	1.5
AC302	11	2.4	AC333	9	2.1	AC364	16	2.5
AC303	9	1.9	AC334	14	1.7	AC365	7	2.5
AC304	7	2.0	AC335	10	2.3	AC366	6	1.6

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AC367	10	2.7	AC398	6	1.8	AC429	7	1.9
AC368	13	1.9	AC399	13	2.4	AC430	10	2.4
AC369	13	2.5	AC400	6	1.7	AC431	16	2.2
AC370	9	2.1	AC401	12	2.6	AC432	11	2.8
AC371	10	2.7	AC402	10	2.1	AC433	11	2.3
AC372	12	1.4	AC403	9	1.9	AC434	6	2.4
AC373	6	2.1	AC404	15	2.4	AC435	12	1.9
AC374	8	2.0	AC405	14	1.8	AC436	12	1.9
AC375	14	2.2	AC406	9	2.0	AC437	8	2.4
AC376	9	2.1	AC407	11	1.9	AC438	12	2.2
AC377	6	1.7	AC408	11	1.0	AC439	8	2.3
AC378	6	1.7	AC409	15	2.0	AC440	16	2.9
AC379	8	1.6	AC410	13	2.5	AC441	7	2.1
AC380	11	1.7	AC411	14	2.2	AC442	10	2.3
AC381	12	1.5	AC412	12	2.7	AC443	10	2.6
AC382	12	1.6	AC413	14	2.8	AC444	11	2.0
AC383	5	2.6	AC414	7	2.3	AC445	15	2.0
AC384	13	2.1	AC415	6	1.5	AC446	16	3.0
AC385	16	2.2	AC416	16	2.4	AC447	13	2.8
AC386	16	2.3	AC417	8	0.9	AC448	8	2.0
AC387	8	2.3	AC418	9	2.2	AC449	12	2.0
AC388	9	1.6	AC419	6	2.0	AC450	17	2.2
AC389	8	1.9	AC420	15	2.7	AC451	8	2.1
AC390	12	2.0	AC421	8	1.3	AC452	15	2.8
AC391	11	1.6	AC422	16	2.8	AC453	5	1.0
AC392	9	1.9	AC423	6	1.3	AC454	9	1.7
AC393	9	1.5	AC424	13	2.0	AC455	16	2.4
AC394	16	2.7	AC425	10	2.0	AC456	3	1.2
AC395	4	2.4	AC426	12	2.0	AC457	5	2.0
AC396	7	1.2	AC427	9	1.9	AC458	10	2.9
AC397	5	1.6	AC428	9	2.7	AC459	8	1.9

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
AC460	6	2.1	AD008	17	3.0	BA006	6	2.0
AC461	10	2.0	AD009	4	0.8	BA007	13	1.5
AC462	7	1.9	AD010	13	2.4	BA008	4	1.8
AC463	7	1.6	AD011	8	2.0	BA009	4	2.0
AC464	13	2.3	AD012	7	2.3	BA010	8	1.4
AC465	10	3.0	AD013	7	1.8	BA011	7	1.9
AC466	12	2.6	AD014	10	2.5	BA012	7	1.7
AC467	6	2.0	AD015	8	2.2	BA013	10	1.9
AC468	15	2.9	AD016	6	2.2	BA014	9	1.8
AC469	9	1.8	AD017	9	1.3	BA015	9	2.6
AC470	11	2.8	AD018	11	2.6	BA016	3	1.7
AC471	7	2.1	AD019	11	2.1	BA017	11	1.4
AC472	7	1.8	AD020	8	1.2	BA018	8	1.3
AC473	6	1.5	AD021	15	2.2	BA019	14	2.7
AC474	11	1.4	AD022	13	2.8	BA020	11	1.4
AC475	9	2.5	AD023	12	2.1	BA021	8	1.1
AC476	15	2.1	AD024	7	2.4	BA022	7	1.6
AC477	14	2.4	AD025	9	2.6	BA023	8	2.9
AC478	11	2.0	AD026	17	2.1	BA024	8	1.8
AC479	11	2.8	AD027	10	1.5	BA025	7	1.2
AC480	11	1.8	AD028	16	3.0	BA026	11	1.9
AC481	18	3.0	AD029	17	2.8	BA027	11	1.5
AC482	9	1.9	AD030	7	2.3	BA028	9	2.1
AC483	10	2.4	AD031	11	1.7	BA029	5	1.8
AD001	12	3.0	AD032	13	2.7	BA030	4	2.4
AD002	18	2.9	AD033	10	1.4	BA031	5	1.2
AD003	10	2.5	BA001	13	2.5	BA032	6	2.1
AD004	11	2.7	BA002	5	2.1	BA033	15	1.5
AD005	9	2.4	BA003	2	2.3	BA034	11	2.2
AD006	10	2.7	BA004	8	2.1	BA035	6	1.6
AD007	13	2.5	BA005	8	2.5	BA036	5	1.3

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
BA037	9	2.1	BA068	8	2.3	BA099	6	1.6
BA038	9	1.9	BA069	9	1.9	BA100	8	2.6
BA039	10	1.7	BA070	8	1.1	BA101	4	2.4
BA040	8	1.5	BA071	6	2.5	BA102	8	1.0
BA041	4	2.7	BA072	9	1.1	BA103	6	1.4
BA042	6	1.7	BA073	5	2.3	BA104	10	1.7
BA043	10	2.5	BA074	8	1.8	BA105	7	1.9
BA044	8	1.6	BA075	6	1.9	BA106	5	2.1
BA045	10	1.7	BA076	8	2.3	BA107	9	1.3
BA046	4	1.7	BA077	7	1.9	BA108	3	2.6
BA047	5	0.4	BA078	5	0.9	BA109	14	2.9
BA048	7	2.7	BA079	8	1.9	BA110	11	1.9
BA049	14	2.8	BA080	9	2.7	BA111	8	2.3
BA050	6	2.1	BA081	5	1.2	BA112	8	2.3
BA051	9	2.0	BA082	9	2.0	BA113	7	2.2
BA052	11	2.6	BA083	3	2.0	BA114	7	2.4
BA053	5	2.2	BA084	4	0.6	BA115	7	0.9
BA054	4	1.1	BA085	4	2.4	BA116	7	1.5
BA055	11	2.7	BA086	7	1.5	BA117	4	1.6
BA056	9	1.9	BA087	9	2.5	BA118	6	2.0
BA057	11	2.2	BA088	7	2.1	BA119	5	1.6
BA058	12	2.8	BA089	5	2.2	BA120	4	1.8
BA059	7	1.2	BA090	7	1.3	BA121	3	1.3
BA060	7	1.7	BA091	11	2.8	BA122	6	2.1
BA061	9	0.8	BA092	9	2.2	BA123	7	2.5
BA062	6	1.6	BA093	9	1.9	BA124	9	1.7
BA063	10	2.5	BA094	10	2.3	BA125	8	1.8
BA064	6	2.5	BA095	9	1.8	BA126	7	1.5
BA065	9	2.3	BA096	8	2.0	BA127	7	1.9
BA066	5	1.5	BA097	7	2.8	BA128	5	2.1
BA067	6	0.9	BA098	8	1.1	BA129	7	1.8

APPENDIX C: Performance and Confidence of Students (Continued)

Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
BA130	6	1.3	CA018	5	1.5	CA049	6	2.0
BA131	6	0.9	CA019	4	1.6	CA050	6	1.2
BA132	12	2.5	CA020	10	2.6	CA051	6	2.3
BA133	7	1.4	CA021	3	1.8	CA052	9	2.2
BA134	9	2.5	CA022	7	2.1	CA053	5	2.9
BA135	8	2.3	CA023	8	1.8	CA054	5	1.1
BA136	4	1.6	CA024	5	1.5	CA055	5	1.3
BA137	2	1.9	CA025	7	1.6	CA056	9	2.7
BA138	10	2.6	CA026	8	1.6	CA057	8	1.2
BA139	8	1.5	CA027	7	2.8	CA058	6	1.7
BA140	7	1.5	CA028	5	2.5	CA059	6	0.5
BA141	7	1.9	CA029	5	2.4	CA060	7	2.2
BA142	7	2.2	CA030	6	2.2	CA061	8	1.5
BA143	6	1.7	CA031	7	1.9	CA062	3	1.2
CA001	6	1.2	CA032	3	2.1	CA063	6	0.9
CA002	5	1.5	CA033	6	2.5	CA064	7	2.8
CA003	3	0.8	CA034	4	2.0	CA065	7	2.0
CA004	5	1.8	CA035	8	2.5	CA066	5	2.3
CA005	8	1.6	CA036	6	2.4	CA067	3	1.8
CA006	9	1.7	CA037	3	1.6	CA068	5	1.2
CA007	7	2.4	CA038	5	2.5	CA069	5	1.6
CA008	3	1.8	CA039	2	2.8	CA070	4	2.2
CA009	5	2.8	CA040	4	1.3	CA071	7	1.9
CA010	6	1.8	CA041	3	1.3	CA072	7	0.9
CA011	7	1.9	CA042	1	1.0	CA073	5	2.1
CA012	4	2.6	CA043	2	1.5	CA074	7	2.6
CA013	10	3.0	CA044	6	1.0	CA075	7	2.6
CA014	4	2.1	CA045	4	2.3	CA076	5	1.5
CA015	9	1.2	CA046	8	2.3	CA077	6	1.5
CA016	4	1.9	CA047	6	2.7	CA078	4	2.7
CA017	5	2.2	CA048	8	2.2	CA079	8	2.8

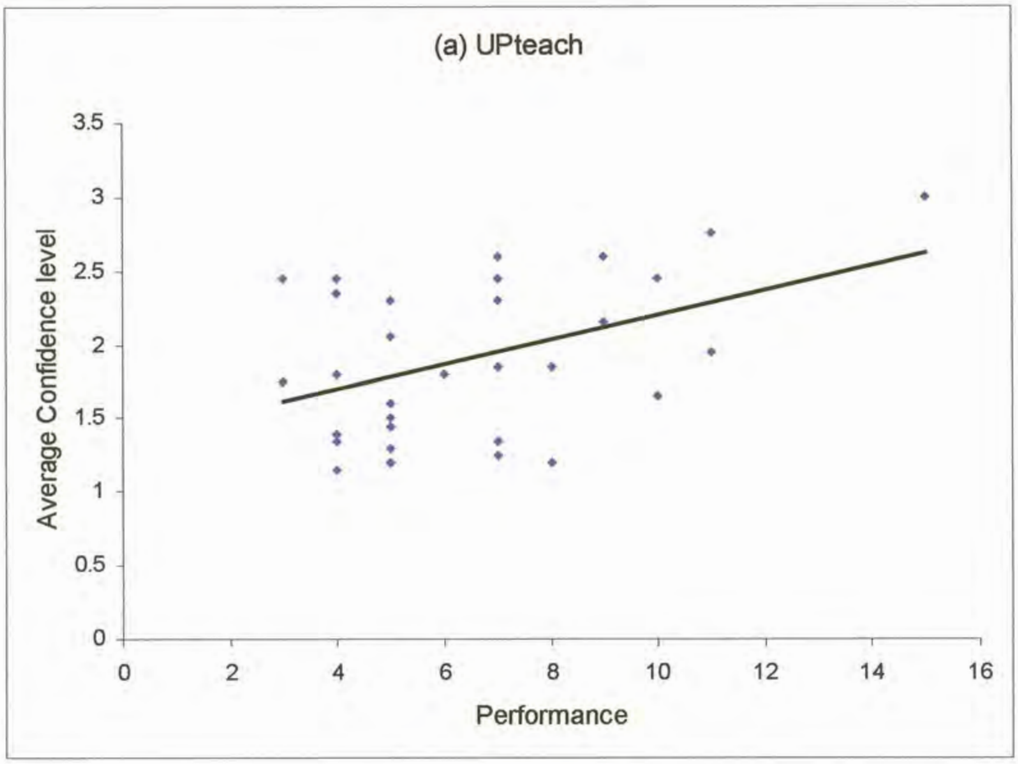
APPENDIX C: Performance and Confidence of Students (Continued)

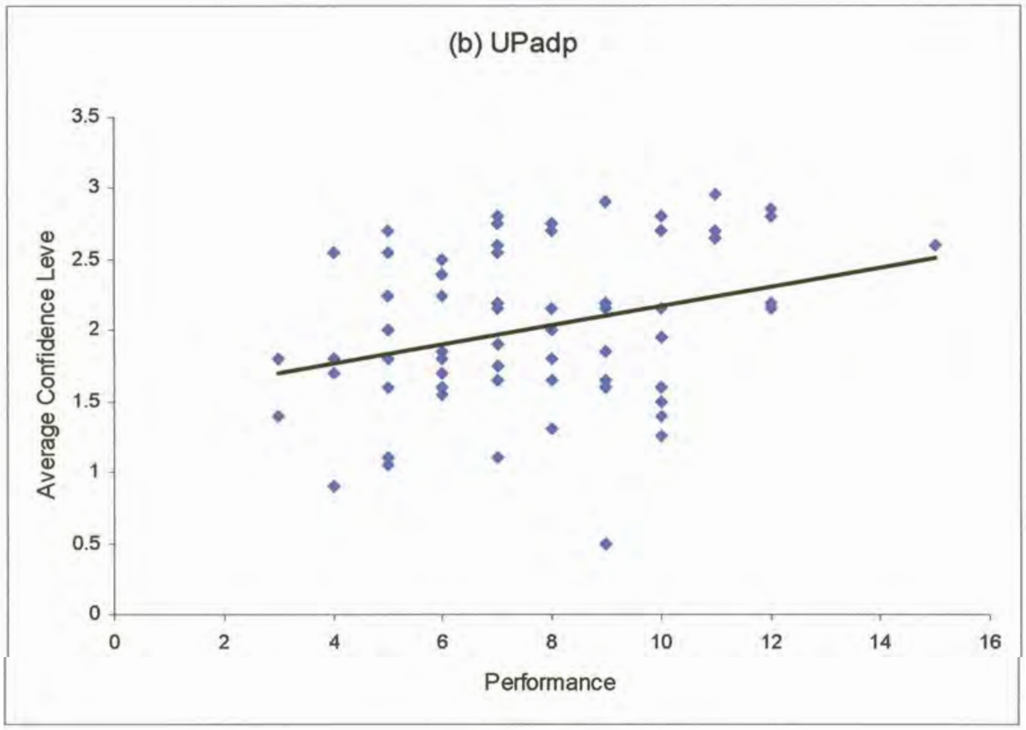
Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
CA080	4	2.0	CB009	9	2.5	CB040	4	2.3
CA081	6	2.0	CB010	11	2.7	CB041	5	1.7
CA082	8	2.1	CB011	4	1.8	CB042	8	1.8
CA083	4	1.8	CB012	13	1.5	CB043	5	2.1
CA084	4	2.0	CB013	4	1.7	CB044	6	1.8
CA085	3	1.2	CB014	5	1.7	CB045	10	1.6
CA086	8	1.9	CB015	3	2.2	CB046	9	2.7
CA087	5	1.8	CB016	8	1.4	CB047	6	2.2
CA088	2	1.5	CB017	5	1.3	CB048	6	2.4
CA089	8	2.4	CB018	3	2.2	CB049	6	0.8
CA090	3	1.2	CB019	2	2.2	CB050	4	2.3
CA091	5	1.8	CB020	6	1.8	CB051	4	2.4
CA092	8	1.7	CB021	5	1.6	CB052	5	2.4
CA093	5	2.1	CB022	7	1.8	CB053	7	2.0
CA094	6	2.1	CB023	11	2.9	CB054	14	2.1
CA095	6	2.1	CB024	3	2.1	CB055	9	1.8
CA096	3	2.5	CB025	7	1.9	CB056	8	2.0
CA097	6	0.5	CB026	7	2.3	CB057	5	1.8
CA098	5	1.6	CB027	10	3.0	CB058	9	2.0
CA099	5	2.3	CB028	5	2.3	CB059	8	2.6
CA100	8	2.0	CB029	9	2.3	CB060	8	3.0
CA101	6	2.2	CB030	8	2.4	CB061	9	2.4
CA102	4	1.6	CB031	5	1.7	CB062	8	1.5
CB001	10	2.1	CB032	3	1.3	CB063	8	2.1
CB002	7	1.5	CB033	8	1.7	CB064	12	1.9
CB003	5	1.7	CB034	4	2.2	CB065	8	2.3
CB004	14	2.1	CB035	8	2.8	CB066	14	2.0
CB005	4	2.1	CB036	2	2.4	CB067	7	2.0
CB006	5	2.8	CB037	9	2.9	CB068	9	1.9
CB007	9	2.4	CB038	3	1.7	CB069	2	1.5
CB008	9	1.9	CB039	11	1.0	CB070	7	1.5

APPENDIX C: Performance and Confidence of Students (Continued)

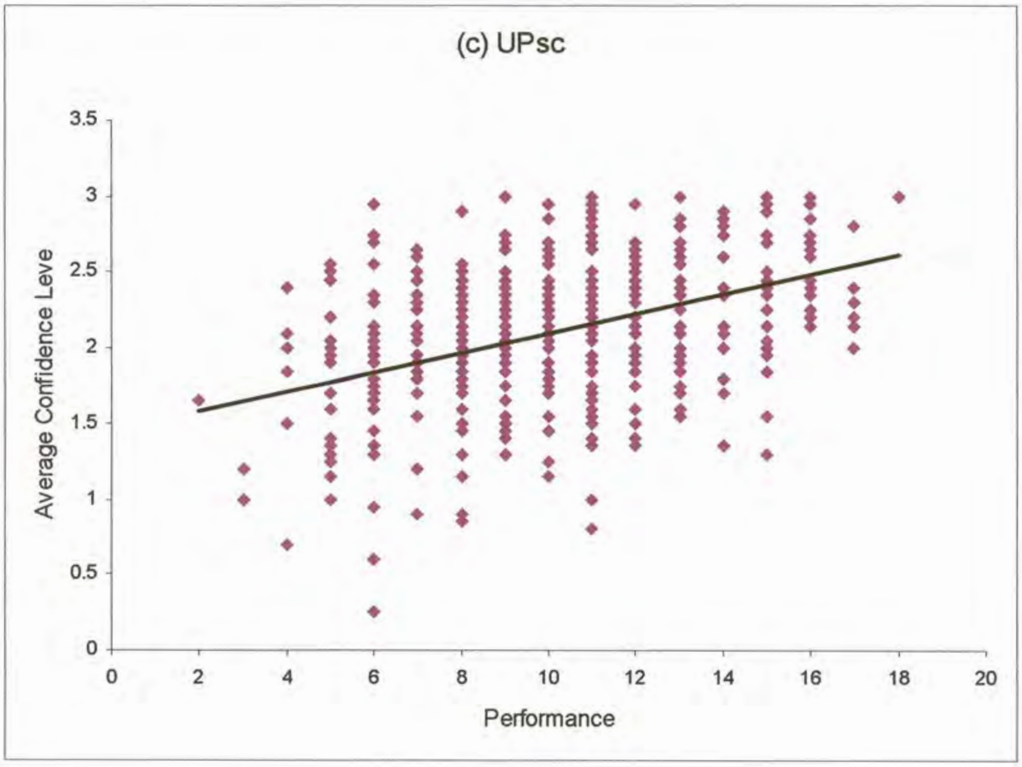
Student Code	Performance	Confidence Level	Student Code	Performance	Confidence Level
CB071	8	1.9	CC023	5	1.6
CB072	6	2.3	CC024	6	2.4
CB073	2	2.8	CC025	7	1.8
CB074	3	2.5	CC026	8	2.4
CB075	5	2.2	CC027	4	2.1
CB076	4	1.4	CC028	12	2.8
CB077	5	2.5	CC029	8	1.1
CB078	7	1.9	CC030	10	2.6
CB079	10	2.3	CC031	7	2.2
CC001	9	1.3	CC032	12	2.0
CC002	10	1.6	CC033	8	2.1
CC003	9	2.0	CC034	5	2.8
CC004	12	1.8	CC035	8	2.0
CC005	10	1.8	CC036	5	2.5
CC006	10	2.8	CC037	2	1.2
CC007	9	1.2	CC038	8	1.0
CC008	3	1.8	CC039	7	2.1
CC009	10	1.9	CC040	6	2.3
CC010	11	1.6	CC041	3	1.8
CC011	5	2.4	CC042	2	2.0
CC012	9	2.3	CC043	9	2.2
CC013	8	1.8			
CC014	8	2.3			
CC015	10	1.9			
CC016	7	1.5			
CC017	8	2.7			
CC018	6	2.5			
CC019	5	2.4			
CC020	3	1.8			
CC021	7	2.2			
CC022	4	1.8			

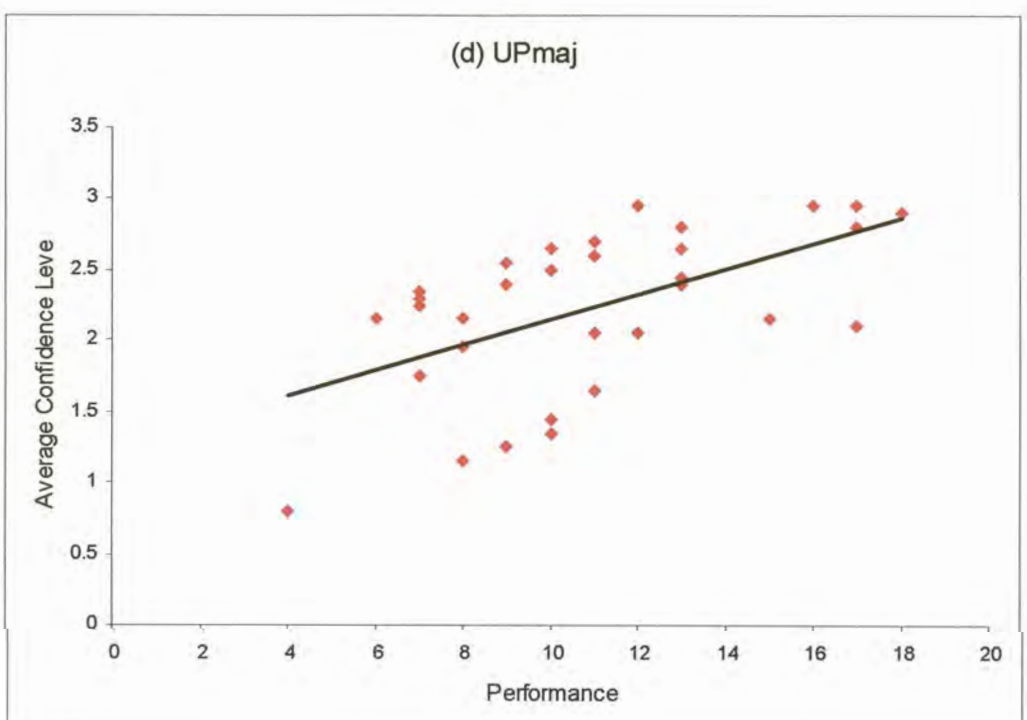
APPENDIX D: Scatter plots for the performance and confidence levels of students



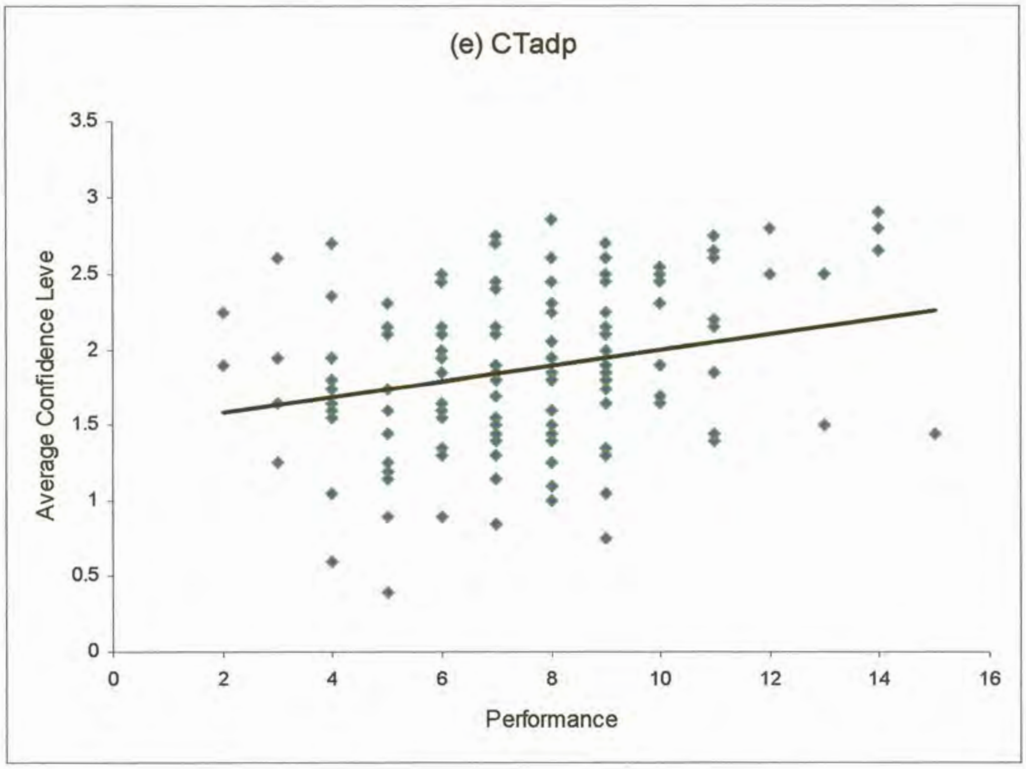


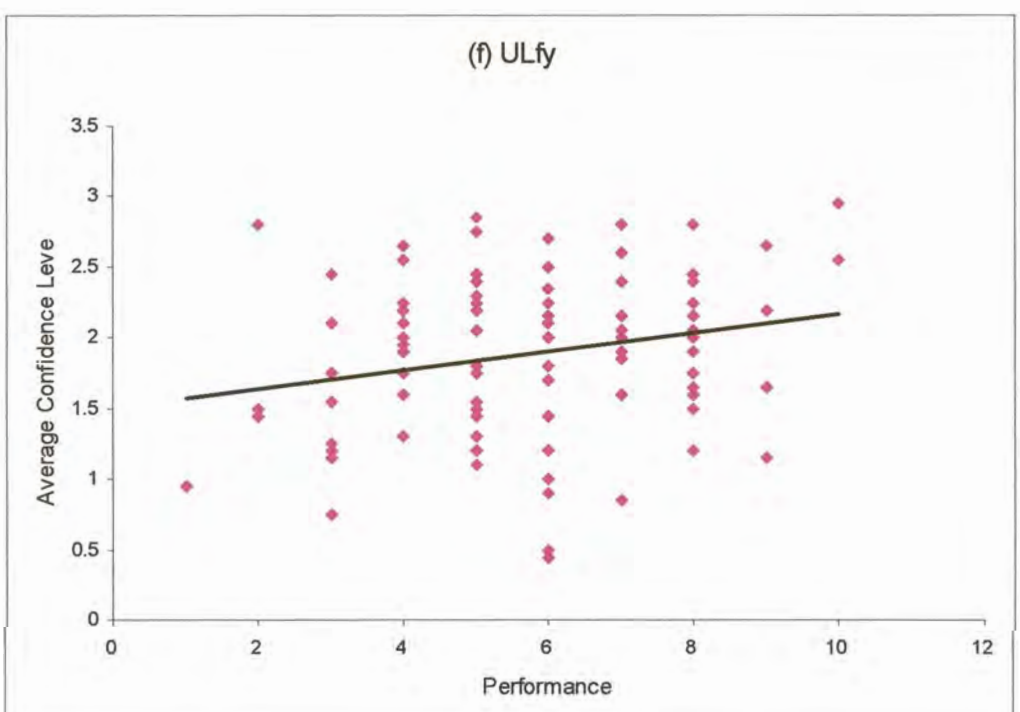
APPENDIX D: Scatter plots for the performance and confidence levels of students





APPENDIX D: Scatter plots for the performance and confidence levels of students





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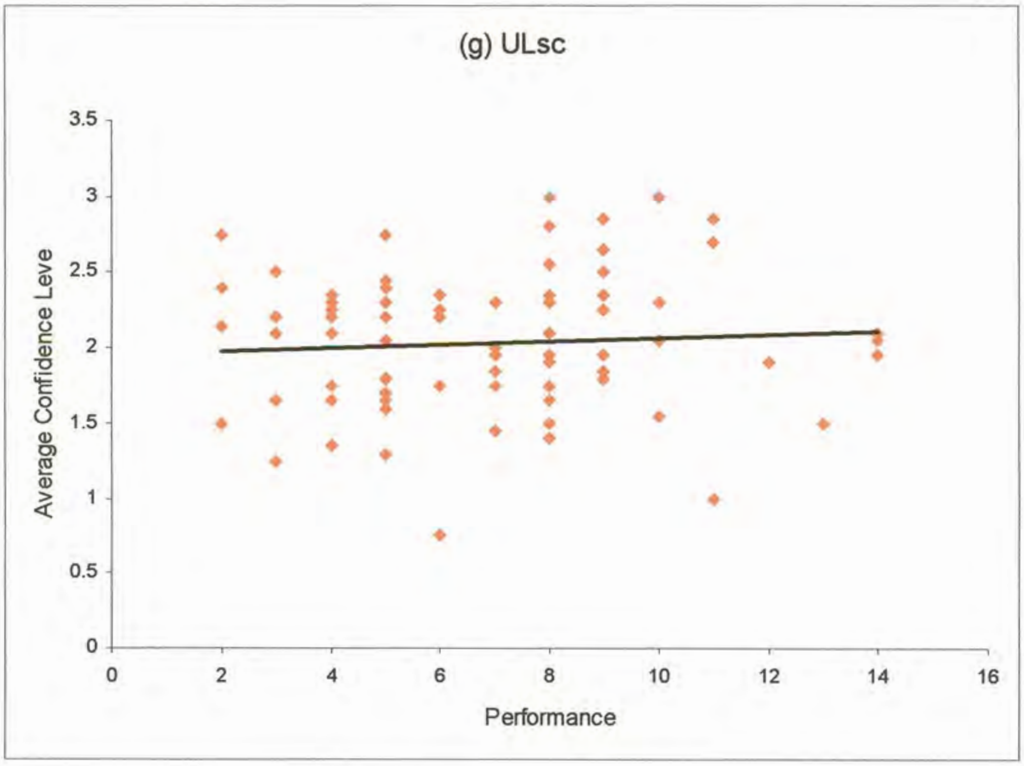
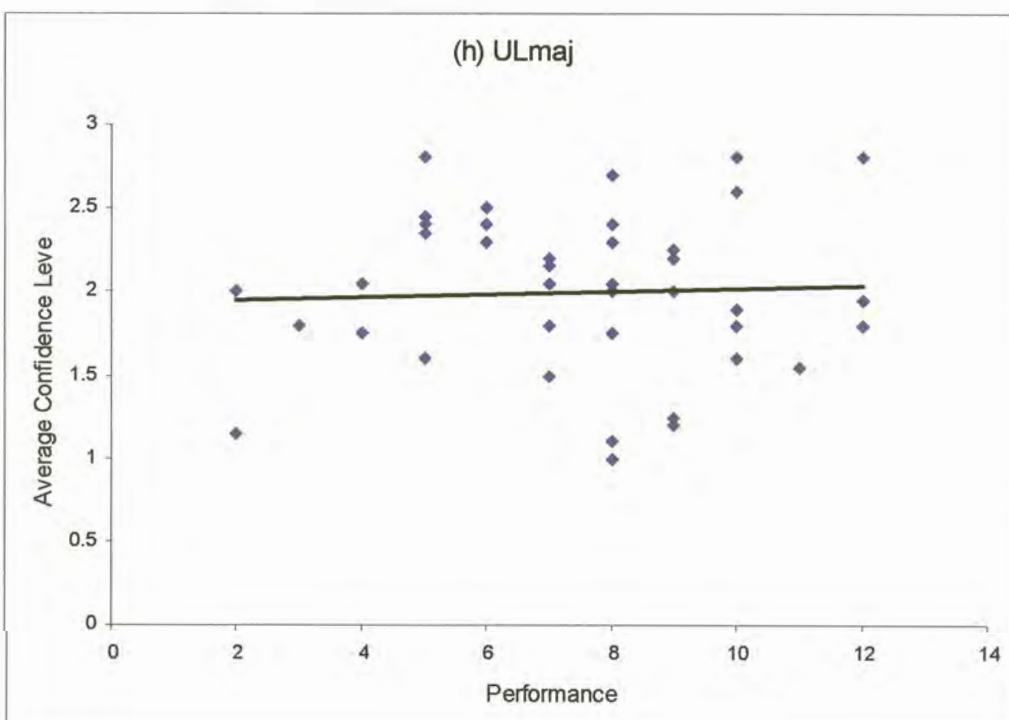
APPENDIX D: Scatter plots for the performance and confidence levels of students





APPENDIX E: Students' Educational Backgrounds

		UPteach	UPadp	UPsc	UPmaj	CTadp	ULfy	ULsc	ULmaj
Gender	Male	23	32	183	21	84	54	46	25
	Female	8	36	300	12	59	48	33	18
Home Language	African Language	22	27	60	13	90	101	78	43
	Afrikaans	6	27	213	12	7		1	
	English	3	13	190	7	42			
	Another European Language		1	12		1	1		
	Other			8	1	3			
Secondary School Medium of Instruction	African Language	4	4	1	2	8	13	11	7
	Afrikaans	6	39	177	11	5	2	1	
	English	21	25	305	20	130	87	67	36
Medium of Instruction by Grade 12 Teacher	African Language	2	2	5	3	12	3	3	4
	Afrikaans	6	28	178	11	3	4	1	
	English	23	38	300	19	128	95	75	39
Type of Grade 12 Secondary School	Private	2	6	123	6	27	16	12	4
	Township	4	4	25	6	34	20	8	9
	Farm	1	3	3		1	4	1	1
	Rural	13	8	34	6	22	50	48	27
	Town/City	11	47	298	15	59	12	10	2