THE IMPACT OF INTERACTIVE-ENGAGEMENT MODELS IN THE TEACHING AND LEARNING OF PHYSICS TO FIRST YEAR EDUCATION STUDENTS

by

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DECLARATION

I declare that **THE IMPACT OF INTERACTIVE-ENGAGEMENT MODELS IN THE TEACHING AND LEARNING OF PHYSICS TO FIRST YEAR EDUCATION STUDENTS** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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(MR M N KHWANDA)

ABSTRACT

The aim of this study was firstly to evaluate the impact of two interactive-engagement models of instruction, namely Whole Class Discussions (WCD) and Computer Simulations (CS) on first year physics student-teachers' conceptual understanding of Newtonian mechanics, and on their epistemological beliefs about physics. The force concept inventory was used to evaluate the impact on conceptual understanding while the Epistemological Beliefs About Physical Science questionnaire was used to evaluate the impact on their epistemological beliefs. The findings suggest that interactive engagement models had a positive impact on students' conceptual understanding of Newtonian mechanics, and on their epistemological beliefs about physics. The study also contributed WCD and CS activities that can be used or adapted with an aim of enhancing conceptual understanding in physics. The study did not show any direct relationship between students' conceptual understanding of Newtonian mechanics and their epistemological beliefs about physics.

Key words:

Interactive-engagement, Whole Class Discussion, Computer Simulations, epistemological beliefs, physics education, teacher training, conceptual understanding.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Introduction

Research has established that physics curricula should meet some criteria in order to accommodate the majority of students (Mbajiorgu & Reid, 2006). Some of the criteria identified by Mbajiorgu and Reid (2006) at the University of Glasgow which are also applicable in South Africa were the following:

(a) Meet needs of all the learners
(b) Build on school physics and the way learning takes place
(c) Aim at conceptual understanding
(d) Take into account the way students learn
(e) Offer genuine problem solving experience
(f) Take account of language and communication (p. 2).

Wieman and Perkins (2005) concurred with Mbajiorgu and Reid (2006) on the necessity for aiming the physics curriculum at achieving conceptual understanding which was regarded as the first aspect of learning. They argued that through conceptual understanding, students can apply knowledge gained in a physics class in different contexts. However, Hake (1998) has shown empirically that not all models of instruction are effective in enhancing conceptual understanding. For example, traditional models of instruction were and are still reported to be ineffective in enhancing conceptual understanding (Wieman and Perkins, 2005) whereas interactive-engagement models resulted in high conceptual gains as measured by the Force Concept Inventory (Hake, 1998). Some of the academic physicists are said to be resisting change in teaching, learning and assessment approaches (Gunstone, McKittrick, & Mulhall, 1999) and still prefer to use traditional models. However, Wieman and Perkins (2005, p. 36) were in favour of change and argued that: "The science community needs to change science education to make it effective and relevant for a larger fraction of the student population than in the past."

Guskey (as cited by Gunstone, McKittrick and Mulhall, 1999, p. 524) argued that teacher's acceptance of innovation and change comes after the teacher's personal exploration of the innovation in his or her own class. The implication is that the involvements of student teachers in the use of the new integrated-interactive teaching approaches that take into account student's needs, the way student learn and the way learning takes place smoothly paved the way for ownership and the application of the new approaches in their own classes. One of the teaching approaches used by Gunstone, McKittrick, and Mulhall (1999) at Monash University was structured cognitive discussions. These discussions demand intellectual engagement from all students in the class. In this study, structured cognitive discussions were adapted and operationally defined as Whole Class Discussion (WCD). They claimed that the teaching approaches that demand intellectual engagement and recognition of existing ideas from all students in class enhance conceptual understanding in physics. In addition to the recognition of student's existing ideas, Wieman and Perkins (2005) established that the use of tools in the teaching and learning of physics helped teachers to move students from mindless memorization to understanding and appreciation. One of the tools that have currently gained momentum in the teaching and learning of physics is the use of computer simulations. It is for this reason that this study explored the impact of the two interactive-engagement models of instruction, namely: Whole Class Discussion (WCD) and Computer Simulations (CS) on promoting conceptual understanding of Newtonian mechanics of first year education students of Central University of Technology in Bloemfontein, South Africa.

1.2 Background

South Africa has inherited a fragmented system of science education which failed to provide adequate access to the majority of the population and poorly served those whom it educated (Naidoo & Lewin, 1998). This could be one of the reasons for the underperformance of physical science students in grade 12. Some of the documented reasons for the under-performance of students in physical science in South Africa and globally are:

(a) The use of under-qualified or unqualified science educators (Makgato and Mjii, 2006).
(b) The shortage of science teachers (Govender, 2008)
(c) The language of learning and teaching science (Muwanga-Zake, 2001; Prophet & Badebe, 2006; Mbajiorgu & Reid, 2006) and
(d) The students' prior knowledge (Kolari & Savander-Ranne, 2000; Cimer, 2007; Sherin, 2006) which always differs from scientific views (Bayraktar, 2008).

In addition to those reasons given, the use of traditional teaching models of instruction (Kolari & Savender-Ranne, 2000; Lee & Avalos, 2002) and epistemological beliefs about physical science (Redish, Saul, & Steinberg, 1998; Redish, 2003) were included in the lists of the reasons for the underperformance of physical science students. After realizing the negative impact of these factors on the performance of science students, the South African Cabinet approved eight priorities for consolidating, widening and deepening the national strategy for Mathematics, Science and Technology Education (MSTE) in January 2004. The aim of the strategy was to provide action plans to improve the quality of teaching and learning of mathematics, science and technology in South Africa schools. Some of the key areas for improving learner performance in the National Strategy for Mathematics, Science and Technology Education (Department of Education [DoE], 2004) envisaged to address the following:

(a) Poor output of Mathematics and Physical Science Graduates in grade 12.
(b) Under-qualified and unqualified Mathematics and Physical Science teachers.
(c) A lack of adequate facilities and resources for effective teaching and learning.

The MSTE strategy approved the following priorities with their performance indicators and targets dates for monitoring its implementation:

(a) Performance targets were set for all schools.

(b) Placement of a qualified and competent teacher in every mathematics, science and technology classroom.
(c) Improvement of the language of teaching and learning.
(d) Increased capacities for the identification of talents and potential, the nurturing thereof and provision of appropriate support to improve throughput so as to attract quality recruits into the teaching profession.
(e) To strengthen the cooperation between the Department of Education and the Department of Science and Technology in pursuit of the objectives of the Strategy.
(f) To enter into a social contract with various communities, partners, networks and professional bodies to raise the required resources and mobilise the requisite technical support and expertise.
(g) Evaluate and regulate programmes operating in and out of school to ensure broader equity and access as well as to ensure quality in respect of such programmes
(h) To make interactive digital content on Mathematics, Science and Technology available via satellite, television, internet multimedia, print supplements and the educational portal (DOE, 2004; p. 4).

The attainment of the goals in the MSTE and their performance targets could be possible through the training of pre-service teachers and the re-training of in-service science teachers in the implementation of the new models of instruction that involve an interactive-engagement of students all the time.

The shortage of skills which includes the shortage of science educators in South Africa were also highlighted by the former deputy President of South Africa, Mlambo-Ngcuka (2008), who urged scientists around the world to help South Africa using human resource development programmes to increase the number of skilled scientists. The shortage of scientists in South Africa has a negative impact on the technological development of the country (Makgato & Mjii, 2006).

1.3 Statement of the problem

In attempting to help bridge the gap identified as the cause of low performance in science in South African schools, a pilot survey was conducted in 2007 on the first year B.Ed (FET): Natural Science program at the School of Teacher Education at the Central University of

Technology (CUT) in Bloemfontein. The survey was aimed at diagnosing problems that students bring from high school to the program. The grade 12 physical science results of the students were analysed and the Force Concept Inventory (FCI) was administered with the following aims:

(a) to assess the actual students' understanding of Newtonian mechanics
(b) to diagnose misconceptions student brought to the first year level physics and
(c) to assess the effectiveness of traditional methods of instructions in handling the misconceptions students have.

The analysis of the pilot survey of the students' physical science grade 12 results revealed that students who registered for physics had low symbols in physical science and that few of them (20%) studied it at higher grade (HG) while 80% at standard grade. Only 2% of the higher grade students obtained an A symbol while the rest obtained E symbols. Figure 1.1 represents a breakdown of the students' grade 12 physical science results The poor performance of the students in grade 12 physical science confirmed the claim by Dewey and Dykstra (2008) about the traditional folk theory.

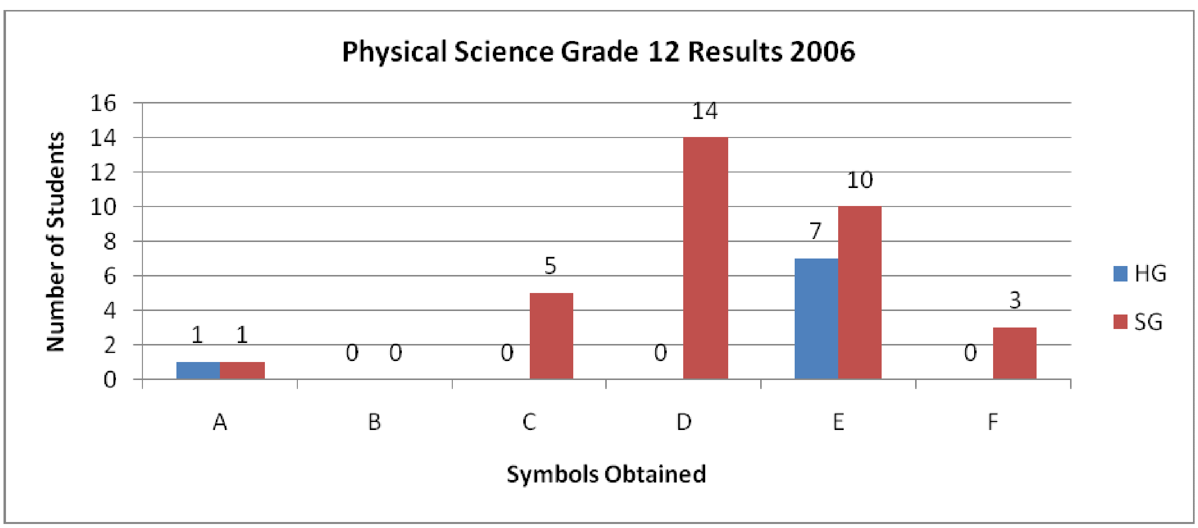


Figure 1.1: Physical Science Grade 12 results of students studying Physics 1 Education at CUT in 2007, Bloemfontein Campus

The traditional folk theory regards the teaching of physics as the presentations of established ideas by approved methods for the benefit of the deserving students. The folk theory can be associated with the traditional beliefs of the teachers, who regard physics as a difficult subject which is usually mathematically orientated and very challenging to students (Mulhall & Gunstone, 2008). The proponents of the theory believed that there are only few students who can understand physics and that the rest should study other subjects. A recent qualitative study of ten volunteer secondary school physics teachers in Australia concluded that "most teachers did not appear to have given much thought to the nature of physics or physics knowledge nor the role of mathematics in physics" (Mulhall & Gunstone, 2008, p. 435). In other words, teachers ignored some of the criteria to be included in the physics curriculum as mentioned earlier in paragraph 1.1. They just teach students to get the correct answer mathematically and forget about building students' conceptual understanding. A study on physics classroom engagement by Dewey and Dykstra (2008) concluded that a teaching based on the folk theory failed in engaging students to develop new understanding and they suggested new alternative models of instruction, which are student understanding-driven. Dewey and Dykstra (2008) further suggested that teachers should change the way they used to teach and make use of new models of instructions that engage students in constructing their own knowledge in order to enhance the students' conceptual understanding in physics.

1.4 Aims of the study

The aim of this study was firstly to determine the combined impact of two interactive-engagement models of instruction, namely Whole Class Discussions (WCD) and Computer Simulations (CS) on students' conceptual understanding of Newtonian mechanics. The second aim was to establish the impact of these models on first year student teachers' epistemological beliefs about physics. The study was guided by the following research questions:

(a) Do Whole Class Discussions (WCD) and Computer Simulations (CS) as interactive-engagement models of instruction have an impact on first year physics student-teachers' conceptual understanding of Newtonian mechanics?

(b) Do Whole Class Discussions (WCD) and Computer Simulations (CS) as interactive-engagement models of instructions change first year physics student-teachers' epistemological beliefs about physics?

1.5 Rationale for the study

The poor performance of students in mechanics is common world-wide (Henderson, 2002). The teaching of Newtonian mechanics is regarded as the most extreme example of the failure of the teaching of physics at high schools and the beginning college level (Hake, 1987). The failure is accredited to traditional models of instruction which are reported to fail in enhancing and building students' understanding of Newtonian Mechanics (Hake, 1998, 2002), in helping them apply concepts learnt in class in different contexts (Steinberg & Sabella, 1997) and developing students' ability to reason critically (Osborne, 2007). Traditional models of instruction have failed because they are only used for teaching quantitative problems at the expense of building students' conceptual understanding (Mulhall & Gunstone, 2008).

Interactive-engagement models are reported to be superior in promoting students' conceptual understanding of physics, (Savander-Ranne & Kolari, 2003; Cahyadi, 2004), enhancing students' confidence and beliefs (Kolari, Savander-Ranne & Tiili, 2004) and on reducing misconceptions students have (Cahyadi, 2004). The importance of promoting students' conceptual understanding is also regarded as one of the components that constitute the goal of physics education (Osborne, 2007). The other three components that form the primary goal of any science education as mentioned were the following:

(a) The cognitive which attempts to develop students' ability to reason critically in a scientific manner.

(b) Ideas about science which is an attempt to develop students' understanding of both epistemic (how we know what we know) and processes, values and implications of scientific knowledge.

(c) The social and affective which attempts to develop student's ability to work collaboratively and to offer engaging and stimulating experiences (Osborne, 2007, p. 177).

For these goals to be achieved, Wieman & Perkins (2005) voiced out the need to change physics education to make it effective and relevant for the majority of the student population. In order to make these changes, the training of teachers was identified as the starting point (Masood, 2007). Teachers in the field and those that are currently being prepared should be equipped with skills, knowledge and relevant approaches that are reported to be effective in enhancing students' conceptual understanding in physics. Based on the attempt to meet primary goals of science education as advocated by Osborne (2007), and criteria for any physics curriculum advocated by Mbajiorgu and Reid (2006), the study assumed that interactive engagement models (WCD and CS) would impact positively on students' conceptual understanding of Newtonian mechanics which during the process would improve students' epistemological beliefs about physics towards a sophisticated expert-like approach.

1.6 Context of the study

The study was conducted in the four year B.Ed (FET): Natural Science Programme in the Bloemfontein campus of the Central University of Technology offered in the School of Teacher Education. Students enrolled in the program are trained to be natural science educators specialising in at least two majors selected from the subjects Mathematics, Physics, Chemistry and/or Biology. Most of the students registered in the School of Teacher Education are from the surrounding areas and mainly comprise learners from historically disadvantaged communities like Botshabelo and Thabanchu. The majority of the students come to the programme as a last resort after being rejected by other schools or are attracted to the school by the Department of Education's Funza Lushaka bursary scheme.

All students registered for physics study mathematics. The Physics lecturer is responsible for lecturing Physics I, II and III and Mathematics I. There were 4 double periods per week where one double period is for laboratory work, another one for tutorials and the rest for teaching. There is no laboratory technician and the laboratory is not fully equipped as it was started 4 years ago. All 76 students were taught in one class. Students were divided into two groups when doing Computer Simulations since the Computer lab could only accommodate 45 students at a time.

1.7 Operational definitions of terms

The following operational definitions are applicable to the study:

Computer simulations: This is a computer program that attempts to simulate an abstract model of a particular system in physics.

Epistemology: In the study, it was operationally defined as the beliefs about knowledge and knowing (Hofer, 2006).

Traditional models of instruction*:* In the study, Hake's (1998) definition of traditional models was adopted. According to Hake (1998), traditional models of instruction are those models that make little or no use of interactive engagement models and rely primarily on passive-student lectures, recipe labs, and algorithmic-problem exams.

Interactive engagement models of instruction: In the study, Hake's (1998) definition of interactive-engagement models was adopted. According to Hake (1998), Interactive-engagement models are those designed to promote conceptual understanding through interactive engagement of students using heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors.

1.8 Brief chapter overviews

Chapter One

This is an introductory chapter which describes the statement of the problem, the aim of the study, the research questions, rationale for the study, context of the study, and lastly the operational definitions of terms commonly used.

Chapter Two

This chapter gives a summary of the literature review regarded as a barrier to the teaching and learning for conceptual understanding of physics. The topics described are misconceptions, language of learning and teaching, epistemological beliefs, traditional models of instruction, whole class discussions and computer simulations.

Chapter Three

The chapter focuses on the research methods used in the study including the research design, the sample selection, data collection instruments and procedures, data analysis methods and other ethical issues.

Chapter Four

The chapter presents the analysis and discussions of pre-intervention results and the conclusion reached.

Chapter Five

The chapter gives the details of the activities done as interventions.

Chapter Six

The chapter presents an analysis and discussions of results based on the research questions.

Chapter Seven

The chapter gives a summary of the study including the findings of the study, conclusions reached, implications of the study, limitations and suggestions for further studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In the previous chapter the rationale of the study was discussed and the two research questions that guided the study were identified. In this chapter, overviews of the following factors that have an impact in the teaching and learning for conceptual understanding in physics are discussed:

- The language of learning and teaching physics.
- Students' perceptive knowledge and misconceptions.
- Students' epistemological beliefs.
- Models of instruction.

Finally a summary of the chapter is given.

2.2 The language of learning and teaching science

South Africa is a multilingual country that mostly uses English as the language of instruction for teaching and learning in physics. Like in Botswana, English is recognized for both economic and political reasons (Prophet & Badebe, 2006). Since South Africa has 11 different official languages which include English, English is a second language for the students and poses a barrier in the learning and teaching of physics. The barrier is widened by the difference between scientific or technical English and common English usage (Muwanga-Zake, 2001). The language barrier could account for the difficulty that learners and teachers find in science. Farrel and Ventura (1998) established that the understanding of words could have a direct bearing on the students' performance in science. For example, a slight alteration of a question could bring an improvement in performance and the conceptual understanding of physics concepts. In their study, for example, Farrel and Ventura (1998) replaced "*pungent smell*" with "*choking smell*" in a question and the correct percentages of responses increased from 80% to 95% after the replacement. Figure 2.1 represents statistics of the claimed knowledge of physics words versus actual knowledge of physics words adapted from Farrel and Ventura (1998). Similar findings were also confirmed by Prophet and Badebe (2006) when certain words were replaced in examinations.

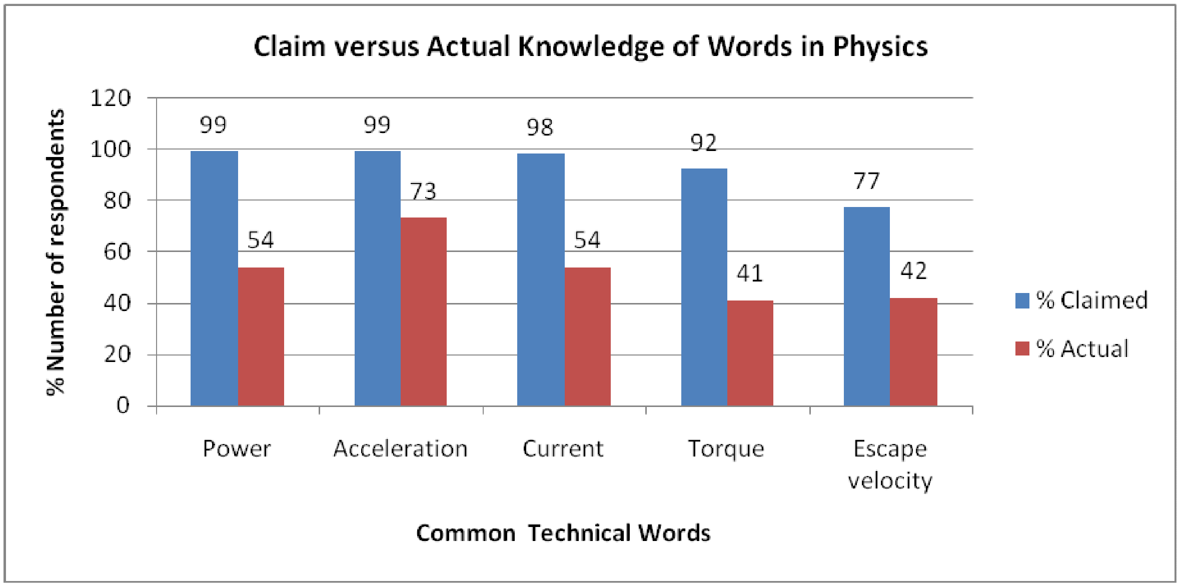


Figure 2.1: Comprehension of some of the common technical words adapted from Table 1 Farrel & Ventura (1998, p.249)

It follows from those findings that people generally claim to know some of the words they actually do not know due to the fact that in a scientific context, words have more exact meanings than in everyday situations (Farrel & Ventura, 1998). Farrel and Ventura (1998) further advised science teachers to be sensitive to their students' understanding of ordinary words, and also to take action to overcome potential misunderstandings due to language. Physics as a subject uses English words from everyday language in a precise way, for example words like power and work have different meanings in physics and spoken English, and therefore the carryover of everyday language into physics is confusing (Mbajiorgu & Reid, 2006).

The low correlation between the 'claimed' and 'actual' percentages as shown in figure 2.1 implies that teachers should take precautionary measure in their planning to prevent similar problems and also highlighted the importance of understanding words within a contextual setting. The language of science presents difficulties to both mother tongue and second language speakers, but second language speakers are said to be more negatively affected (Prophet & Badebe, 2006). Knowledge of the effect of language on conceptual understanding of science from the literature paved the way in planning for successful Whole Class Discussion activities during this study.

2.3 Students' perceptive knowledge and misconceptions

Sherin (2006) defines knowledge that is gained prior to formal instruction as perceptive beliefs or commonsense knowledge. It is called perceptive beliefs or prior-knowledge because it is based on earlier beliefs and assumptions which are sometimes inaccurate or erroneous (Kolari & Savender-Ranne, 2000). It was found that perceptive beliefs about motion are contradictory to the Newtonian theory of mechanics and are also stable in such a way that traditional physics instruction does little to change them (Halloun & Hestenes, 1985). If perceptive knowledge is restructured, it automatically forms a component of expertise (Sherin, 2006). Perceptive beliefs or prior- knowledge which is not compatible with the accepted view of science has different names like misconceptions, alternative conceptions or commonsense knowledge. The term misconception is adopted in the study. Misconceptions must be addressed as they pose an obstacle to the acquisitions of expert knowledge. Misconceptions like any other errors students make are good indicators of how students believe and understand the concepts. What students believe about the concept at that moment is regarded as the only focus where changes desired by the teachers may begin (Von Glasersfeld, 1992). To link what students should learn with their personal experiences can be a challenging task (Liljedahl, 2002) that needs professional strategies in line with the constructivist approach. The constructivist approach takes into consideration the role of students' pre-knowledge in their constructions of new understanding. In addition to the use of professional strategies derived from the constructivist theory of teaching and learning, Beeth and Hennessey (1996) emphasized that student's ideas in their current form must be taken seriously and must be treated equally with the ideas of teachers, researchers and all other scientific communities to facilitate the process of learning.

A diagnosis of a learner's perceptive or pre-knowledge is important for teachers in order to plan consequent teaching activities and help students to link new material to what they already know (Cimer, 2007). A teacher's awareness and ability to cope with learner's misconceptions and preconceptions are of crucial significance in linking what is known by learners to what is known by the teacher. After determining students' misconceptions and making them aware of their misconceptions, teachers need to introduce scientific concepts using conceptual change strategies to help them to construct new knowledge. Hewson and Thorley (1989) identified four conditions necessary for conceptual change, namely, the conception must be intelligible, plausible, fruitful and must cause dissatisfaction to the learner about their current conception to enable change. Conceptual change conditions can be integrated in different strategies, for example, Grayson (1996) used concept substitution as a strategy for promoting conceptual change in electricity. The concept substitution strategy is used in situations where "students appear to have a correct intuition associated with inappropriate physics term" (Grayson, 1998, p.152). The knowledge of the impact of the misconceptions and the conceptual change strategies were used in the study when designing and selecting WCD and CS simulations activities.

2.4 Students' epistemological beliefs

The beliefs about knowledge and knowing which Hofer (2006) called the epistemological beliefs can be divided into two categories; personal and public epistemological beliefs (Stathopoulou & Vosniadou, 2007). Personal epistemological beliefs are considered to be the beliefs individuals hold about the nature of knowledge and the process of knowing (Stathopoulou & Vosniadou, 2007) which is in this study, referred to as students' epistemological beliefs. Public epistemology on the other hand includes students' beliefs about the nature of knowledge and knowing which also include the nature of knowing and knowledge shared by the community at large or specific disciplinary community (Lising & Elby, 2005). Both personal and public epistemological beliefs have an impact on the teaching and learning of physics.

Many students have misconceptions about the nature of physics (Redish, Saul, & Steinberg, 1998). Redish (2003) further concluded that each student brings a set of attitudes, beliefs, and assumptions about what sorts of things they will learn, what skills will be required, and what they will be expected to do in the physics class. Dewey and Dykstra (2008; p.1) commented that “the different practice of physics teaching rests on the different explanation of the nature and the origin of knowledge and different relationship between the knower and this knowledge”. Students’ responses usually depend on their expectations, and their expectations affect them in selecting activities that will help in the construction of their knowledge base and their own understanding of the subject (Elby, 2001). In other words, students’ view of the nature of scientific information affects how they interpret what they hear and see.

In South Africa, like other countries around the world there is a prevailing traditional belief in the folk theory of physics teaching (see section 1.3) which excludes the epistemological beliefs of students. The understanding of students’ epistemological beliefs is important to physics teachers as it may affect physics learning and also inform strategies that foster productive attitudes and epistemologies that help to improve conceptual understanding in physics (Lising & Elby, 2005).

The interesting findings in studies that investigated the correlation between students’ epistemological beliefs and learning outcomes was that students’ epistemological beliefs about science affect the teaching and learning of physics in complex ways (Hofer, 2006). The reasons being that epistemological beliefs differed in different disciplines (maths, physics etc), as well as according to judgement domains like personal taste, morale, meaning. Buehl (2005) indicated that students with more sophisticated beliefs had higher levels of motivation for task performance in mathematics and history. Buehl’s claim was corroborated in physics contexts by Lising and Elby the same year. Lising and Elby (2005) showed that physics students' learning is significantly related to their perceptions about the nature of physics, physics learning and knowledge. They further claimed that an epistemological intervention could lead to a better conceptual learning while Stathopoulou and Vosniadou (2007) showed that high epistemological sophisticated groups of students achieved deep understanding of Newtonian dynamics as compared to those with less sophisticated epistemological beliefs.

The literature above revealed the importance of students' epistemological beliefs and its effect on the teaching and learning of physics. The next question could be how to measure epistemological beliefs? At this stage, many epistemological beliefs instruments have been constructed for different purposes. For example, the Epistemological Questionnaire (EQ) was developed by Schommer in 1990 to measure students' epistemological beliefs on four distinct and independent dimensions: simple knowledge; certain knowledge; fixed ability; and quick learning (Paulsen & Feldman, 2005), the Maryland Physics Expectations (MPEX) Survey was developed at The University of Maryland with the aim to probe student's expectations and beliefs (Redish, Saul, & Steinberg, 1998) the Views About Science Survey (VASS) developed by Halloun and Hestenes (1998) at Arizona State University, probes a combination of students' epistemological beliefs and their course-specific expectations as well as their study habits. Another instrument namely, the Epistemological beliefs about physical science (EBAPS), a forced-choice instrument designed to probe students' epistemologies, their views about the nature of knowledge and learning in the physical sciences (Redish, 2003) was initially developed by Andrew Elby and his colleagues at the University of California (Elby, 1999). The epistemic beliefs inventory (EBI) was constructed as a modification of the EQ by Schraw, Bendixen, and Dunkle (2002). Some of the critics of the EBAPS like Stathopoulou and Vosniadou (2007) constructed a new instrument called Greek Epistemological Beliefs Evaluation for Physics (GEBEP) which is context dependent and physics subject specific.

Not all instruments can directly measure the epistemological beliefs of physics students. For example, EQ and EBI are regarded as general and not science specific whereas MPEX, VASS and GEBEP are instruments which are related to science in general, with GEBEP having been specifically designed for physics students. According to Stathopoulou and Vosniadou (2007, p. 257) GEBEP represents an advancement over existing quantitative measures like MPEX, EBAPS and VASS because:

(a) it is domain specific, as it measures only physics-related epistemological beliefs,
(b) it focuses on the core dimensions of epistemological beliefs leaving out beliefs about learning and intelligence and
(c) it represents a beginning attempt to capture some of the implicit, context dependent aspects of a personal epistemology through the inclusion of debated items.

Since the GEBEP is still new, it needs to be subjected to strict tests to verify the claims mentioned above by its creators. Based on the literature of epistemological beliefs, the question that one can ask could be "Which models of instruction can be used for epistemological interventions to enhance the conceptual understanding of physics?"

2.5 Models of Instruction.

2.5.1 Background.

The models of instruction were categorized into traditional and interactive-engagement models based on their compliance to behaviourist and constructivist theories of teaching and learning (Snow, 2003). Behaviourist theory views knowledge as a deliverable quantity that can be easily transferred from a teacher to a passive student (Snow, 2003). The models of instruction that are aligned with behaviourism theory are referred to as traditional models of instruction. Contrary to behaviourism, constructivism views knowledge as something that can be constructed by students themselves when interacting with others and the world around them (Snow, 2003). The next section will deal with traditional models of instruction. Constructivism theory which is the backbone of interactive-engagement models will later be discussed in section 2.5.3.

2.5.2 Traditional models of instruction

Traditional models of instruction, can in simple terms, be defined as all models of instruction that do not involve students. In other words, the models are teacher-centred approaches where the instructor is the only information-giver to students in class (Hanley, 1994; Cimer, 2007). Traditional models rely primarily on passive-student lectures, recipe labs and algorithm-problem exams (Hake 2002). During lectures or presentations of the lessons, students are not required to engage intellectually with the presented ideas. The sitting arrangement of the traditional models is usually in a pattern shown in Figure 2.2 and the teacher sits or stands in front of students and dictates terms while the students obey instruction.

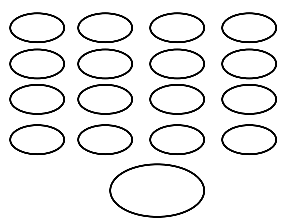


Figure 2.2: Arrangement of students in traditional models

Traditional models of instruction seem to be more advantageous to teachers than students. For example, when traditional models of instruction are used, teachers are highly respected as the authority and sources of knowledge and students may be reluctant to raise questions as doing this is considered to be a sign of disrespect (Lee & Avalos, 2002). Since traditional models are teacher-centered, large amounts of material can be covered, but with little or no understanding on the side of learners (Kolari & Savender-Ranne, 2000). Students end up doing everything the teacher says without even questioning it. This happens because teachers do not model how to construct expert-like processes of solving or attempting to solve problems (Saul, 1998). Again, it was reported that traditional physics instruction seems to promote memorization of facts rather than conceptual understanding of the subject and students tend to develop a formula-centered problem solving strategy or see the selection of the correct formula as the key to problem solving. In other words, their problem solving strategy follows the route of selecting the correct equation, then plugging the given numbers into the equation and finally getting the correct answer. The plugging of numbers into a formula does not help enhance student understanding in physics. In the same vein, Sherin (2006) established that students could solve many quantitative problems using formulas in introductory physics but are unable to answer some basic qualitative questions. Bernhard (n.d.) also found that top students with high scores on quantitative problems had very low scores on the conceptual part when the traditional method of instruction is used. McDermott (1993) claimed that some of the conceptual difficulties that lack a coherent conceptual framework the students bring to an introductory physics class cannot be developed using traditional models of instruction.

On a positive note, traditional lectures offer an opportunity to motivate and inspire students (Redish, 2003). Redish (2003) further cautioned instructors not to make an oversight of assuming that students will comprehend whatever is written on the board. Interestingly, the traditional models of instruction are used and are still going to be used because of their cost effectiveness and the fact that they have been used for a long time (Saul, 1998). Saul (1998) further noted that many university instructors were taught using traditional lecturer methods and they still want to teach the way they were taught. Another reason given by Snow (2003) was that some instructors are unaware of the results of ongoing Physics Education Research that focuses on interactive-engagement models.

2.5.3 Constructivist models of instruction

Constructivism theory presupposes that the role of a student is to be an active participant when teaching and learning is taking place (Atherton, 2009). When the constructivism theory is used in the a teaching and learning process , students' pre-instructional conceptions are taken into consideration (Duit & Confrey, 1996) and learning is viewed as a conceptual change using practical activities which challenges learners' current conceptions leading to a reorganization of their cognitive structures (Garnett & Hackling, 1995) during a process called cognitive conflict. The conflict can be created by asking students' predictions and then contrasting these with experimental results, contrasting the ideas of the students with the experimental results, contrasting the ideas of students and those of the teacher and by contrasting the beliefs among students (Duit & Confrey, 1996). All the models of instruction that aligned with the constructivism theory are referred to as interactive-engagement models in this study.

Both WCD and CS that will be discussed in paragraphs 2.5.3.1 and 2.5.3.2 are grounded by Constructivism theory because, during WCD and CS activities, students actively participate in the construction of their own learning. Interactive-engagement models of instruction are interactive in nature and hence the name interactive-engagement models (Matthews, 1994). Interactive Engagement (IE) models of instruction were defined as "those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors" (Hake, 1998, p. 65). The sitting arrangement in the interactive-engagement instructional settings differs from that of traditional models. The sitting arrangement in the interactive engagement class keeps on changing depending on how the instructor wants students to be engaged. In other words, there is no fixed pattern in terms of sitting arrangements.

Different varieties of interactive-engagement models have the following common characteristics: contextual, dialectical, empirical, methodological, pragmatic etc

(Mathews, 1994). An interactive-engagement class is usually achieved by questioning students or challenging them to think or to do something that requires thought. This is normally the starting point. During the process of interactive-engagement, students interact with one another, with the teacher or a computer. Interactive models are based on the assumption that learning takes place as the result of the learners' own activities. The two interactive-engagement models used in the present study were Whole Class Discussions and Computer Simulations. The literature on constructivism theory guided the study when formulating WCD and CS activities.

2.5.3.1 Whole Class Discussions

Ybarra (n.d.) defines whole class discussion as "the synthesis of the ideas generated individually or during small groups with the aim of helping students to make connections and apply these ideas to other relevant contexts". Jones and Tanner (n.d) argued that the quality of whole class discussions depends on the type of scaffolding used, the opportunities created for reflection and the degree of students' ownership. Managing whole class discussions is regarded as a complex activity. It needs dynamic teachers to encourage students to participate, while discouraging few individuals from dominating the discussions. An environment should be created where students need to feel comfortable asking genuine questions and make challenging the controversial comments when they disagree with the teacher.

Advantages of WCD

As WCD is one of the models derived from constructivism, there are many advantages associated with this model. For example, Grouws and Cebulla (2002) argued that WCD is effective when used for sharing and explaining a variety of solutions by which individual students have solved problems. As students address challenges to their methods, they strengthen their understanding of concepts and procedures. Students resolve differences in thinking or confusions in reasoning by working together. According to Snow (2003), the WCD model involve students all the time because they are obligated to wait to be nominated to speak, to respond when questioned and to have their talk evaluated by others. Grouws and Cebulla (2002) claimed that WCD can be an effective tool for assessing the depth of understanding concepts and to identify the misconceptions students have. WCD create an environment that is conducive to social interaction between the students and the teacher that promotes meaningful learning. In Whole Class Discussions, students are given few minutes to solve their problems individually or in small groups and then share their solutions with the whole class (Wood, Cobb & Yackel, 1993).

Hatano and Inagaki (1991) argued that WCD provides good opportunities for students to actively engage themselves and construct their own knowledge because they are supported by social motivation factors. Since knowledge is a social construct, students' learning is evidenced by the ability to engage in appropriate discourse. Salient students are often involved in a whole class discussion because participants sometimes nominate peers whose ideas they agree with and can learn through these peers' utterances (Hatano & Inagaki, 1991; McGraw, 2002).

Disadvantages of WCD

Like other models, WCD is not free from drawbacks. The model is problematic when used for large groups of students. Inagaki, Hatano and Morita (1998) argued that in large groups, many students remain silent and may lose interest in the discourse and fail to learn.

Again Scott, Asoko and Driver (1992) commented that if the view of science teaching and learning by students is different from that of the teacher, a barrier to teaching and learning can be created. For example, if the students' view is transmissive, they will not participate and they can only wait for the teacher to give them solutions because they do not see any reason to search or look for an answer if the teacher knows the answer. They will only expect the teacher to give them the correct answers so that they can reproduce them in tests and examinations. Lastly, due to the diversity of a class, some students could be afraid to participate because of language barriers and their epistemological beliefs that lead them to avoid engaging in arguments (Nussbaum & Bendixen, 2003).

2.5.3.2 Computer Simulations

Computer Simulations (CS) are programmes used in physics to model the behaviour of a physical system and allow students to explore and visualize graphic representations (Concari, Giorgi, & Giacosa, 2006). Before the introduction of simulations in the teaching and learning of physics, computer applications were only used to facilitate various tasks like data acquisition, provision of real-time data display and in analysis of data (Finkelstein, Adams, Keller, Podolefsky, & LeMaster, 2005).

Many students who wanted to study physics using distance education before the computer simulation and internet era, were unable to do so because of the lack laboratory facilities as doing practical work was one of the minimum requirements (Sahin, 2006). These problems have been solved by the use of computer simulation programmes most of which are freely downloadable from different websites (Nancheva & Stoyanov, 2005).

Computer Simulations offer students a unique opportunity of experiencing and exploring a broad range of environments within the walls of the classrooms. Students can observe and manipulate normally inaccessible objects, variables and processes in real time. Choi and Parker (2003) claimed that computer simulations make experiments which are difficult to carry out in the laboratory possible due to the complexity of the equipment.

There is still an argument among researchers over the specific position of computer simulations. This relates to the question of whether it has to be used in conjunction with real traditional labs or as a substitute for real lab or not. In terms of using CS as a substitute for the laboratories, studies are still being conducted and presently, Finkelstein et al*.,* (2005) argued that they can be used as a substitute for real hands-on laboratory whereas Concari, Giorgi, and Giacosa (2006) argued that computer simulations are not substitutes for real laboratory experiences, but can provide powerful supplements that help students to visualise physics because when using simulations, complex motion can be clearly demonstrated. Concari, Giorgi and Giacosa (2006) concluded that integrating the pen and pencil problem solving method, free simulations and lab work make didactical resources of great potential for students who are not conscious of the modelling they use or the validity and scope of their model.

Advantages of CS

Computer Simulations can help in solving relative open problems which are practically impossible to solve through real experiments (Concari, Giorgi, and Giacosa, 2006). For example, the research which is currently in progress on tracing exactly what happens immediately before the Big Bang can be only be done using simulations because the Big Bang happened many years ago.

When working with simulations, students can interact with the system, modifying its state, changing parameters and observing the results of manipulations (Concari, et al., 2006). The changing of parameters can sometimes yield unexpected useful results. At the same time, simulations can be good in improving students' hypothesis constructions and prediction skills (Sahin, 2006).

Computer simulations programmes can increase students' interest and motivation for learning science and can challenge their fantasy and curiosity (Choi &Park, 2003). They also generate a high level of engagement, exploration and understanding among students of diverse backgrounds and ages (Perkins & Wienman, 2006).

Disadvantages of CS

Computer simulations have all the disadvantages related to the use of a computer. For example, advocates of hands-on experiences in laboratory see simulations as potentially harmful to students because they claimed that CS lack pedagogical characteristics and real touch of the physical apparatus (Corter, Nickerson, Esche, Chassapis, Im, & Ma, 2007). Touching the real physical apparatus was regarded as important learning opportunities. They further claimed that up to date, there have been no large randomised studies which examined how these technologies might affect learning outcomes. The use of computer simulations requires more preparation time on the side of the instructors and technicians. Instructors and technicians have to make sure that all simulations in each computer are working properly before students use them. Another disadvantage is when online simulations are used; they sometimes take a while to process the information or cannot connect when the host website has problems.

2.6 Summary of the chapter

The chapter started by focusing on the language of learning and teaching which seems to create a barrier to the teaching and learning of physics (section 2.2). In addition to the language problems, are the misconceptions (section 2.3) and students' beliefs about the nature of physics and how they think it should be taught (section 2.4). It was reported that what students believe affect how they respond to a question (Elby, 2001). The two constructivist models of instruction (section 2.5) used in this study for the teaching and learning of physics were discussed. An attempt was made to look at their advantages and disadvantages in enhancing students' conceptual understanding in physics.

CHAPTER 3 RESEARCH METHODS AND PROCEDURES

3.1 Introduction

In the previous chapter a review of literatures was discussed. The literature reviewed guided this study in selecting the research design and, in adapting the Interactive Conceptual Instruction (ICI) model to form the Integrated-Interactive Conceptual Instruction (IICI) model.

This chapter focuses on the descriptions of methods and procedures used in the study. These include the research design, the sample, the instruments used for data collection, teaching approach, procedures and the statistical techniques used in the data analysis. Finally the validity and reliability of the instruments used and ethical issues considered are explained.

3.2 The research design

The importance of knowing pre-instructional knowledge (section 2.3), beliefs (section 2.4) and how students learn in terms of constructivism theory (section 2.5), guided this study to adopt mixed methods designs, namely, One-Group Pretest-Posttest design , CS survey and Interview questionnaires. The Pretest-Posttest design was used because the aim of the study was to evaluate the impact of the models of instruction (Raffeld & Reynolds, 1977) by comparing groups with an aim of measuring change (Dimitrov & Rumrill, 2003). In order to measure change in conceptual understanding of Newtonian mechanics and in their epistemological beliefs about physics, the participants were tested before and after interventions by WCD and CS (Bless & Higson-Smith, 1995). CS survey and interview questionnaire were used to triangulate the results from pre-test and post-test.

3.3 The sample and participants in study

From a population of all first year B.Ed. FET: Natural Sciences' students registered for the 2008 academic year in the School of Teacher Education at CUT in Bloemfontein , a convenient sample of only first year physics education students were used as the participants in the study. The participants use English as their second language. They were 76 in total, but only 48 were considered for the FCI and EBAPS data collection because they wrote both the pre and post tests. The remaining students were either not present at the time when the pre or post tests were written. In computer simulations questionnaire, students who were present in class were considered for the collection and analysis of the data. For example, all students who returned the Computer Simulations questionnaire that were distributed among them were considered. A sample of students interviewed was randomly selected from those who participated in both FCI and EBAPS tests using Moonstats statistical software program.

3.4 Instruments used for data collection

Four instruments were used for data collections. Due to the difficulty involved in developing new instruments and the considerable amount of time and skill needed (Fraenkel & Wallen, 2003), it was convenient for the researcher in this study to use two already developed and improved instruments and two newly constructed instruments. The FCI and the EBAPS were already developed and improved while the CS survey and an interview questionnaire were newly constructed. In this study, the Force Concept Inventory (FCI) and Epistemological Beliefs About Physical Science (EBAPS) instruments were used as main data collection instruments, whereas the structured interview and computer simulation questionnaires were newly constructed by the researcher. The next thing after acquiring or developing an instrument is to confirm its validity and reliability which will be discussed later (see paragraphs 3.4.1.3, 3.4.1.4 and 3.4.2.3).

3.4.1 Force Concept Inventory

The Force Concept Inventory (FCI) is composed of 30 multiple choice questions based on Newtonian mechanics. The instrument was designed to probe students' beliefs and how these beliefs are compared with Newtonian Concepts (Hestenes, Wells & Swackhamer, 1992). The FCI is regarded as one of the most carefully researched tools to probe student conceptual learning in Newtonian mechanics (Steinberg & Sabella, 1997). It compels students to make a choice between common sense beliefs and the Newtonian counterpart (Hestenes, Wells, & Swackhamer, 1992). They further contend that the instrument divides the force concept into six conceptual dimensions which are dependent on one another e.g. Kinematics, Newton's first, second and third laws, superposition principles and different types of forces. Since its publication in The Physics Teacher Journal in March 1992, it has played a major role in the development of curriculum and instructional strategies (Steinberg & Sabella, 1997). The FCI can help the teacher to analyse the students' thinking based on the misconceptions they have. It also " provides a potent tool not only for improving student learning but also for improving teachers understanding and approaches to teaching" (Savinainen & Scott, 2002, p. 52). The FCI assesses a student's overall grasp of the Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992). The instrument is reported to be less affected by context. A study recently conducted by Stewart, Griffin and Stewart (2007) on the contextual effect of the FCI concluded that low FCI scores in traditional instruction cannot be attributed to context. They further claimed that the FCI is a good estimate of the actual state of students' knowledge of Newtonian mechanics. The following is an example of an FCI question (item no 1):

Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single 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 as for the lighter one.

(B) about half as long for the lighter ball as for the heavier one.

(C) about the same 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.

3.4.1.1 Some of the reported uses of the FCI

The instrument is usually used for the evaluation of instruction and as a diagnostic tool to identify and classify misconceptions (Hestenes, Wells & Swackhamer, 1992). However, Hake (2007; p. 25) noted two major advantages of using FCI tests, namely:

(a) Its multiple-choice formats facilitate a relatively easy administration of the tests to thousands of students;
(b) The questions probed for conceptual understanding of the basic concepts in Newtonian mechanics are presented in a way that is understandable to the novice who has never taken a physics course.

In addition to the advantages mentioned above, Savinainen and Scott (2002) claimed that the instrument can be used as a tool to monitor student learning and to plan teaching while Savinainen and Viiri (2008) showed that it can be used as a measure of students' conceptual coherence.

3.4.1.2 Disadvantages of FCI

The instrument is said to be difficult to interpret and tend to overestimate students' learning due to its multiple choice format because sometimes students can guess the correct answer (Redish, 2003). Huffman and Heller (as cited by Savinainen & Viiri, 2006, p. 719) claimed that the FCI measures only bits and pieces of students' knowledge basing their argument on their results of factor analysis. The claim was disputed by Hestenes and Halloun (1995) as baseless because they said Huffman and Heller disregarded relevant analysis of published papers and advice on using the FCI.

3.4.1.3 The validity of the FCI test

The FCI questions were validated through interviews of about 1500 students from ninth grade to graduate level (Rebello & Zollman, 2004).The test was also examined by a number of physics professors and graduate students (Savinainen & Scott, 2002).

3.4.1.4 The reliability the FCI test

The reliability of the FCI was established by interviewing a sample of students who took tests and by statistical analysis of the test results. Its Kuder-Richardson reliability coefficient was found to be 0.86 for the pre test and 0.89 for the post test (Savinainen & Scott, 2002). Based on the fact that it was administered world-wide and consistent results under different contexts were obtained, it was no longer necessary to conduct reliability and validity tests of the instrument.

The instrument was chosen because it was reported to be good in identifying and classifying the misconceptions students have, to evaluate the effectiveness of the instruction and lastly was regarded as one of the most widely used instruments in physics education (Hestenes & Halloun, 1995). The slightly modified version of the FCI by Dick Hake, Ibrahim Halloun and Eugene Mosca in 1995 was used in the study. The version was used because it was the latest updated version which took into consideration some of the comments and suggestions made on earlier versions (Redish, 2003).

3.4.2 Epistemological Beliefs about Physical Science (EBAPS)

Like the FCI, the Epistemological Beliefs About Physical Science is also a 30 items multiple-choice instrument designed to assess students' epistemologies; their views about the nature of knowledge and learning in the physical sciences (Redish, 2003). The instrument was developed and validated by Andrew Elby (University of Maryland), John Frederickson (University of California – Berkeley), Christina Schwarz (Michigan State University) and

Barbara White (University of California – Berkeley) after an extensive literature reviews on epistemology research (Redish, 2003). EBAPS probes students' views along five dimensions; the structure of scientific knowledge, the nature of knowing and learning, real-life applicability, evolving knowledge and the source of the ability to learn (Redish, 2003).

Each item on the instrument is scored from 0 to 4 where 0 represents least sophisticated beliefs and 4 the most sophisticated expert-like beliefs. The scoring of EBAPS is non-linear and takes into account question by question variations. The subscale score is taken as the average of the scores on each item under that subscale. The instrument has three different item types; likert-scale (agree/disagree) items; multiple choice items and debate items. An example of one of the debate questions (item no 24) in EBAPS is the following:

Justin: When I'm learning science concepts for a test, I like to put things in my own words, so that they make sense to me.

Dave: But putting things in your own words doesn't help you learn. The textbook was written by people who know science really well. You should learn things the way the textbook presents them.

(a) I agree almost entirely with Justin.
(b) Although I agree more with Justin, I think Dave makes some good points.
(c) I agree (or disagree) equally with Justin and Dave.
(d) Although I agree more with Dave, I think Justin makes some good points.
(e) I agree almost entirely with Dave.

In the present study, EBAPS was used because of the fact that the instrument is widely used and was also intended to be used for High Schools, Colleges or Universities students taking introductory physics, chemistry or physical science.

3.4.2.1 Advantages of using EBAPS survey

Elby (2001) noted the following advantages of using the EBAPS:

(a) It targets both high school level science classes and introductory physics students at colleges or universities which often involves less mathematics.

(b) The question items combine both multiple-choice and mini-debate questions

(c) It probes both students' epistemological beliefs about knowledge and their expectations about physics.

3.4.2.2 Disadvantages of EBAPS survey

Problems associated with EBAPS available at EBAPS website include the following:

(a) Separating epistemology apart from expectations
(b) Testing beliefs apart from goals and
(c) Inferring students' sophistication based on agreement with experts.

3.4.2.3 Validity of EBAPS

The instrument was validated through its revision based on pilot participants and informal feedback from community college students. In this study, no further validity tests were necessary since the instrument is used internationally.

3.5 Computer Simulations Questionnaire

Different experts on the subject, such as a lecturer assistant who holds a PhD in physics from the neighbouring university and a Natural Science Programme Head (who was also a physics lecturer, also has a PhD) were requested the validate the questions on the questionnaire. The first draft of the questionnaire was constructed by the researcher. It was then given to other colleagues to check if it will serve the purpose it was intended for. After inputs and suggestions from the colleagues, the questionnaire was administered to third and second year students during the first term. Based on the analysis of the responses from the students, corrections were made and the corrected version was given to first year physics students after they have done the computer simulations (see Appendix A). It was clearly stated that the information received from the questionnaire will only be used for research purposes and that the students could complete and hand in the completed questionnaires when convenient to them on or before the due date. Some of the questions on the questionnaire probed if CS helped them to understand concepts they did not understand in class or whether CS further confused them. The last question was an open-ended question that required students to comment or share with the researcher their experiences or concerns regarding the use of CS in a physics class.

3.6 Whole Class Discussion and Computer Simulations Activities

The Whole Class Discussion and computer simulation questions selected were informed by research from PER and were regarded as indispensable for future understanding of other topics, such as questions that help students to differentiate amongst speed, velocity and acceleration. Samples of questions used in WCD and CS are the following:

Sample Question 1:

When throwing the object upwards, what happens to its acceleration on its way up, at the maximum height and on its way down?

Sample Question 2:

A person throws two stones from the top of a cliff. The stones have identical initial speeds, but stone 1 is thrown downward at some angle below the horizontal and stone 2 is thrown at the same angle above the horizontal. Neglecting air resistance, which stone strikes the water with greater velocity? Give reasons for your answer.

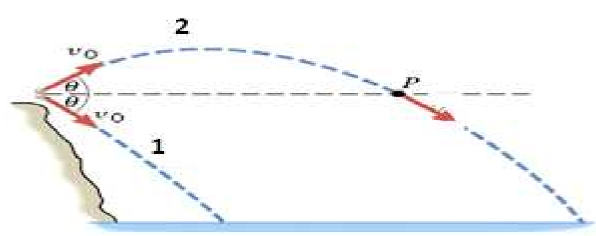


Fig 3.1: Two ways to throw a stone activity adapted from Cutnell and Johnson (2007)

Circle the correct option and then give reasons for choosing that option

A. Stone 1 will strike the water with greater velocity

B. Stone 2 will strike the water with greater velocity

C. Both stones will strike the water with the same velocity

3.7 Structured Interview Questions

Structured interviews were conducted to gain an in-depth understanding of the impact of whole class discussions and computer simulations on the conceptual understanding of Newtonian mechanics, epistemological beliefs about physics and the overall feelings about the students' preferred models of instruction. The interview questions were composed of two conceptual questions directly taken from FCI, two epistemological beliefs questions, also taken directly from EBAPS and another two questions. One of these questions probed their preferences between the two interactive-engagement models used while the other explored students' reasons for choosing physics as a subject.

3.8 The Teaching Approach: Interactive Conceptual Instruction and Integrated-Interactive Conceptual Instruction

The teaching approach in the study adapted the Interactive Conceptual Instruction (ICI) by Savinainen and Scott (2002) to form an Integrated-Interactive Conceptual Instruction Model (IICI). The ICI model aimed at developing students' conceptual understanding of the force concept in mechanics. It is composed of four components, namely: the conceptual focus, classroom interactions, research-based materials and the use of texts. According to Savinainen and Scott (2002b) the conceptual focus focuses on developing conceptual understanding, the second feature involves promoting different forms of *classroom interactions* and is based on the premise that meaning making is a dialogic process, the third feature involves use of *research-based materials* (e.g. Question-and-answer conceptual exercises designed by the teacher are used in the early stages of meaning making), and lastly involves the ways in which texts are used to promote understanding through reflection.

In the adapted IICI model, the last component (the use of text) in the ICI model was replaced by the component *mathematical description of concepts*. The mathematical description of concepts was included in order to show students the relationship between mathematics and physics. The components used in the adapted model as a path that enables active participation in class were the following:

- Conceptual focus
- Research-based materials
- Classroom interactions
- Mathematical descriptions of concepts

3.9 Explanation of the Integrated-Interactive Conceptual Instruction model (IICIM)

The IICI model, grounded by constructivism theory, is an integrated interactive approach used in the study to enhance conceptual understanding of Newtonian mechanics. It was used in the study with an aim of promoting students' interactive engagements during the process of teaching and learning physics using whole class discussions and computer simulation. The model consists of three parts and is illustrated in figure 3.2.

Part 1: *Conceptual focus stage*

Students write diagnostic pre-tests (FCI and EBAPS) before any instruction. In this study, FCI pre-test was written on the second day of class while the EBAPS was written on the third day. The lecturer selected research-based materials and /or the literature on the topic to be presented. Research-based concepts tests, questions, exercises or demonstrations were used to initiate classroom discussions in line with cognitive conflict strategies discussed in section 2.5.3. The topics selected were also informed by research and were regarded as indispensable for the future understanding of other topics. In this study, the conceptual focus mostly revolved around questions about speed, velocity and acceleration.

Part 2: Classroom-Interactions

The second stage involves the promotion of classroom interactions using different interactive-engagement models. Students' interaction is the key element of constructivist theory. In this study, classroom interaction was achieved using WCD and CS models. All stages one way or another overlapped with one another. For example, the conceptual focus can be determined and is dependent on research-based resources and classroom interactions envisaged. This stage focuses on the development of conceptual understanding by utilising the principle of concept first with little or no mathematics (Savinainen & Scott, 2002b). In other words, a concept is discussed through WCD or CS to gain conceptual more qualitative understanding of the concept under discussion. This stage deals with the qualitative description of the concept and only when students have a good grasp of the concept can that mathematical description be done as a summary of the concept taught. That was done to implement the suggestion by McDermott (1998). She suggested that students should have some practice in qualitative reasoning about the phenomena under study before mathematical formalization is introduced.

At this stage, the IICI model sometimes integrates three levels (macro, micro and representational) of concept representations in physics (Mbajiorgu & Reid, 2006).
The macro stage describes "what can be perceived by senses without the aid of the instruments" (Mbajiorgu & Reid, 2006, p. 3). The micro stage is said to relate with the abstract nature of physics where things can only be perceived with the aid of instruments or inferences. The symbolical represents the mathematical nature of physics where equations, models and symbols are used to represent a concept. The model integrated all these levels but one at a time to avoid information overload.

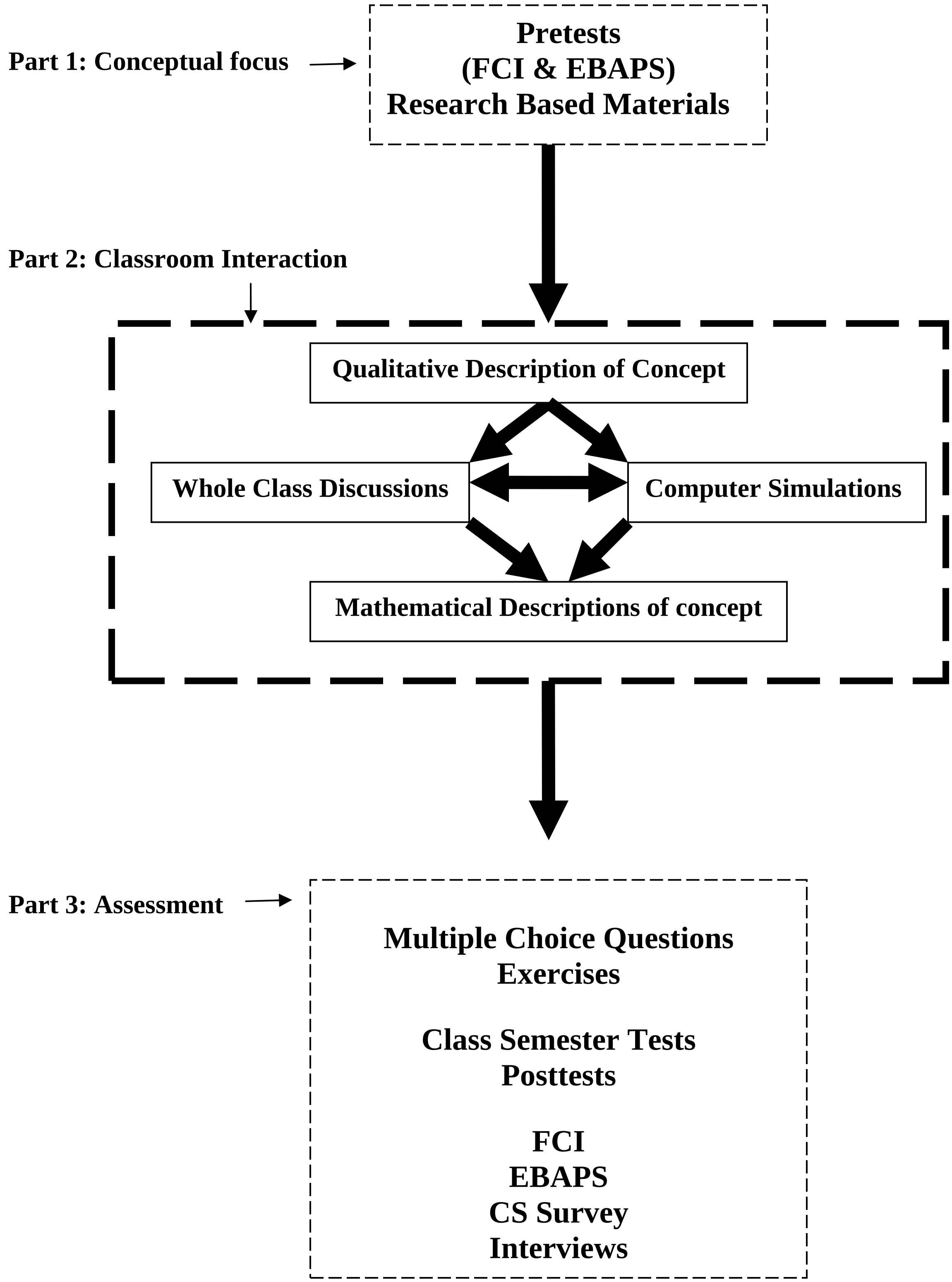


Figure 3.2: An Integrated-Interactive Conceptual Instruction Model (IICIM)

Part 3: Assessment stage

This stage deals with continuous and summative assessment. Students are assessed through class exercises which included multiple choice questions, semester tests, examinations and at the end of the intervention through post-tests.

3.10 Procedure for the application of Integrated-Interactive Conceptual Instruction model

The application of the IICI model was done using the following steps:

(a) Based on research, the lecturer selected suitable conceptual questions.

(b) Students individually or in small groups find the solution.

(c) Nominated or volunteered students share the solution with the whole class.

(d) The whole class was engaged using the following procedures adapted from (Gunstone, McKittrick, & Mulhall, 1999).

1. The whole class is asked to agree or disagree with the speaker one at a time and always to give reasons. For example, the moment he or she stands up, when answering, the first thing is to say: I agree or disagree with speaker **X** because of the following reasons.
2. The whole class again is given an opportunity to state follow up questions or to disagree with the previous speaker etc.
3. During the process, the lecturer, when necessary can ask provoking questions to motivate students to further discuss the problem when necessary. The process continues until the whole class is satisfied (That can be seen when, there is no further disagreement).

(e) The lecturer then summarises the discussions and lastly discusses the mathematical concepts involved in the topic.

(f) Students are given conceptual multiple choice questions, concept questions and problems that require mathematical calculations on WebCT. (WebCT is an online virtual learning system (course tools) that is sold to educational institutions. Instructors can communicate with all students and can also add or delete the learning material placed on WebCT courses. It is accessible to where there is an internet connection by simply login your username and password.)

(g) They discuss the problems with a Supplementary Instructor (SI) if they have difficulties in answering them or they consult the lecturer.

(h) Computer simulations activities were done using a data projector in class and in other activities students individually used computers in the laboratory.

3.11 The Computer simulations laboratory activities procedures

On the first day students went to the computer laboratory. They were told that the main aim for that day was to familiarize them with computers and computer simulations. At first, the lecturer instructed the students to follow the instructions on the data projector on how to access the computer simulations programme on the computer. Students were instructed to play around or interact with all the simulations during that period in preparation for the real experiments. Some of the computer simulations instructions were as follows:

> "Part 1 Instructions:
>
> Take g = 9.81 m/s^2 and m = 1 kg
>
> Go to a file **PED** in My Document. Double click **ph14e open box**, then **extract** and double click **ph14e**, double click **projectile**. On the top yellow bar click and **allow blocked content.** Then Yes. **Press reset** and set the **initial height to be 0.000**, initial speed to be 5 m/s and the initial inclination angle to be **15 degree**. Then press start and observe the motion. When it stops record the horizontal distance (R) and maximum height (H). Then click on the velocity on the bottom right. Then reset and start. Again observe the motion carefully then record values of (v_x, v_y and v) when it stops. Follow the same procedure and complete the whole table"

PED was a file on the computer where Computer Simulations were stored and the Ph14e open box was a short cut to extract simulations activities while projectile was the name of the activity. The press reset button enabled students to manipulate variables like initial speed, height etc. The computer simulations used were downloaded free of charge from http://www.walter-fendt.de/download/ph14dl.htm and was updated in 2008 by Walter Fendt. The software programs were selected because they were found to facilitate students' development of understanding of Newtonian mechanics and uses model-based reasoning (Thomas, 2001). An example of the colourful computer screen is shown in Figure 3.3.

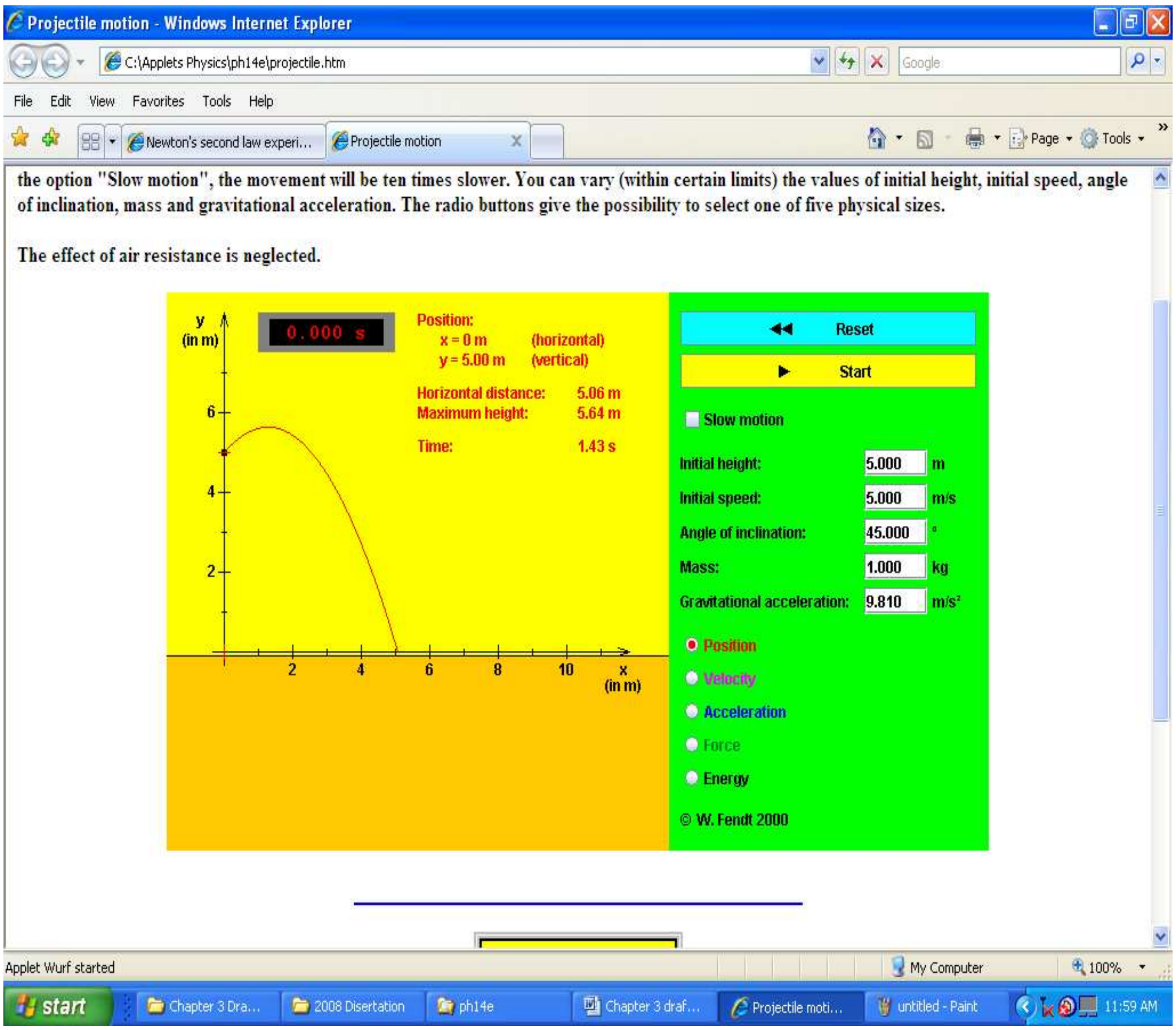


Figure 3.3: An example of a computer screen taken from http://jersey.uoregon.edu/newCannon/nc1.html

The simulations programs were chosen because students could play around with the variables and get different results. They can draw conclusions within a second. Looking at the figure above, students can change the initial height, speed and the inclination angle.

Each time these variables are changed, the shape of the graph changes. For example, the final speed is affected by the change in each variable.

3.12 Data collection: Strategies and procedures

The data in the study were collected using concept tests (FCI and EBAPS), computer simulations questionnaire and structured interviews.

On the first day students came to the Physics I class, the ground rules were agreed upon. Students were encouraged to participate in all activities and also to ask questions if they did not understand. As one of the suggestions by Cahyadi (2004) who conducted a similar study in introductory Physics in the Faculty of Engineering at the University of Surabaya (Indonesia), the rational and the purpose of the interactive engagement to be conducted throughout the year, was explained to the students. In order to encourage active participation, students were told that some of their tests and examination questions will be based on activities done in class (Cahyadi, 2004). Students were instructed to listen attentively during the lesson so that they could ask relevant questions. They were also encouraged to learn to ask and answer “why” and “how” questions.

On the second day, students wrote the FCI pre-test to assess their current knowledge of Newtonian mechanics while they were still fresh from their respective high schools. On the third day, students took an EBAPS pre-test.

Current knowledge of each topic to be covered by students was continuously assessed as follows: Approximately 15 minutes before the end or the beginning of each lesson, students were given a few questions to answer in writing and the lecturer took all the answer papers and scanned the solutions. After scanning the solutions, discussions were initiated based on the answers provided by students and then conceptual change strategies were employed to address the misconceptions or problems students had. To encourage active-engagement of all students throughout the lesson, they were told that during the discussion process, the lecturer could nominate any student to comment or tell the whole class his or her view about what is being discussed. This was done to make sure that everyone participates actively since they would not know who would be next to answer or comment.

After interventions using WCD and CS models, the Computer Simulation survey which also included open-ended questions was handed to students the first Monday immediately when students came back from practice teaching in the beginning of August 2008. The due date for submitting back the questionnaire was Friday of that week. Lastly, interviews were conducted from Monday, the second week of August and were completed on Friday of the same week.

3.13 Justification of the statistical techniques for analyzing data

3.13.1 Descriptive statistics

Descriptive statistics make no inferences or predictions, but simply reports what has been found in a variety of ways. Descriptive statistics provides simple summaries about the sample (Trochim, 2006). In order to compare and summarize the results of the study, the mean, standard deviation, range and skewness were computed.

3.13.2 Inferential statistics.

In order to generalize to a population of individuals based on a limited number of research participants, inferential statistics was used (Gay & Airasian, 2000). In this study, two inferential statistics, namely the average normalized gain and the paired t test were used to make a decision about the effectiveness of the intervention.

3.13.3 Average normalized gain <g>

The use of the average normalized gain to interpret the results of the FCI is currently preferred by PER (Hake, 1998). The average normalized gain is defined by Hake (1998) as "as the ratio of the actual average gain <G> to the maximum possible average gain $< G >_{\max}$." Symbolically, it can be represented by the formula:

$$< g >= \frac{\% < G >}{\% < G > \max} = \frac{\% < post > - \% < pre >}{100 - \% < pre >}$$

Where <G> is the actual percentage gain (%posttest average-%pretest average) and the maximum possible gain being 100 - % pretest average. The percentage class average normalized gain is now recognized by PER as a figure of importance that can be used to determine the extent to which the intervention is effective (Hake, 2002; Redish, 2003). The average normalized gain gives an index that helps in the comparison of the extent to which the treatment is effective (Hake, 2007). Based on the average normalized gain, the effectiveness of the models of instruction was further classified according to the average normalized gain as follows:

(a) High-g courses: $\langle g \rangle > 0.7$

(b) Medium-g courses: $0.3 < \langle g \rangle < 0.7$

(c) Low-g courses: $\langle g \rangle < 0.3$

According to the classifications suggested above, low-<g> courses are associated with traditional models of instruction which were operationally defined by Hake (1998) as "those that relied primarily on passive-student lecturers, 'recipe-following' laboratory sessions and algorithmic quantitative problem solving examinations". The high <g> courses were regarded as those that mostly used interactive-engagement models while the medium <g> courses were those that integrated both traditional models and the interactive-engagement models. The average normalized gain was used in the study because it is an internationally accepted value to classify the models of instruction and to measure the effectiveness of the intervention (Redish, 2003; Hake, 2007).

3.13.4 Paired t-test statistics

This is used to compare the actual mean difference observed from the difference expected by chance (Gay & Airasian, 2000). In other words, it determines whether the two means are significantly different at the selected probability level. The paired group t-test were used in this study because the same groups of students were not initially exposed to treatment when the pretests were written, they were then exposed to treatment and finally wrote the posttests after being exposed to treatment. A t-test was done on the overall mean pre- and post-tests data to examine whether impact of instruction was significant.

3.14 Ethical Issues considered in the study

Ethical issues in educational research mean conforming to the standards of conduct of a professional body (Fraenkel & Wallen, 2003). In the planning of this study, all students in class were supposed to have been included, as it was recommended by Trochin (2006). According to Trochin, good research practices often require the use of a no-treatment control group because it is like a sort of discrimination. Before interviews were conducted, all participants were told that the interviews were voluntary, and their names would be confidential and that the interview information would be used for the purpose of the research only. In a pretest and posttest only student numbers were used. That was done to abide by the principle of anonymity which requires that the participants be anonymous throughout the research processes (Trochin, 2006).

CHAPTER 4: DATA ANALYSIS AND DISCUSSIONS OF PRETESTS

4.1 Introduction

In the previous chapter, research procedures and design as well as instruments used for data collection were described. This chapter focused on the analysis and discussions of pretest data using Moonstats software program (included in a book by Welman & Kruger, 2001) with the view of assessing students' conceptual understanding of Newtonian mechanics and their epistemological beliefs about physics before intervention using interactive engagement models.

4.2 The descriptive analysis of pilot FCI tests results

This study started after the analysis of the pilot 2007 FCI results where traditional models of instruction described in section 2.5.2 were used. The FCI pre and post test results indicated that no students managed to get at least 15 (50%) as shown in table 4.1 and figure 4.1.

Table 4.1: Summary of 2007 pilot FCI results and 2008 Pretest results

Variable	N	Mean	StDev	Minimum	Maximum	Skewness
FCI Pretest 2007	39	6.38	2.79	1	13	0.45
FCI Posttest 2007	39	7.97	2.94	1	14	0
FCI Pretest 2008	48	6.15	2.66	2	12	0.45

An analysis of the responses from students to questions in FCI indicated that students had misunderstandings regarding certain concepts, which could be the consequence of commonsense knowledge that they possess about the concepts. The percentage class average score of 60% in the FCI is regarded as an entrance score for students beginning to comprehend Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992). Students got the mean of 21% and 27% in the pre and post-tests respectively. Even in 2008, the FCI pretest mean was 21% with the same skewness of magnitude 0.45. The results of the pilot

FCI test and the 2008 FCI pre-test indicated that students did not master Newtonian mechanics from high school.

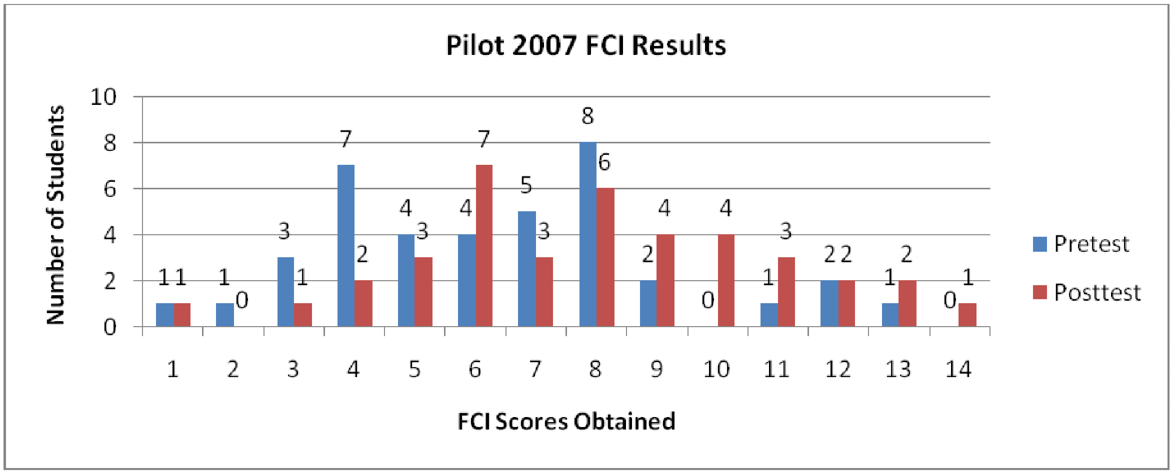


Figure 4.1: FCI Pretest and Posttest Results of Physics I Education Students at CUT in 2007, Bloemfontein Campus

To bridge the gap, the use of new models of instruction which deals with the challenging of students' misconception were suggested when the average FCI score is 60% (Hestenes, Wells, & Swackhamer, 1992).

4.3 The average normalized gain of the pilot FCI test

The pilot average normalized gain for the FCI test was 8%. This value was too small when compared to the average normalized gain achieved using interactive engagement models. After the analysis of different models of instruction, Hake (2002) associated the average normalized gain of 8 % under low g courses which are the results of using traditional models of instruction. The results of the FCI pretests suggest that the models of instruction used in high school were traditional. The results of the pilot FCI tests and 2008 FCI pretest support the idea of Halloun and Hestenes (1985) who claimed that traditional models do little or nothing in terms of bettering students' conceptual understanding of Newtonian mechanics.

4.4 The EBAPS pre-test results

Before the EBAPS results were interpreted, the likert scale was converted to a score from 0 to 4 in a non-linear manner. In other words different questions were scored differently. The scores on each question were out of 4. A score of 0 indicated less sophisticated beliefs while a score of 4 represented the most sophisticated beliefs, similar to those of experts. To be consistent, only students who wrote both the EBAPS and FCI tests were considered for the analysis of the data.

4.4.1 Descriptive analysis of EBAPS pretest results

Table 4.2 indicates a summary of the EBAPS pretest results. From the table, it can be seen that the mean was 1.87 (47%). That shows that most students' epistemological beliefs about physics were less sophisticated before interventions when compared to those of experts.

Table 4.2: The l summary of EBAPS Pre-test results

Variable	N	Mean	StdDev	Minimum	Maximum	Skewness
EBAPS Pretest	48	1.87	0.23	1.40	2.46	0.15

4.4.2 Analysis per Axis

The mean mentioned in section 4.4.1 is the combined results of different axes. Looking at individual axes in table 4.3, the results suggest that students were beginning to have sophisticated beliefs in the axes, real life applicability (54%) and source of the ability to learn (59%) when they wrote EBAPS pretest. It seems as if students did not believe in evolving knowledge as indicated by 31% on that axis.

Table 4.3: Summary of EBAPS pretest results per dimension

	Structure of knowledge	Nature of learning	Real-life applicability	Evolving knowledge	Source of ability	Overall
% Pre EBAPS Mean	41.95	45.31	53.58	31.08	58.75	46.74

4.3 The overall conclusion about the pre-tests results

The results of the FCI pretests indicated a lack of conceptual understanding of Newtonian mechanics by students from high school. Students' epistemological beliefs about physics were better when compared to their conceptual understanding of Newtonian mechanics. The detailed results of the tests will be discussed in chapter 6.

CHAPTER 5: TEACHING INTERVENTIONS ACTIVITIES

5.1 Introduction

The previous chapter dealt with the analysis and discussions of the pilot FCI results and the 2008 FCI and EBAPS pretests results. This chapter focuses on the analysis and discussions of the activities done during interventions using WCD and CS as interactive engagement models of instruction.

5.2 WCD and CS activities

Whole class discussions and computer simulations were models of instruction that were used for teaching and learning. It should be noted that Computer Simulations were not used as a replacement of the traditional laboratory work. In most activities in this study, both WCD and CS were used one after the other or at the same time. The results of WCD and CS activities done in class over a period of 9 weeks are presented and discussed next. Table 5.1 indicates the list of activities done including the models of instruction used. Other models on the table refer to demonstration or quantitative explanations of the concept.

Table 5.1: Summary of WCD and CS activities

		Interactive Models of Instruction		
Activity	**Topic**	**WCD**	**CS**	**Other**
1	Speedster got caught	❖		
2	Speed ,velocity and acceleration	❖	❖	
3	Acceleration	❖		
4	Newton's second law of motion		❖	❖
5	Velocity and acceleration directions	❖	❖	
6	Gravitational Acceleration	❖	❖	
7	Bigger and Smaller objects falling	❖		❖
8	Ball moving towards the edge of the table	❖	❖	
9	Projectile motion	❖	❖	
10	Traveling with a convertible car	❖	❖	
11	Motion in two dimensions		❖	❖
12	Elastic and Inelastic collisions		❖	

Since one of the aims of the present study was to assess the conceptual understanding of Newtonian mechanics, the content of the prescribed mechanics syllabus was reduced and all activities were centered around speed, velocity and acceleration in line with suggestions by Reid and Mbajiorgu (2006). According to Reid and Mbajiorgu (2006), when teaching and learning is aimed at the improvement of conceptual understanding, students must be offered opportunities to develop critical thinking and be able to weigh evidence. This is only possible when there is a significant content reduction. In this study, it was assumed that speed, velocity and acceleration are the backbone for understanding mechanics.

5.2.1 Activity 1: A speedster got caught

This activity was done in class and consisted of three questions related to speed and its effect on real life. The questions were also set in the examination and used as posttest. The results shown are those for before and after the intervention (examination). Only students who took both the FCI and EBAPS tests were considered for the analysis and discussion.

Activity 1:

Read the following passage adapted from News24 (2007) and then answer all questions giving reasons.

"The founder member of a popular Radio Station is apologizing for being found on the wrong side of the law this week. While driving from the Eastern Cape on Sunday, he was stopped by the traffic official driving his Audi TT at 257km/h in a 120km/h zone."

Questions:

1. Define speed using your own words.
2. Is 257 km/h he was caught driving an average or instantaneous speed? Give reasons for your answer.
3. Do you know that speed kills? Give reasons for your answer.

Question 1: Students' definition of speed

Students were asked to define speed using their own words. Their responses were classified into three categories; correct, partially correct and incorrect. Correct responses were considered as the scientifically acceptable, while partially correct responses were considered to lack a few things to make them acceptable and incorrect responses were regarded as being unscientific. From figure 5.1, it can be seen that only 17 (35%) students gave the correct definition of speed while 7 (15 %) got it partialy correct and 24 (50%) responded incorrectly to the question. The activity was then discussed in a double period of 80 minutes. In an examination which was written 4 months after the WCD intervention, 41 (85%) answered the question correctly.

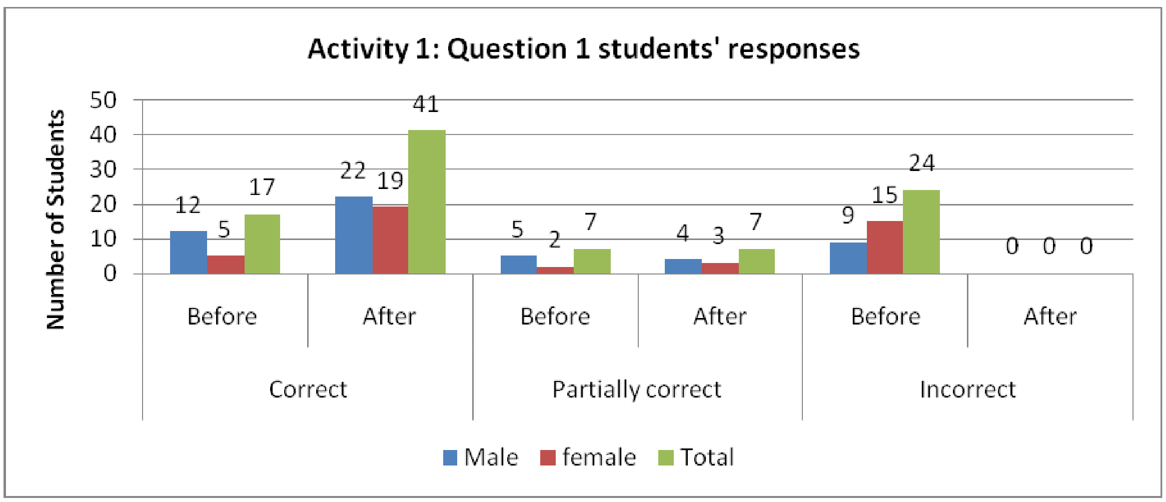


Figure 5.1: Results of students' understanding of speed

The findings on this question show that most students initially relate speed with anything greater than 120km/h in South Africa. This finding support Bayraktar (2008) who claimed that students' prior knowledge is sometimes different from the scientific view. Their way of thinking started to change after the WCD. The change in reasoning by the students indicated that one of the aims of physics to help students look critically at the understandings derived from physics (Mbajiorgu & Reid, 2006) was achieved. The results of this activity show that WCD succesfully helped students to understand the definition of speed. This was demonstrated by the fact that 85% of the students defined speed correctly after the intervention. The fact that above 85% of the students answered the question correctly suggests that WCD was successful in helping the students to retain their new understanding of speed for a longer time after intervention.

Question 2: Students' understanding of the difference between average and instantaneous speed

This question was answered correctly by 31(65%) before the intervention, but at the same time, only 2 out of 31 gave the correct explanation or reason as shown in figure 5.2. The results suggest that most students were able to choose or guess the correct answer, but had incorrect reasons. Before the intervention, most students did not understand the difference between instantaneous and average speed. For example, some students understood instantaneous speed to be very high speed. One can conclude that WCD helped in revealing some of the misconceptions the students had.

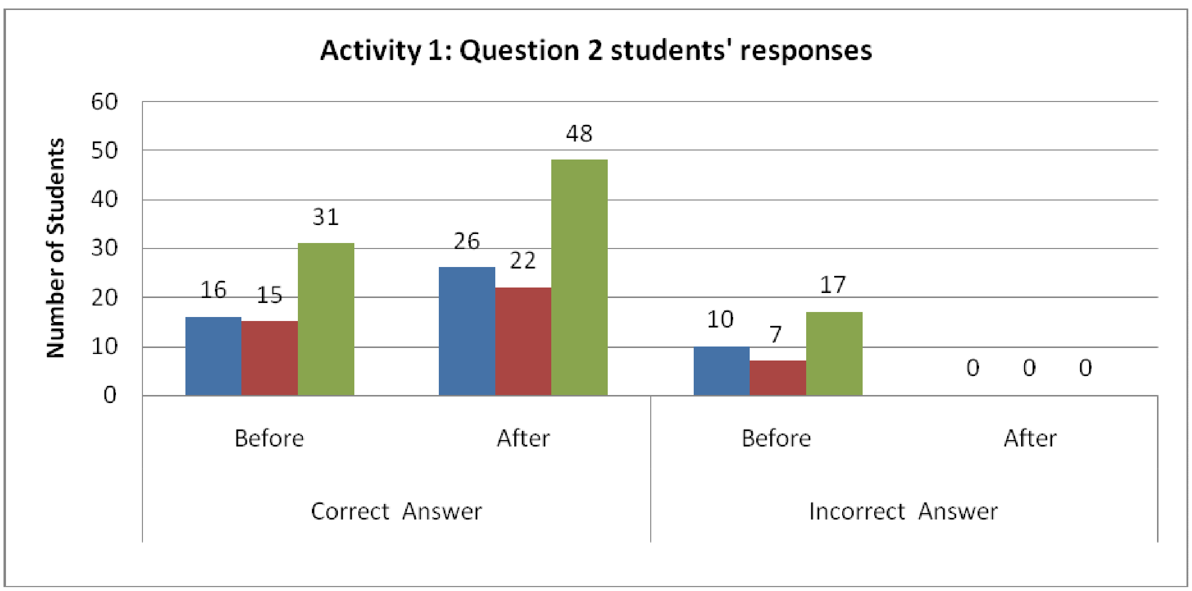


Figure 5.2: Students' understanding of the difference between instantaneous and average speed

The fact that all students differentiated between instantaneous and the average speed after interventions, showed that WCD had a positive impact on the students' conceptual understanding of the qualitative difference between instantaneous and average speed. The results of this question concur with Fagen, Crouch and Mazur (2002) who claimed that students' discussions sometimes waste time, but have a considerable learning gain.

Question 3: Students' understanding of whether speed kills or not

Before the WCD, 34 (71%) students in the sample as shown in figure 5.3, thought speed kills, but the reasons they gave were not scientific and again depended on the South African Arrive Alive campaign. After the intervention, the situation changed remarkably, the students were able to defend their options using reasonable scientific explanations. For example, students gave other factors like fatigue that could contribute to the killing of people or accidents while speeding.

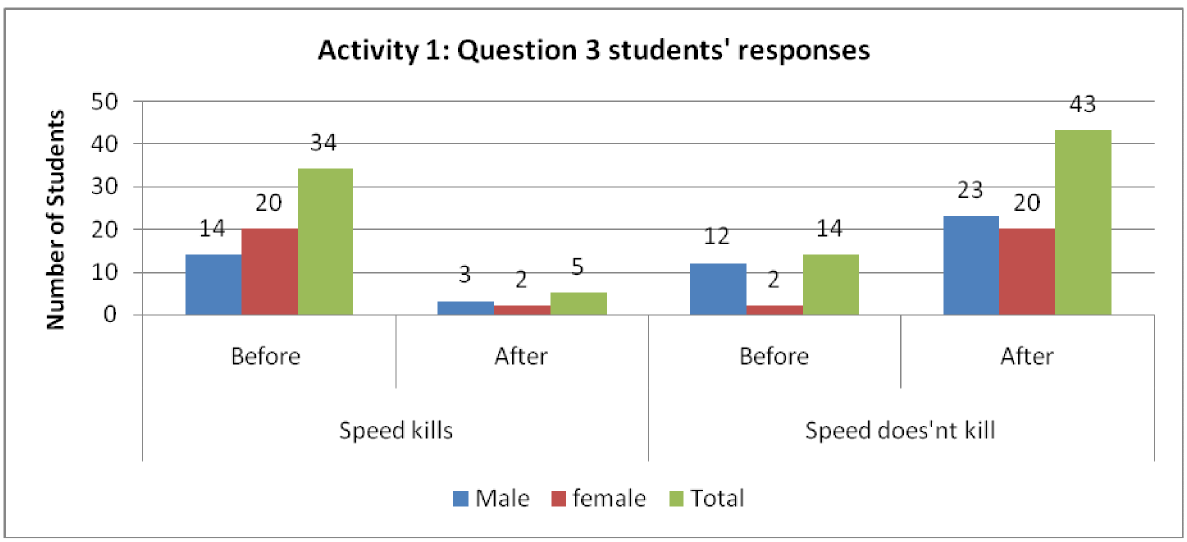


Figure 5.3: Results of students' understanding of whether speed kills or not

One of the conversations of the lecturer with different students during WCD was as follows:

Lecturer: What is speed?

Student: Change in position with repect to time or distance covered per time interval.

Lecturer: Do you think speed kills

Student: Yes, it kills

Lecturer: O' K, you said speed is change in position with respect to time. Is that so?

Student: Yes , it is so

Lecturer: Then look at me, I am walking from the corner of the class to another. Did I speed up?

Students:Some said yes and some said no

Lecturer: For those who said no, why?

Student: Because it was slow and you did not reach 120 km/h.

From the conversation, it was clear that the students had memorised the definition but were unable to interpret its direct application. After the conversations, students ended up realizing that speed is just a change in position with repect to time. After the intervention using WCD, 43 (90 %) students changed their ideas and said speed alone does not kill. The results support the idea by Mbajuiorgu and Reid (2006) about some of the skills that are developed through the learning of physics. According to them students who are studying physics should be able to learn to weigh evidence and take reasonable decisions. From the conversation above, students made decisions by weighing evidence and came to a sound scientific conclusion that speed alone does not kill. The results of this question seems to be consistent with those of Heron, Shaffer and McDermott (2007) who found that students deepen their understanding of difficult concepts when they first go through reasoning development strategies. These reasoning development strategies are also possible when using WCD as a model of instruction.

5.2.2 Activity 2: Speed, velocity and acceleration

This activity was done using WCD and CS using a data projector in the classroom. The question in the text box below was displayed on a screen from a data projector. Students were requested to quickly write down on a piece of paper their options that represent the correct answer.

Question:

A ball is thrown vertically upwards from the surface of the earth. Consider the following quantities based on the motion of the ball.

(1) Speed; (2) velocity; (3) acceleration

Which of these is (are) zero when the ball has reached the maximum height?

A: 1 and 2 only, B: 1 and 3 only, C: 1 only, D: 2 only, E: 1, 2 and 3

The aim of the activity was to help students differentiate speed, velocity and acceleration in terms of magnitude. The results of this activity as shown in figure 5.4 suggest that speed, velocity and acceleration were still a problem to students because only 14(23%) managed to answer correctly. The majority of the students 27 (44%) selected option D. This indicated that they could still not differentiate between speed and velocity with confidence as well as to explain instances where the magnitude of velocity is the same as that of the speed.

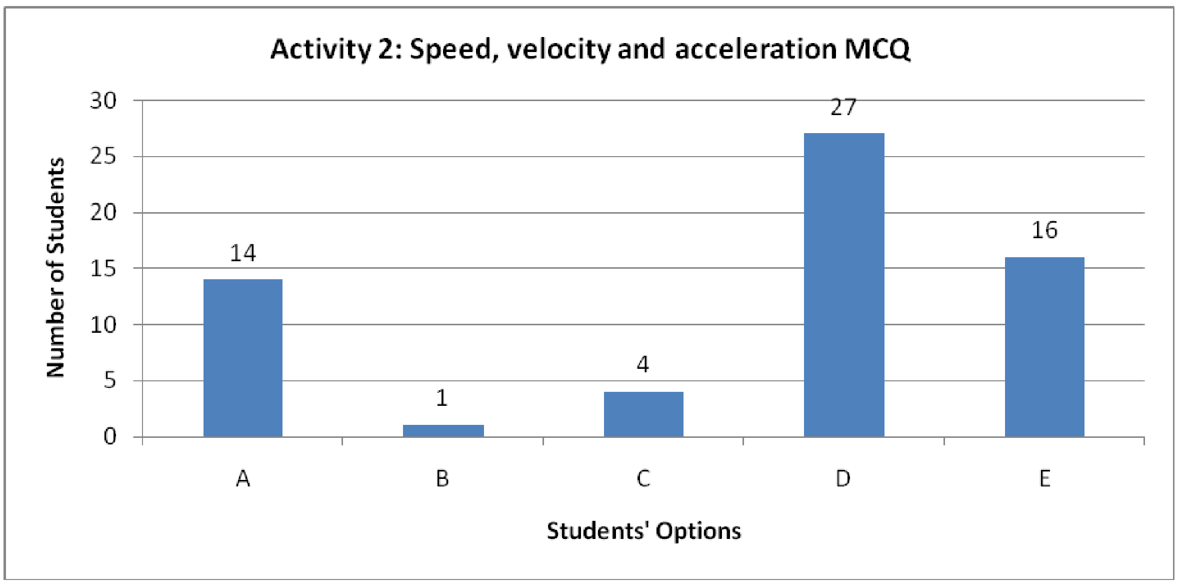


Figure 5.4: Speed, velocity and acceleration MCQ results

In this activity, WCD was supplemented by CS, where the demonstration of an object moving upwards until reaching the maximum height and then falling back was displayed on a screen using a data projector. When the object was moving, the change in speed and velocity were clearly seen. After these demonstrations, students were engaged in WCD to improve their functional understanding by actively involving them intellectually as suggested by Heron, Shaffer and McDermott (2007). After WCD, all students understood why option A was correct.

5.2.3 Activity 3: Acceleration

The main aim of this activity was to assess the students' qualitative understanding of acceleration. The students were instructed to write down the solutions for the following questions and elaborate or give reasons to justify their answers. The following questions were written on the board:

Questions:

1. What do you understand by the term acceleration?
2. An object is accelerating at 10 m/s^2, explain what it means referring to the motion of the object.
3. What does it mean to say an object is accelerating?

The answers the students gave were analyzed and categorized under correct, partially correct, have an idea and no idea. The results of this activity are shown in figure 5.5. These results are contradictory because more than half of the class, 39 (53%) out of 74, were able to define acceleration correctly but, at the same time no student was able to explain the qualitative meaning of acceleration in question 2.

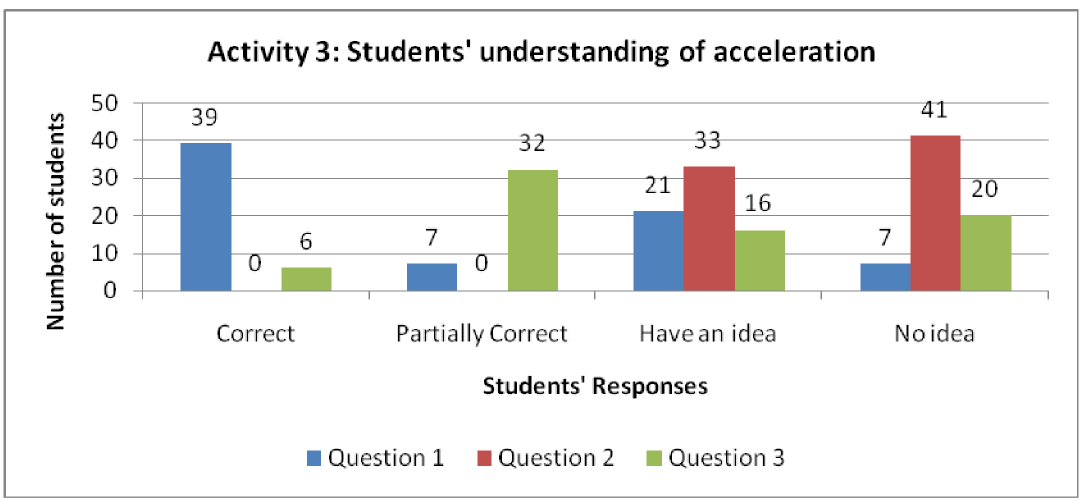


Figure 5.5: Students' understanding of acceleration

Legend: Questions 1 and 2

Correct (C):Q1: Rate of change in velocity). Q2: Every second the velocity changes by 10m/s
Partially Correct (PC):Q1: Rate of change in speed. Q2: Every second speed increase / decrease by 10m/s
Have an idea (HI): Mentioning of change in velocity or speed in a certain time
No Idea (NI): Mentioning of anything not related to above

Legend: Question 3.

- C Rate of change of velocity which implies change in magnitude of velocity or change in direction or both
- PC Either increase or decrease in velocity
- HI Change of position
- NI Moving with constant motion and not one of the above

The answers the students provided in question 2 suggest that they memorized the definition of acceleration in high schools because no one was able to explain the scientific meaning of 10 m/s^2. The results for question 2 were not surprising because the majority of the students are reported to have left their high schools and started their undergraduate physics studies before they understood the meaning of acceleration (Bernhard, 2000). This shows that models of instruction that were used in high schools did not help in improving the students' conceptual understanding but encouraged memorization. Performance in question 3 was answered better but not acceptable, because only six students answered correctly compared to question 2.

The results of this activity suggest that the concept acceleration is still difficult to conceptualise. The reasons for the difficulty could have been due to the barrier caused by language (Mbajiorgu & Reid, 2006) and/or the traditional models of instruction used at their respective high schools (Heron, Shaffer & McDermott, 2007). Mbajiorgu and Reid (2006) have noted that physics uses every day English words in a technical manner. During the intervention, WCD revealed the misconception that students associate acceleration with only the increase in the magnitude of speed and velocity. Students did not view the continuous change of the directions of velocity as acceleration. After the intervention, students were able to understand that acceleration is just a rate of change in either or both magnitude and direction of velocity.

5.2.4 Activity 4: Newton's second law of motion

Students were expected to answer parts 1, 2 and 3 of this activity. They were instructed to work on part 2 and fill in the table in part 3 in a computer laboratory using a simulations programme. Then they were told to do part 1 and other questions on the activity at home. Students were given a week to complete this activity.

Activity 4: Part 1

Activity:
A wagon of mass 100g is connected to a hanging object of mass 1g as shown in the diagram above.
Take g = 9.81 m/s^2

(i) Calculate the acceleration of the system if the frictional force between the 100g block and the surface of the table is ignored.

(ii) Calculate the acceleration of the system if the coefficient of friction between the 100g block and the surface of the table is 0.001.

Part 1 of this activity was done after Newton's second law was discussed. Questions in the text box above were given to the students for them to calculate the acceleration of the system. 45 students who submitted the activity calculated the solutions for (i) and (ii) correctly. The reason for them to calculate correctly could be that each step followed in the algorithm of solving problems related to Newton's second law, that were discussed using WCD. It was reported that students had a tendency to memorize steps that would help them to get the correct answers because they believe that the key to solving physics problems is to find the right formula (Heron, Shafter, & McDermott, 2007).

Activity 4: Part 2

Part 2 of this activity was a CS replication of part 1 where students were expected to make use of simulations to read the magnitude of acceleration. It was intended to verify the results obtained in part 1. The simulation version of part 2 is shown in figure 5.6. In this part, the CS calculates the magnitude of the acceleration as indicated on the bottom-left hand side of figure 5.6.

> **Part 2**
> Go to a file PED in My Document. Double click "ph14e **open box"**, then extract and double click "**N2law"**, double click the top yellow bar to allow blocked content.
>
> (i) Press reset and then set the mass of the Wagon to be *M* = 100g and the hanging mass to be *m* =1g and lastly **µ** to be **0.000**. Then press start and then press pause when the Wagon reaches the red pole. Lastly, record the magnitude of acceleration as indicated on simulations: **a** = ---------
>
> (ii) Press reset and then set the mass of the Wagon M to be 100g and the hanging mass to be 1g and lastly **µ** to be **0.001**. Press start and then press pause when the Wagon reaches the red pole. The write down the magnitude of acceleration as indicated on simulations: **a** = ---------
>
> (iii) Compare the results you obtained in (i) and (ii) with the manual calculated results obtained in Part 1.

The students were expected to follow instructions and perform the simulation and then record the magnitude of the acceleration which was 0.097 m/s^2 for (i) and 0.087 m/s^2 for (ii).

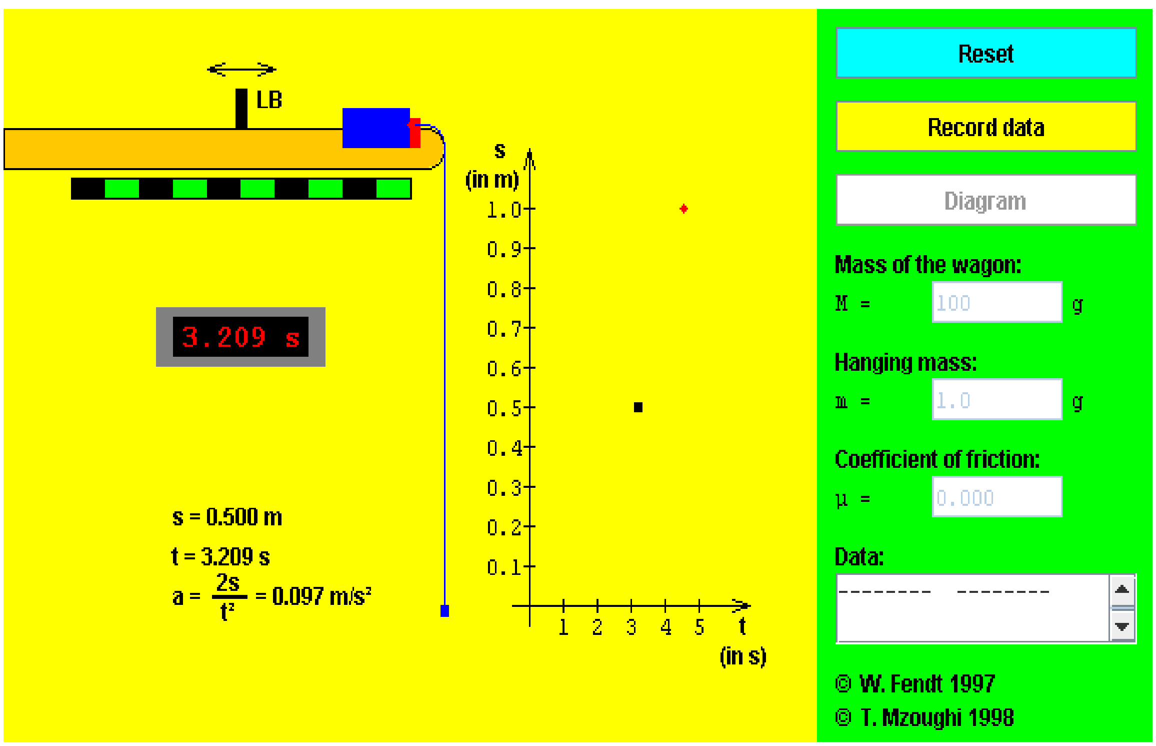


Figure 5.6: Computer Simulation set-up version of part 2

Sixty (98%) out of 61 students recorded the magnitude of the accelerations correctly in (i) and (ii). Only 23 (38%) students gave the correct answer for (iii) while other students skipped the question. The reasons students gave ranged from being results of ignorance to not knowing how to explain.

Activity 4: Part 3

The total number of 61 students responded to questions in this part. The results of Part 3 are shown in figure 5.7. The first part required the students to make use of CS to fill in the table in activity 3. From figure 5.7, it is clear that only 34 (56%) students completed the table using data obtained from CS, but exactly 60 (98%) students were able to draw a correct straight line graph through the origin.

Part 3:
Repeat the instruction in part 2
Keep the Mass of the Wagon constant at 100g and then change the hanging mass (*m*) and complete the following table. Calculate the Weight and then record the acceleration as indicated on the diagram for each trial for different hanging masses.

M	*m* (g)	$\sum F = mg$	a
100g	1		
	2		
	3		
	4		
	5		

Then draw the force against acceleration graph making use of values in the table above. (Select your own scale)

Follow-up Questions:

(i) What happens to the acceleration when you increase the mass of the hanging object?
Give reasons for your answer.

(ii) From the graph one can conclude that Force is (indirectly, directly) proportional to acceleration. Give reasons for your answer.

(iii) Complete: According to Newton's second law, the net force is…………………………………………………………………………………

The results suggest that most students drew the graph without using the data obtained from the table. They used their personal experiences about the graph of force versus acceleration.

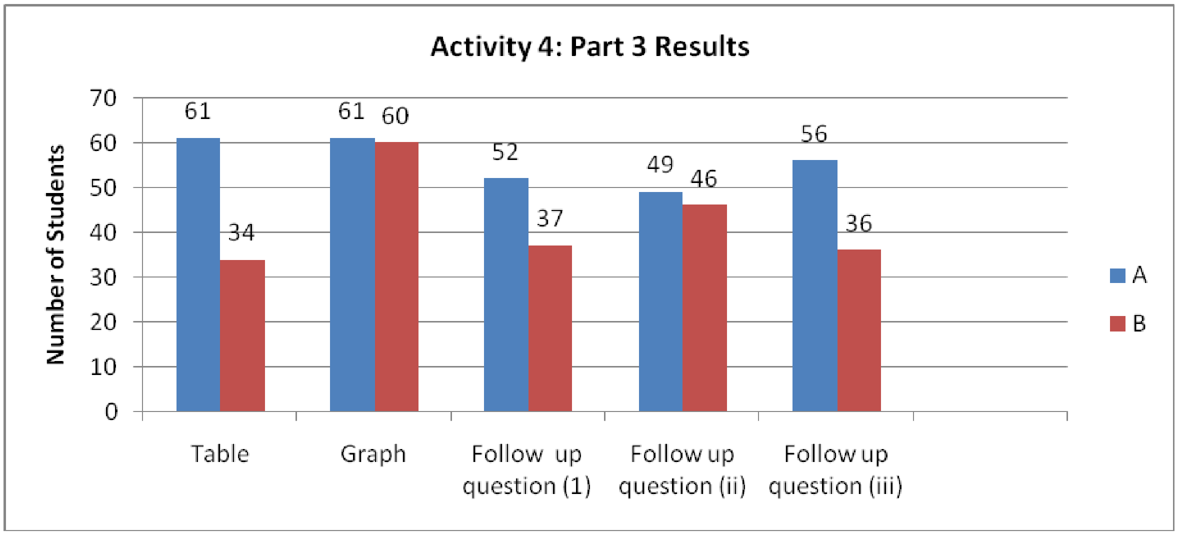


Figure 5.7: Newton's second law of motion Part 3 activity results

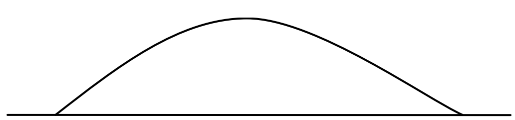
Legend:
A: Number of Students who answered the question
B: Number of students who answered the question correctly

Follow-up question (i), shows that 37 (65%) students out of 57 who attempted the question answered it correctly, but the problem was that they did not use the graph to answer the question as instructed. The results of this activity suggest that CS should only be used in topics identified as challenging. Otherwise, students will answer all questions correctly without using the given instructions.

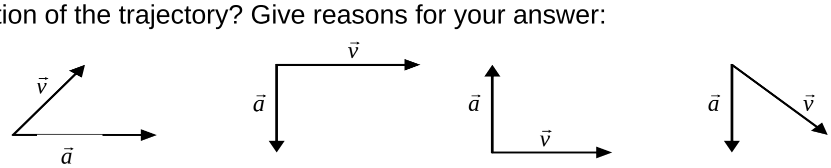
5.2.5 Activity 5: Directions of velocity and acceleration in a projectile motion

The activity was done by students in groups consisting of three students each.

A projectile is fired into the air and it follows the parabolic path shown in the diagram, landing on the right. There is no air resistance. At any instant, the projectile has a velocity $\vec{v}$ and acceleration $\vec{a}$.



Which one or more of the drawings could not represent the directions of velocity and acceleration of the trajectory? Give reasons for your answer:



A **B** **C** **D**

The activity was about selecting the incorrect diagrams that do not represent directions of the velocity and acceleration of a projectile fired at an angle into the air. The students were instructed to give reasons for their choices. This activity was also repeated using CS in the computer lab. The students were expected to select one or more of the following options given, by writing the correct letter on a piece of paper. The options that do not represent the directions of the velocity and acceleration were A and C. From the figure 5.8, it is clear that C was an obvious choice because the acceleration of a falling object in air cannot face the vertically upward direction. At the same time, students did not realize that in option A, the acceleration must be downwards.

Some of the reasons given by the students were the following:

Option B

Group 8: B is not correct because the gravitational acceleration is constant, but in this case the gravitational acceleration is decreasing.

Group 17: B is not because the gravitational acceleration must be in the same direction as the velocity.

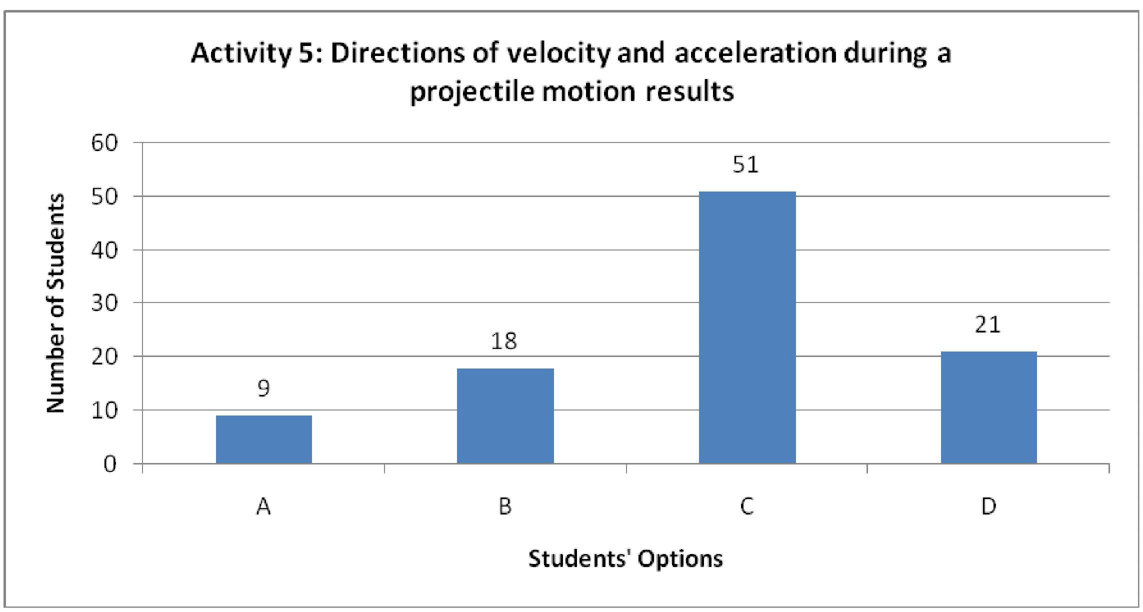


Figure 5.8: Velocity and acceleration directions during a projectile motion

An analysis of the reasons given by the groups opted for this answer lead to the mathematics number line, where the downwards direction indicate that something is decreasing. The implication of this reasoning for teachers is that they should clearly distuinguish between vectors and number lines when they teach to avoid these kinds of problems. The problem was clarified after using WCD to lead the students to understand that the meaning of the positive and negative signs for vectors is that they only indicate direction.

Option C

Group 7: Because acceleration is increasing while it is supposed to be constant.

Group 3: Because the vertical and horizontal motion were indicated and acceleration increases while velocity is constant.

Option C was also the correct answer but some students had incorrect reasons for choosing it. This shows that students just guessed the correct option. After the discussions, these students went to the Computer lab where the activity was repeated using the simulations as represented in figures 5.9 and 5.10.

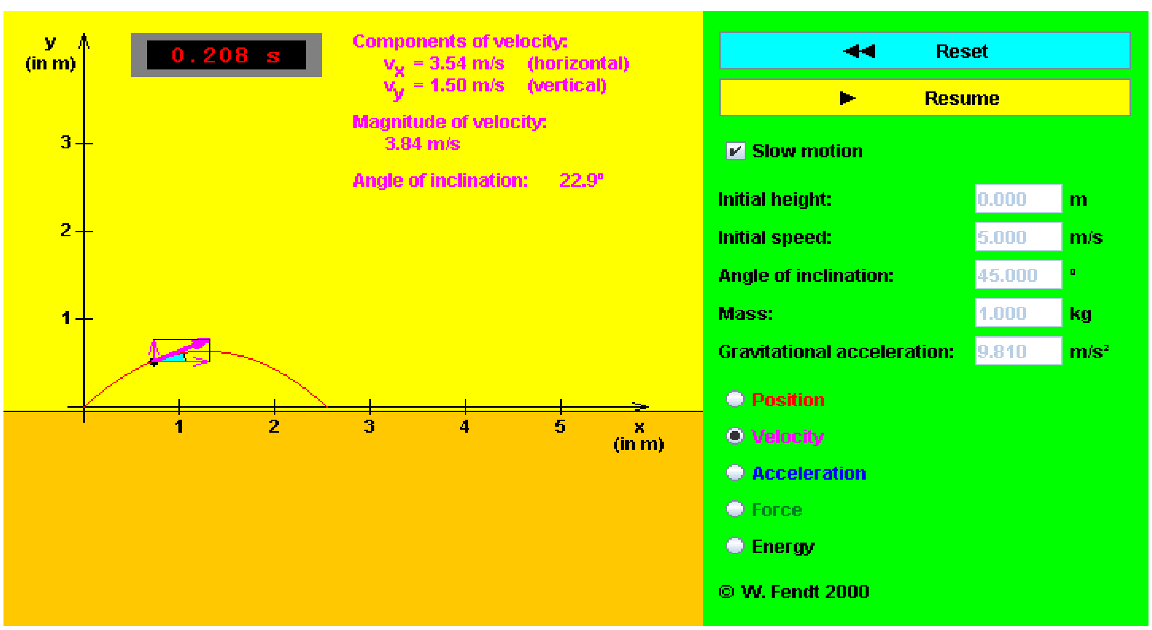


Figure 5.9: Direction of velocity during a projectile motion

The students were instructed to use projectile simulations. They were advised to tick the slow motion option.

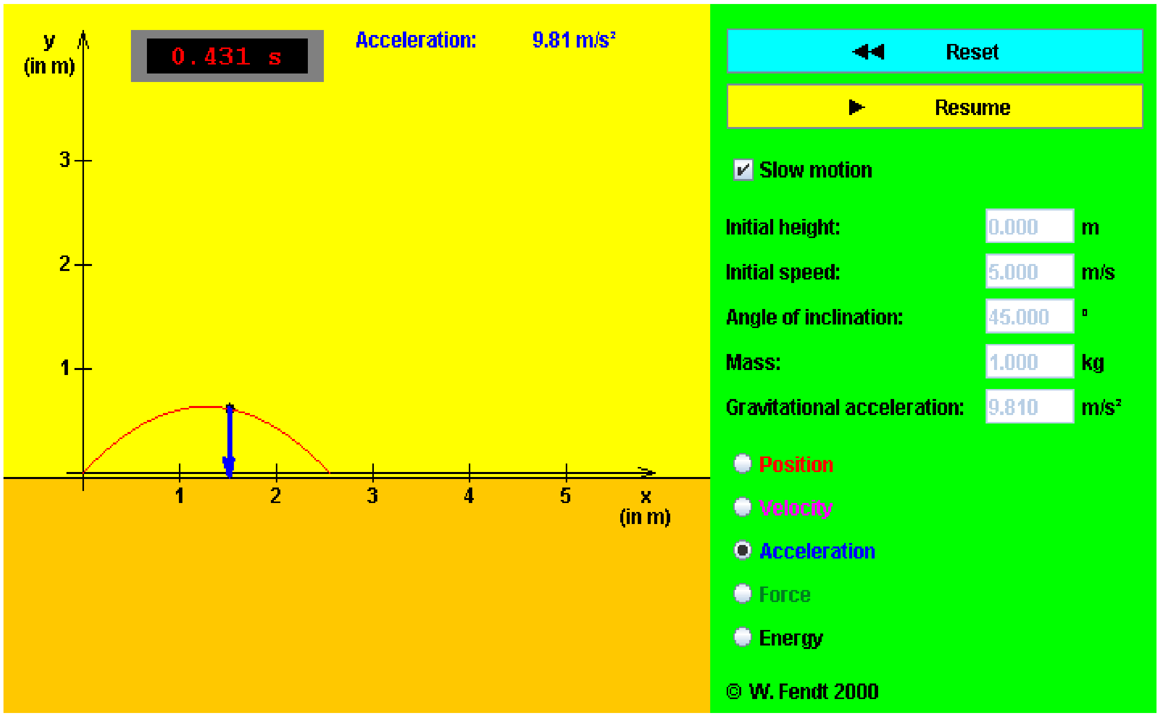


Figure 5.10: The direction of acceleration during a projectile motion

They were then instructed to select velocity and observe the direction carefully. After observing the velocity simulation, they were instructed to select the acceleration option and observe again. Lastly they had to write down the options they think did not represent the directions of the velocity and acceleration. All students chose option A and C as these options were not shown on the computer simulations. In this activity, the use of CS was helpful in enabling to understand directions of velocity and acceleration during a projectile motion.

5.2.6 Activity 6: Gravitational acceleration

This activity was first done using WCD and then later by CS by making use of a data projector.

Question: An object is thrown vertical upwards. While in air its acceleration (Increase, decrease or remain the same) Give reasons for your choice

The number of students participated in this activity, were 73 and 38 (52%) as shown in figure 5.11 chose the correct option and gave the correct reasons, while 34 (47%) chose the incorrect options.

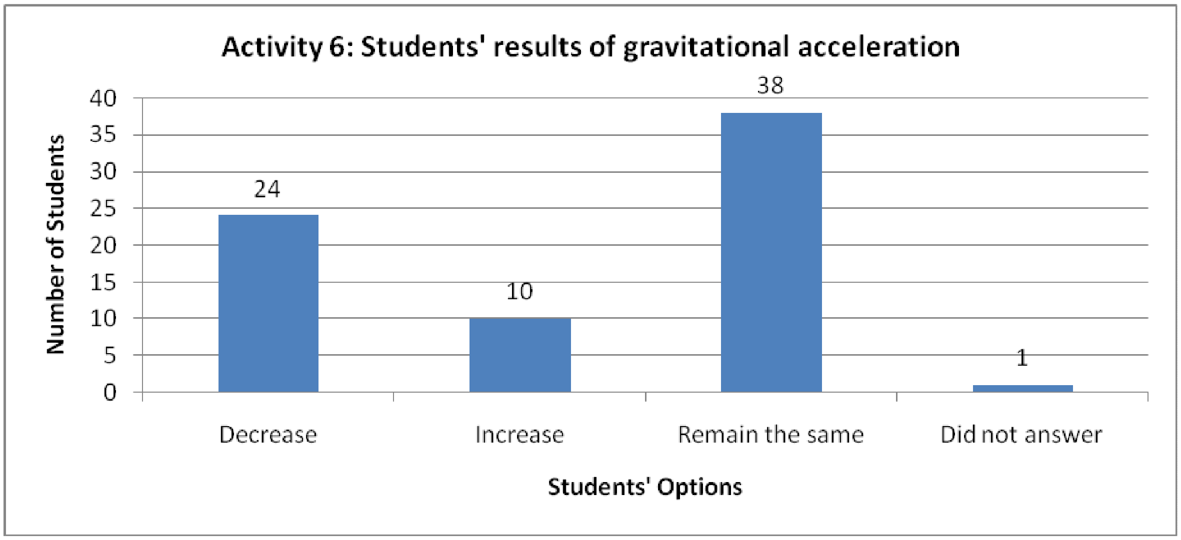


Figure 5.11: An object thrown vertically upwards results

It was surprising that one student did not respond even if it was a multiple choice. The WCD was then centered on incorrect options to explore reasons behind the students' choices of incorrect options. During the process of WCD some of the reasons given by those who did not choose the correct option were summarized as follows:

Decrease:

- Acceleration is in direct proportion to velocity. When velocity changes so does acceleration
- Decreases because the gravitational force is acting against the object
- When going up its acceleration is opposing the gravitational force
- Change in velocity with the same rate in opposite direction
- Two opposite velocities causes the acceleration to decrease

Increase:

- The more the distance the more the acceleration
- Gravitational force increases which causes an increase in acceleration
- The more velocity changes the more acceleration is gained
- Acceleration is greater when reaching a maximum height.

From this activity, one can again conclude that even when acceleration was dealt with in the previous sections, most students' still relate acceleration and velocity as being directly proportional to each other. Similar results where students did not differentiate the concepts of velocity and acceleration were noted by Halloun and Hestenes (1985). Students also memorized that, at maximum height the velocity is zero, but they failed to understand, however, that acceleration during the motion is gravitational acceleration. Lastly, one could argue that to be able to define a concept does not necessarily imply the understanding of a definition or concept. The computer simulation was then displayed. After students observed the CS, they were required to answer the following questions using WCD as a way to help them further understand the concept.

Question 1: What does it mean when we say an object is accelerating?

Question 2: In which direction does the force of gravity act?

Question 3: When an object is moving upward in which direction is the force of gravity acting?

Question 4: What happens at maximum height?

Question 5: What will the acceleration be at maximum height?

Question 6: What do you think causes an object to slow down when going up and to speed up when going down?

It was assumed that the students will be able to answer these questions, as some of them were dealt with in the previous activities.

5.2.7 Activity 7: Bigger and smaller objects falling from the same height

Using a data projector, the following question was displayed 15 minutes before the end of a classroom session.

Question:
Predict which object will reach the ground first when two objects of different masses (that can be measured by an ordinary spring balance in the lab) are made to fall from the same height at the same time.

The question itself had a strong distracter because it quickly channeled students to think about only two answers (either bigger or smaller object) whereas the correct answer is both will reach the ground at the same time. The question was similar to the first question on the FCI test which only 12 (25%) students answered it correctly in the pretest.

The following day after reading their predictions, their answers were classified into four categories depending on their options and reasons. The categories were:

A: Object with larger mass reach first

B: Both at the same time

C: Both at the same time and mentioned conditions.

D: Object with smaller mass first

From figure 5.12, it can be seen that students whose answers fell under category A were 46 (64%), category B were 16 (22%), category C were 7 (10%) and lastly category D had 3(4%).

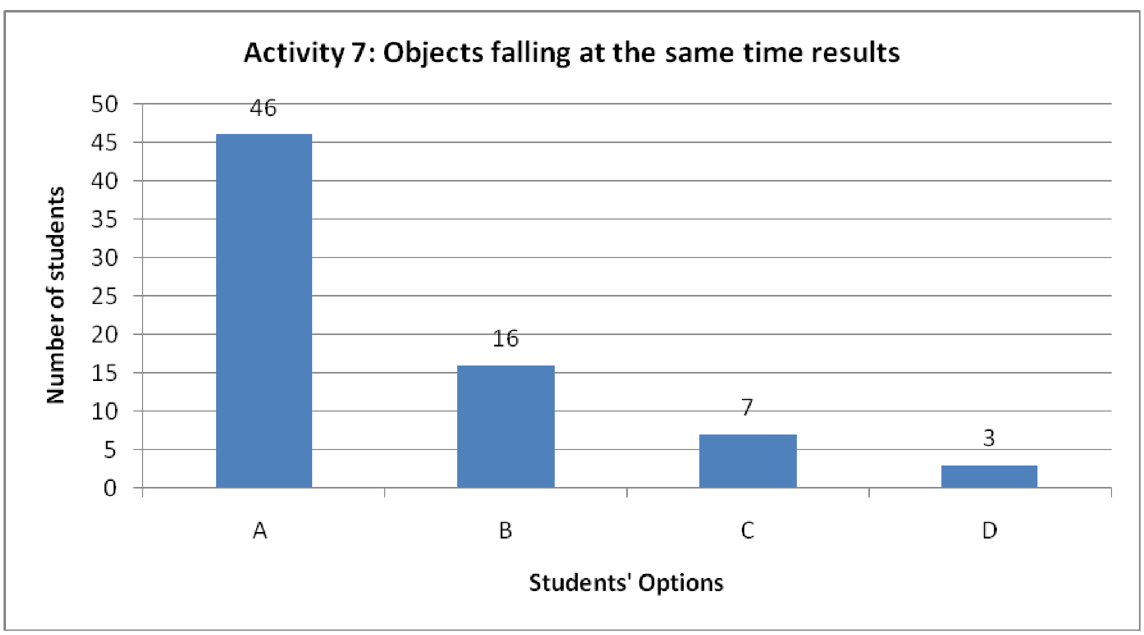


Figure 5.12: Bigger and smaller objects falling results

In each category, different reasons supporting the answers were given. Some of the reasons given by students from each category were the following:

Category A: Object with larger mass reach first:

Students' answers in this category were further divided based on whether air resistance had an effect on motion or not. The effect of air resistance in the motion of an object was also noted by Halloun and Hestenes (1985). Those who mentioned air resistance gave the following reasons:

- Bigger force less frictional force and bigger acceleration.
- Bigger weight denser than air resistance.
- Smaller mass affected by air resistance.
- Bigger mass because the presence of air resistance.
- Bigger mass does not lose direction even when air resistance is available.
- Big objects respond strongly to gravity.
- Bigger mass reduces air resistance.

Those who did not mention air resistance gave the following reasons:

- Bigger mass bigger gravitational acceleration (g) and less mass implies less gravitational acceleration
- Force of attraction is bigger when the mass is big
- Weight is proportional to acceleration
- Bigger mass have bigger gravitational acceleration

Category B: Both at the same time

- Same gravitational acceleration
- When you throw an object upwards, the force on each object is equal
- Force of gravity equal, irrespective of mass.

The last two bullets show that students opted for correct answer but had incorrect reasons because it seems as if they still did not differentiate between the force and acceleration.

Category C: Same with conditions (Ignoring air resistance)

- Same only when air resistance is ignored
- In free fall air resistance is ignored

Category D: Smaller object will reach first

- Smaller mass moves faster because the smaller the weight the faster it is attracted by gravity
- Smaller object can be much quicker than big object

Students were each instructed to take only two objects (which were mostly a rubber and a pen) and let those two objects fall from approximately the same height and then to observe the motion. They were also instructed to repeat the process several times to check if they would get the same results. During the process, most students were amazed by what they were observing and did not believe their observation because they had a strong belief that bigger objects in terms of mass would reach the ground first.
One student said: “Sir, I don’t trust my eyes because I strongly do not believe what I am seeing. The statement suggests that “seeing” does not make them “believe”. Some said they could only believe if I could guarantee them that there were no air resistance or that air resistance was ignored. For example, another student said: “According to my knowledge, it is only when there is no air resistance when objects of different masses fall at the same time”.

In trying to help students understand, the instructions and questions that followed were used in WCD to lead students towards a qualitative understanding of the concepts weight and gravitational acceleration. The students had to consider two objects of different mass, 100kg and 10kg and then had to perform the exercise individually. Before they proceeded to the next question, they were instructed to discuss their individual solutions with the whole class and agree on the correct answer. The instructions were:

(a) Calculate the weight of each object
(b) Then calculate the gravitational acceleration of each object

(c) Explain the following: what does it mean about the motion of an object if its acceleration is 10 m/s^2?

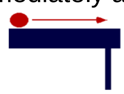
(d) Then what will be the velocity of each object after 1s, 2s and 3s?

(e) Then find the position of each object after 1s, 2s and 3s

After doing the above activity, most students were able to conclude with confidence that the two objects would fall at the same rate because they were all under the same influence of gravitational acceleration. The results of FCI on the same question in a posttest showed that WCD was effective since 40 students in the sample got it correct compared to 12 in the pretest.

5.2.8 Activity 8: Ball moving with constant velocity towards the edge of a table

Question:
Predict and draw the motion of the ball immediately after it reaches the edge of the table.



Both WCD and CS were used in this activity. The students' predictions were categorized into A (the accepted scientific path), B (the ball falls directly downwards), C (the ball first travel in a straight line and then falls down) and D (the ball falls at a fixed angle to the ground). Only 7 (15%) students gave the correct answer in the FCI pretest while in this activity 24 (34%) students got it right as shown in figure 5.13.

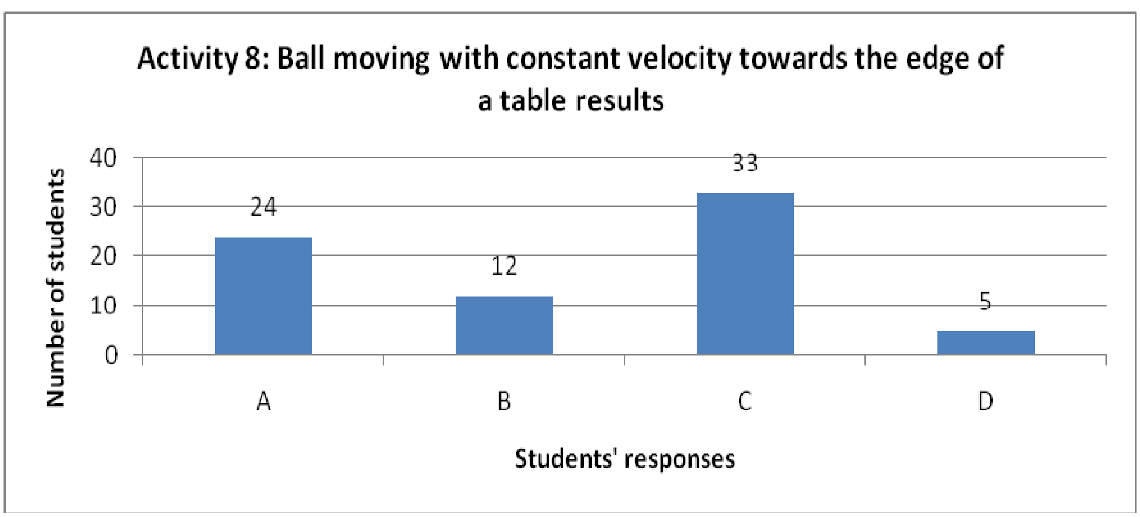


Figure 5.13: Ball moving constantly towards the edge of a table results

One can be tempted to conclude that perhaps the interactive nature of the models of instruction used could have had a positive effect, but at the same time, room for further research to confirm the claim need to be explored. A summary of some of the notable interesting reasons given by the students for selecting their options were as follows:

Option A: Air resistance makes the ball to curve and the gravitational force changes its original direction.

Option B: Because the only force that is acting is the force of gravity that usually acts directly downwards another reason was that a solid base is preventing the ball from falling downwards.

Option C: The ball will continue moving with 2 m/s just after it leaves the edge of the table and stop at certain point and then due to gravity the ball will go down with g.

The reasons given by students were not new in PER, especially A and C.
In other words, the problems students have about motion were similar to those reported by Halloun and Hestenes (1985). Those who selected option D were not able to explain their reasons, and were therefore not included.

After students discussed their responses through WCD, the activity was then repeated as a demonstration using CS on a data projector. The computer simulation display on the screen is shown in figure 5.14.

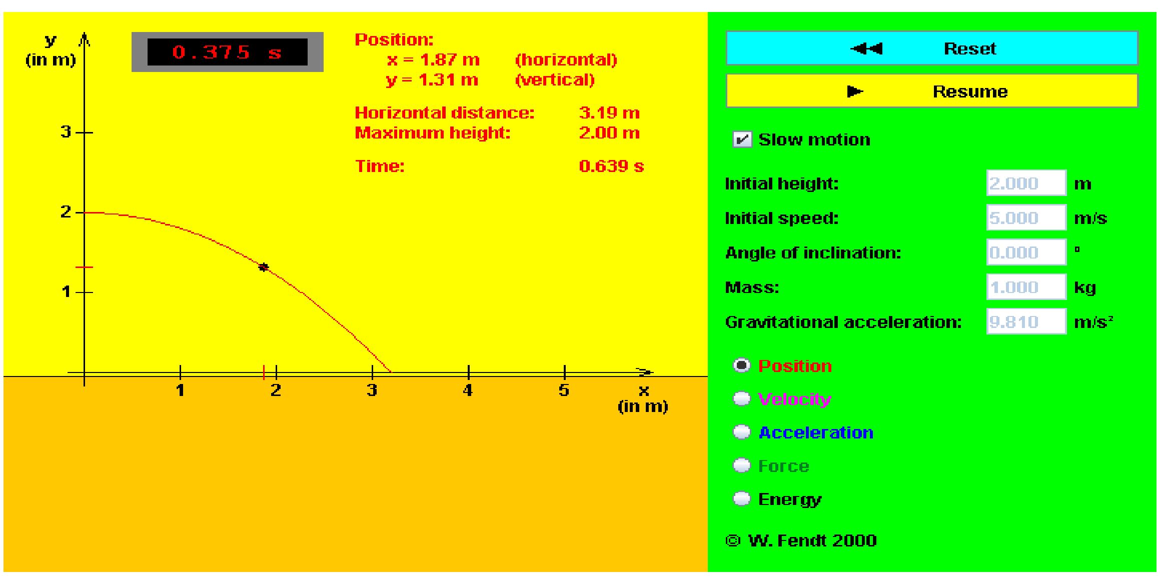


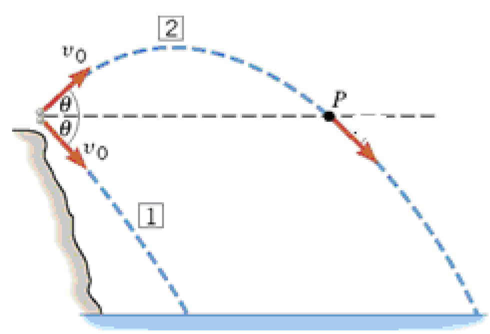
Figure 5.14: Ball moving constantly towards the edge of a table computer simulation display screen

After looking at the screen, students were again instructed to reconsider their previous answers and then in pairs, give reasons for sticking to their answers or for changing it. The ball was represented by the black dot in the simulation. After students observed the path of the black dot as shown in figure 5.14, they nodded their heads and some even said: "*Ahaa! Now I can see why*." The fact that half of the sample got it correct in the posttest shows that the intervention through both WCD and CS simulations helps students to apply knowledge in different contexts. Applying knowledge in different contexts is a sign of understanding.

5.2.9 Activity 9: Two ways to throw a stone

In this activity WCD was first used then followed by CS in the computer laboratory where students shared a computer in groups of two. Only 69 students were present in class.

Question:
From the top of a cliff, a person throws two stones. The stones have identical initial speeds and masses, but stone 1 is thrown downward at some angle θ below the horizontal and stone 2 is thrown at the same angle θ above the horizontal as shown on the diagram. Neglecting air resistance, which stone, if either strikes the water with greater velocity? Circle the correct letter that represents your option and give reasons for your answer.



A. Stone 1 will strike the water with greater velocity
B. Stone 2 will strike the water with greater velocity
C. Both stones will strike the water with the same velocity

As usual, students were first asked to predict their solutions. Their solutions were quickly scanned and then grouped according to similar choices. Refer to figure 5.15 for the students' different responses. The correct answer was option C. Figure 5.15 shows that 33

(48%) of the students answered correctly. Representatives from each group were called to present their solutions.

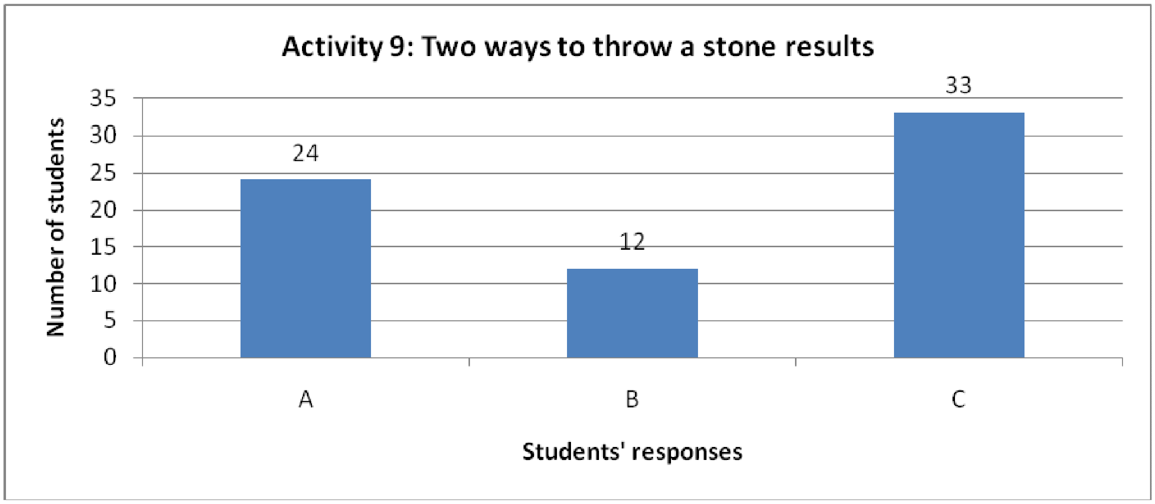


Figure 5.15: Two ways to throw stone results

Some of the conversations of each group with the whole class were as follows:

Group A:

One person from one of the groups that selected A was called to come and convince the whole class why they selected A.

Student A: The group opted for A because stone 2 will take a longer journey by first reaching the maximum height and then comes back while stone 1 will be moving to the surface. Hence Stone 2 will strike the water with greater velocity because g would have acted for a longer time than for stone 1.

One student from other groups asked: What was the question? Did the question asked for time or to compare velocity?

Student A: Ok, It means stone 2 will reach the water with greater velocity

Other Students: We are not convinced about your explanation?

Another Student from Group A: Another reason was that the “effects of air resistance on stone 1 is less than on stone 2.”

From this group one can conclude that its members did not understand the vector nature of velocity. They concentrated on comparing the time the stones spent in the air with velocity because it seemed as if students thought that velocity increased with time.

Group B

One student from group B volunteered to defend their option. The conversation was as follows:

Student B: The main reason is that Stone 1 will travel a shorter distance than stone 2. Hence stone 2 will have a greater velocity that was accumulated after the long distance it traveled. Stone 2 covers and reaches a maximum height and as it falls, it gains more speed than stone 1.

Lecturer: Do you mean that its acceleration is greater than that of stone 1?

Student B: Yes, sir, you can see that when it falls from that height (indicating the height on the board).

Class representative: What is the acceleration of stone 1?

Student B: It is 9.8 m/s^2

Class representative: What is the acceleration of stone 2?

Student B: Is still 9.8 m/s^2

Class representative: Then why are you saying that Stone 2 will have greater velocity?

Student B: Stone 2 was affected by the change in motion or direction where as stone 1 was not affected. That caused stone 2 to gain greater velocity than stone 1.

Another reason given by other groups who selected B was that stone 1 moved with constant motion because it just went down, whereas stone 2 was affected by gravitational forces and increases in velocity. From the statement, it was clear that the students understood the presence of gravitational force, but that they were unable to understand its effect on a moving object.

Group C

All the representatives of this group explained their solutions by first drawing a representation of the problem and then explaining with reference to the diagram.

One of the representatives of group C did the following:

He first drew the diagram in figure 5.16 on the board and then asked the whole class the following questions after presuming that the initial velocity is 20 m/s:

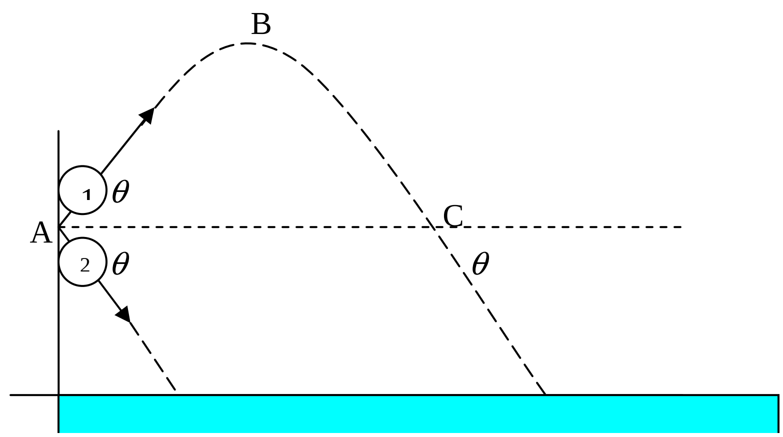


Figure 5.16: Student's geometrical explanation of the results

Student C: What will the final velocity be at point B?

Class: 0 m/s because it is the maximum height.

Student C: What will the magnitude of the velocity at C be?

Class: -20 m/s

Student C: Since the object was accelerated by g then immediately from C they will have the same initial velocity and hence they will both have the same final velocity just before they reach the surface of the water.

After the student explained, the whole class was convinced. They spontaneously clapped their hands and nodded their heads. During this activity, students helped one another to learn using WCD and at the same time, the lecturer identified the misconceptions students had.

The question in this activity probed the students' qualitatively understanding of the vector nature of velocity because in the problem, the resultant velocity of stone 2 from the origin to where it started on the dotted line position C (Refer to figure 5.16) was zero. It was very difficult for the students to realize that. What was surprising was that when they were dealing with falling bodies they were able to deal with calculations correctly. In this activity, 11 groups which translate to 33 (48%) students opted for C (as shown in figure 5.15) which was the correct answer.

After the discussions that took about an hour, students were instructed to use the simulation to check if their answers were correct or not. The simulations took about 20 minutes and in the last 20 minutes the solution was explained using the equations of motion. In the computer simulations, students were instructed to read the final velocity when it reached the horizontal axis of the simulation as shown in figures 5.17 and 5.18. In figures 5.17 and 5.18, the students were surprised to notice that the magnitude of velocity was the same (8.01 m/s) when the projection was done using two opposite angles, i.e. 30^0 and minus 30^0.

Another notable fact was that the students saw was that both figures had the same inclination angle of -57^o. The CS in this activity was done as a re-enforcement of the qualitative WCD conducted previously and lastly, the final velocities of each stone was calculated using the equations of motion.

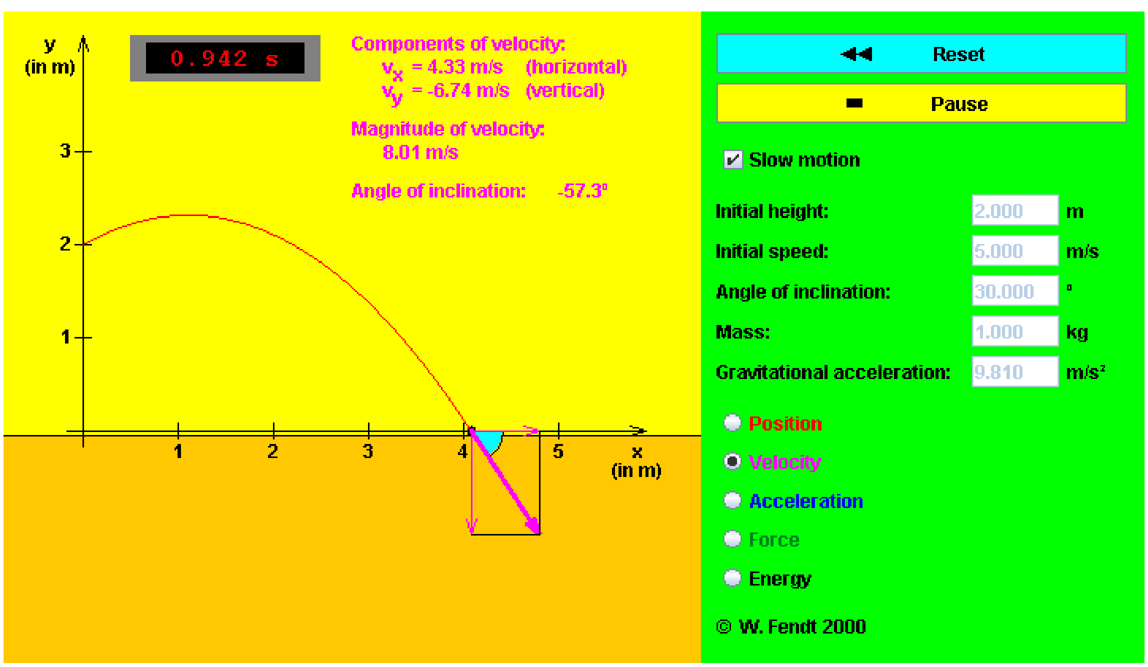


Figure 5.17: Throwing a stone at a projection angle of 30^0

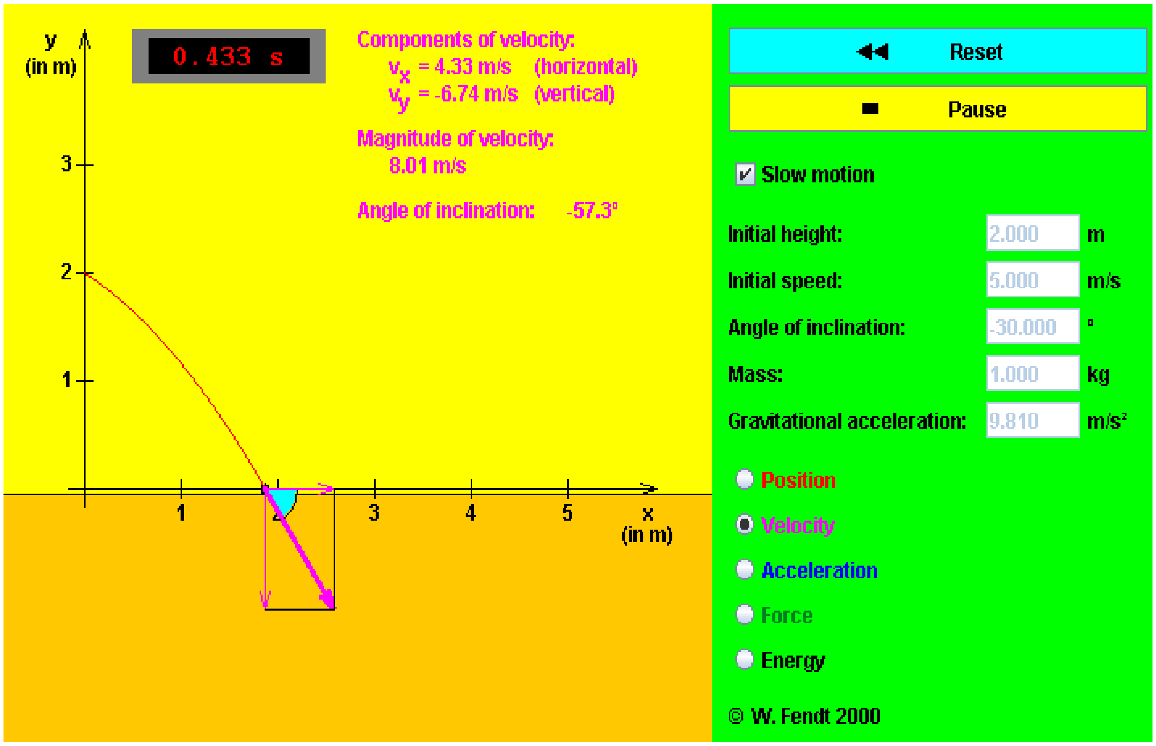


Figure 5.18: Throwing a stone at a projection angle of minus 30^0

After calculations, students were instructed to repeat simulations using different opposite angles in terms of signs. In this activity, both WCD and CS were effective in minimizing some of the misconceptions students had about velocity. However, it cannot be claimed that all their doubts were taken away because of a lesson learnt in activity 7, where some students did not believe what they saw.

5.2.10 Activity 10: Bullet shot into air from a moving convertible car

The activity was done in groups of three students. Students were told to discuss the solution and select the suitable for the group giving reasons (70 students participated in the activity).

Question:
Suppose you are driving a convertible with the top down.
The car is moving to the right at constant velocity. You point a rifle straight up into the air and fire it. In the absence of air resistance, where would the bullet land?

A: Behind you,
B: Ahead of you
C: In the barrel of the rifle?

This activity was done after motion in two dimensions was treated in activity 5. The activity was most challenging to most of the students. The correct option was C and it was very difficult to convince students that C is the correct option. The computer simulation displayed using the data projector was powerful in showing students that, during projectile motion the velocity along the horizontal-axis remains constant. Figure 5.19 represents results of the students' responses to the activity. The results in figure 5.19 show that only 15 (21%) students answered the question correctly while 55 (79%) answered it incorrectly. The results suggest that students still had difficulties in understanding the fact that the horizontal component of the velocity remains constant while the vertical one changes due to the gravitational acceleration.

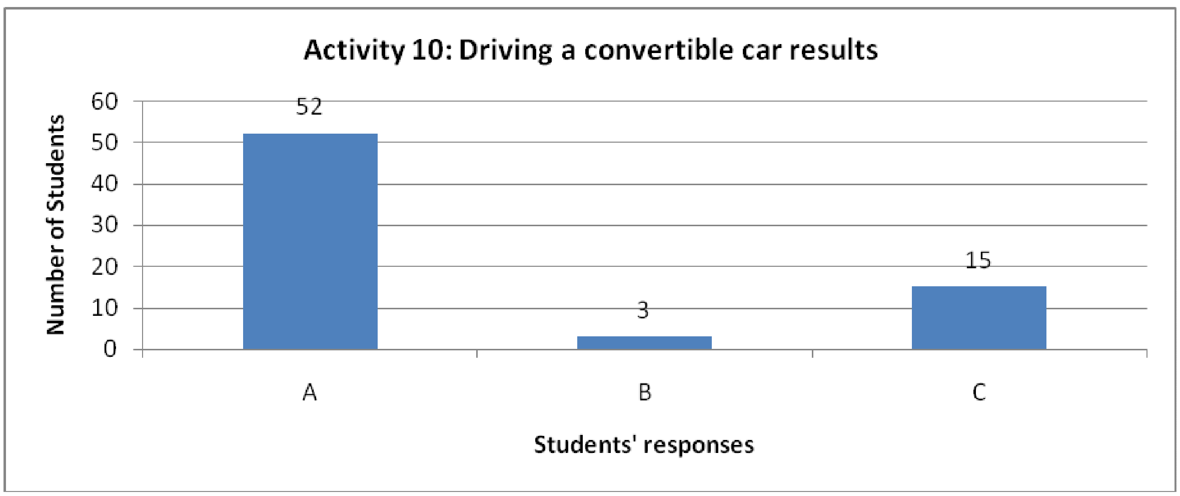


Figure 5.19: Bullet shot into the air from a convertible car results

Legend:

A. behind you,

B. ahead of you, or

C. in the barrel of the rifle

The poor performance in this activity was not expected because the activity about gravitational acceleration had been done previously (activity 6). From this activity, the conclusion could be that CS assisted the students to understand some of the difficult concepts like projectile motion. After the simulation, most students indicated that they understood the reason why the bullet would fall back into the barrel of the gun.

5.2.11 Activity 11: Motion in two dimensions

Activity 11 consisted of parts, 1 and 2. Part 1 was aimed at improving the students' observation and deduction skills. This activity was also done as a follow-up and re-enforcement to the results found in activities 6 and 10. They were instructed to observe the motion of a projectile under different conditions caused by the manipulations of variables like projection angle and initial speed.

Part 1: Instructions: Take g = 9.8 m/s^2 and m =1 kg

Go to a file **PED** in my document. Double-click **ph14e open box**, then **extract** and double click **ph14e**, double click **projectile**. On the top yellow bar click and **allow blocked content.** Then Yes. **Press reset** and set the **initial height to be 0 *m*** and initial speed to be 5m/s. set the initial inclination angle to be **15^0**. Then press start and observe the motion. When it stops record the horizontal distance (R) and maximum height (H). Then click on the velocity on the bottom right. Then reset and start. Observe the motion carefully then record values of (v_x , v_y and v) when it stops. Follow the same procedure and complete the whole table

v_0	ø	R	H	v_x	v_y	v
	15					
	30					
	45					
	60					
5	75					
10						
15						
20						
25	45					

Follow-up Questions:

1. What can you conclude about the magnitude of the horizontal component of the velocity throughout the motion of the projectile for each angle ø?
2. What happens to the vertical component of the velocity throughout the motion of the projectile angle ø?
3. What is the magnitude of the angle that gives the maximum range? Give reasons
4. Is there any relationship between the projection angle and the maximum height reached in a projectile motion? If yes, explain. If no, explain.

It was expected that the students would not have any difficulty in answering follow-up questions 1 and 2 because similar questions had been answered in some of the previous activities. Part 2 was aimed at equipping the students with skills to generalize solutions after several observations and to give reasons for their generalized solutions. In this activity, the number of participants differed per question because some of the students skipped answering some questions.

The results of part 1 of the activity are shown in figure 5.20. In follow-up question 1 and 2, all students participated and were expected to give the correct answer but, the results were against the expectation.

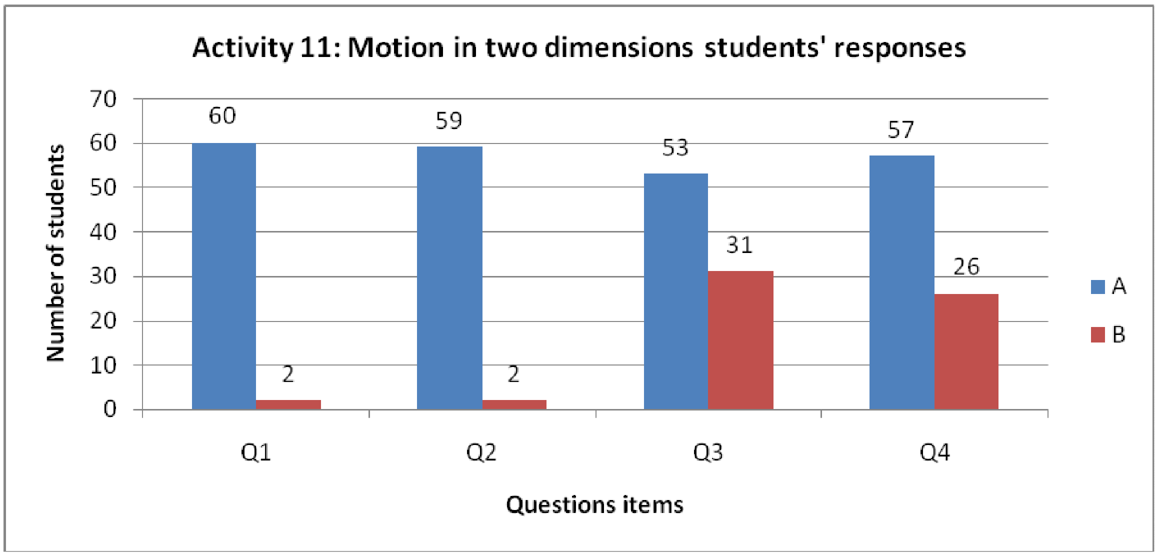


Figure 5.20: Motion in two dimensions CS activity results

Legend:
A: Number of students who answered the question
B: Number of students who partially answered the question correct

No student managed to answer these two questions satisfactorily. For example, only 2 students answered both questions partially correctly. These results were disappointing because it seemed as if the students did not recognize the similarity of this activity to the previous ones. The results of question 3 and 4 were better but not acceptable because 31 (59%) and 26 (46%) had partially correct answers. In question 3, the students were expected to carefully observe and make conclusions based on their observations while question 4 was about finding a relationship between the projection angle and the maximum height reached. This was a tricky question because increasing the projection angle does not necessarily mean that the maximum height will keep on increasing. In this activity, the CS was not successful in helping the students to make relevant predictions and conclusions. One of the reasons could be that, most of the students were only interested in writing down the correct answer. For example in figure 5.22 it was expected that all students who answered all questions should be 60, but looking at question 2, 3 and 4 have different total number of students who attempted to answer those questions.

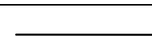
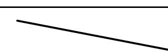
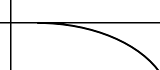
Part 2:

Part 2: Instructions
Press Reset. Then change as follows
Keep initial velocity at 5 m/s, the projection angle 0^0, and initial height 5.0 m and then vary the gravitational acceleration (g). Each time you change g, observe the motion of the object carefully. For consistency start with g =10 m/s^2 and then reduce the values of g it until g = 1 m/s^2 which is the minimum. After observing the motion of the object for several times, you can repeat several times, then predict the motion of the object when g = 0 m/s^2 .

Question:
Draw a rough sketch to indicate your prediction. Give reasons for the shape of the sketch you have drawn.

After playing with the computer simulations, changing the values of gravitational acceleration and observing the shape of the graph, the students were expected to predict the shape of the graph of the motion of an object when gravitational acceleration is zero. It should be noted that the simulation program was programmed in such a way that the gravitational acceleration could not be set to zero. The activity was done to explore if the students would be able to apply the knowledge of gravitational acceleration in different contexts. The results are shown on table 5.2.

Table 5.2: Motion in two dimensions part 2 activity results

	A	B	C	D
Shape of graph				
No of Students	5	13	15	30

In terms of predicting the shape of the graph, it seems most of the students did not consider the fact that the prediction must be made after the observation of the effects of changing gravitational acceleration on the shape of the graph. The results of this activity again confirm that computer simulations were not effective in helping students to apply knowledge gained in simulations to different contexts. The students noticed that when gravitational acceleration is decreased, the horizontal distance increases. They were unable to think beyond this through. It was presumed that all students would draw the correct shape of the graph since they knew that gravitational force caused objects to fall downwards and that no gravity means that there would be no downward force of attraction. Figure 5.21 represents one of the shapes of the graph similar to A in table 5.2.

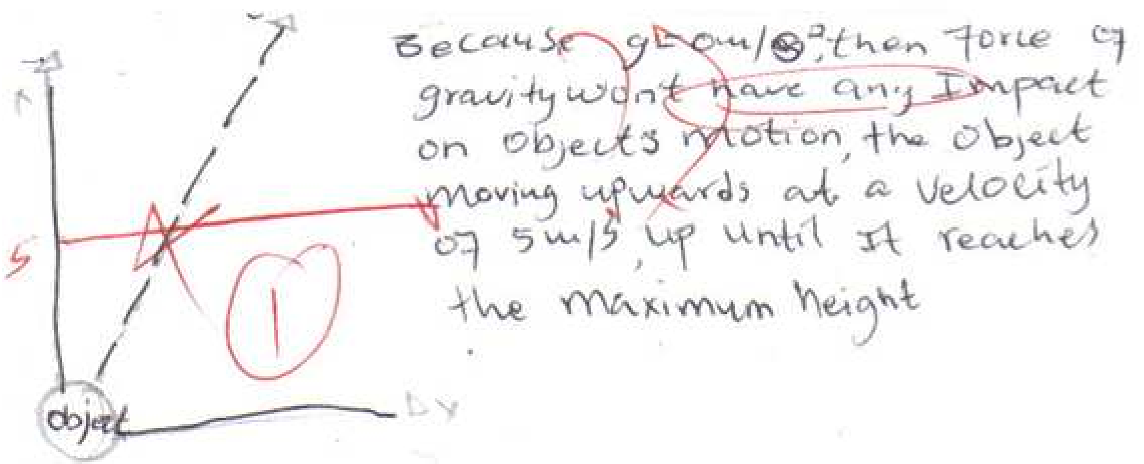


Figure 5.21: A sample of students' results of those who drew a graph similar to shape A on Table 4.7

Some of the reasons given by those students who drew a graph similar to shape C

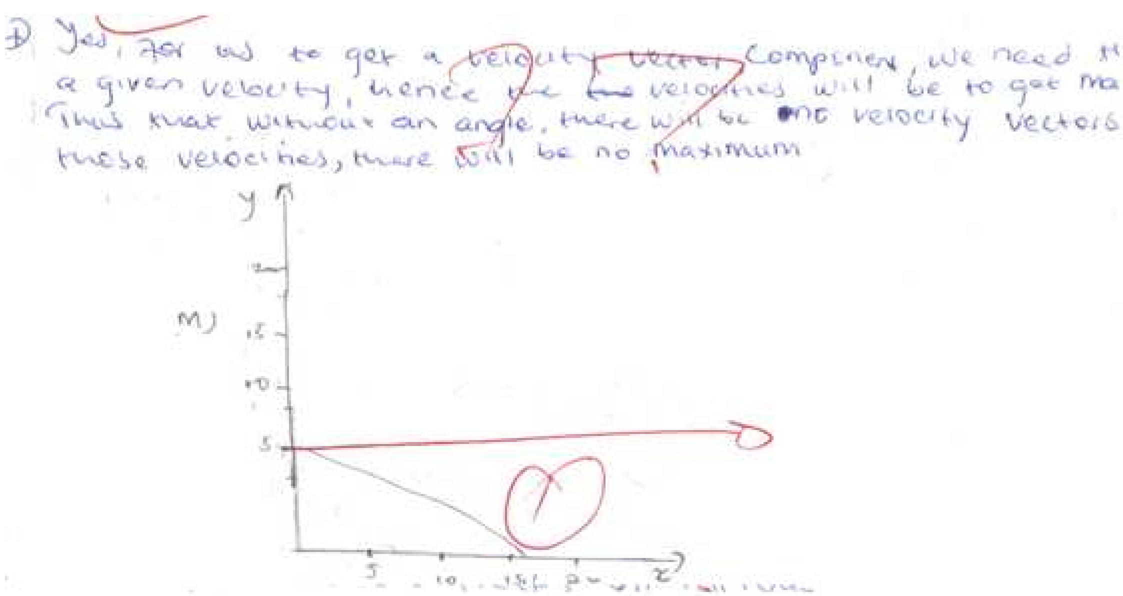


Figure 5.22: A sample students results of those who drew graph similar to shape C on Table 5.2

From the reason given, it can be concluded that the students usually solve physics problems using a formula because they only want to substitute given data.

One of the graphs drawn similar to shape D is shown in figure 5.23

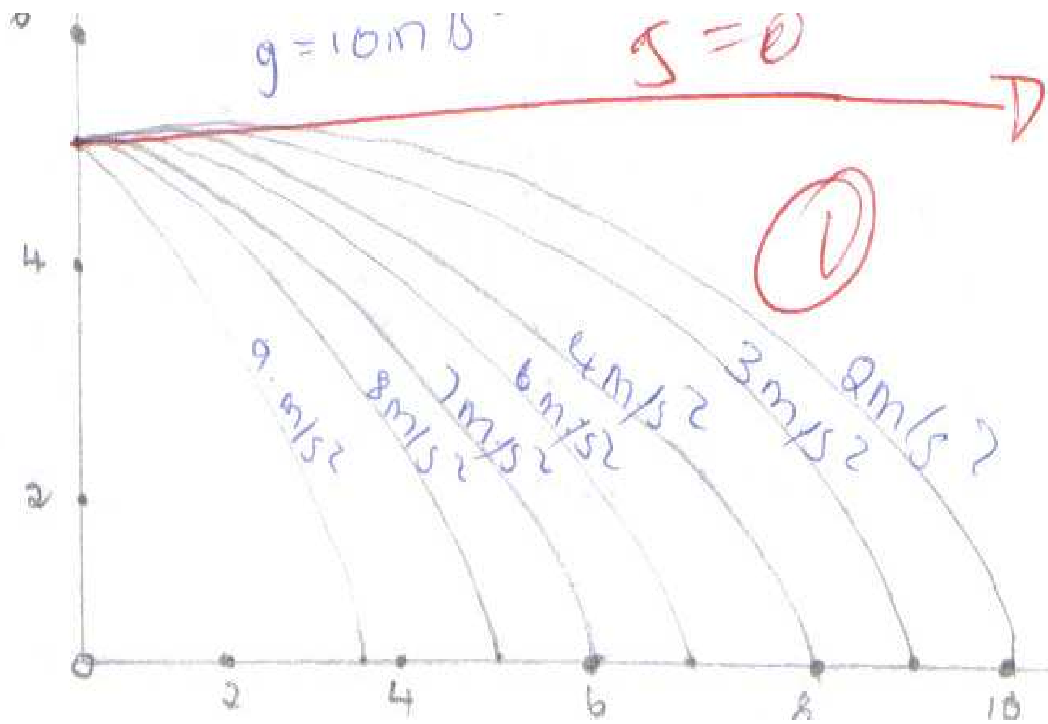


Figure 5.23: A sample students results of those who drew graph similar to shape D on table 4.6

The results of part 2 in this activity suggest that the students were able to observe patterns, but at the same, time unable to realize that if g = 0 m/s^2, then the object would continously move horizontally. This activity had an open-ended question which required students to predict and draw the shape of the graph. It seems as if the computer simulations distracted the students from their normal way of understanding. It was not expected that students would opt for C because a problem like this had been dealt with in activity 8. Looking at the reasons given by students who drew the similar graphs, the study conclude that CS did not help students to predict that the the shape of the graph would be a horizontal straight line.

5.2.12 Activity 12: Elastic and Inelastic collisions

Part 1: Instructions

Go to a file **PED** in my document. Double click **ph14e open box**, then **extract** and double click **ph14e**, double click **collisions**. On the top yellow bar click and **allow blocked content.** Then Yes. Set the masses of both wagons to be 0.5 kg, initial velocity of wagon 1 to be 0.2 m/s and the velocity of wagon 2 to be 0 m/s. First click ***elastic*** on the top right hand corner and then observe the motion of the wagons carefully. Do it several times. Click reset and then start again. Also observe the slow motion. Then fill in the Table 1 by clicking velocity, momentum and kinetic energy. Repeat the same procedure by clicking ***inelastic*** to fill Table 2.

Table 1

Elastic Collision	Before Collision			After Collision		
	Mass	P_o	E_{ko}	v	P	E_k
Wagon 1	0,5					
Wagon 2	0,5					
Total						

Table 2

Inelastic Collision	Before Collision			After Collision		
	Mass	P_o	E_{ko}	v	P	E_k
Wagon 1	0,5					
Wagon 2	0,5					
Total						

Follow up questions:

Analyze the magnitudes of velocities, momentum and kinetic energy before and after collisions for both elastic and inelastic collisions. Based on your analysis of table 1 and 2 answer the following questions:

1. What is difference between elastic and inelastic collisions?
2. Assuming the collision is ***elastic*** and if the initial velocity of Wagon 1 is $0.4m/s$ .Without doing any calculations what do you think will be the final velocity of each wagon after collision? Give reasons for your answer.

   Answe*r: Wagon 1-----------, Wagon 2-------------* ***Reasons***:------------------------------------
3. Assuming the collision is ***inelastic*** and if the initial velocity of Wagon 1 is 0.4 m/s. Without doing any calculations, what do you think will be the final velocity of each wagon after collision?

   Answer: Wagon 1-----------, Wagon 2------------ Reasons*:* -----------------------------------
4. During collision, If $E_{k(before)} \rangle E_{k(after)}$ then the collision is -----------and if $E_{k(before)} = E_{k(after)}$ the collision is ----------------
5. In any collision, is it possible to have $E_{k(befrore)} \langle E_{k(after)}$? Give reasons for your answer.

This activity was aimed at helping students to understand the difference between elastic and inelastic collisions qualitatively. Figure 5.24 represents the answers given by students. The problem of language was evident in this activity. For example one student wrote:

> "In the inelastic collision, bodies stay or move together while in elastic collision bodies repels."

It can be deduced that the student knew exactly what he or she was trying to say but was unable to express it due to language difficulty.

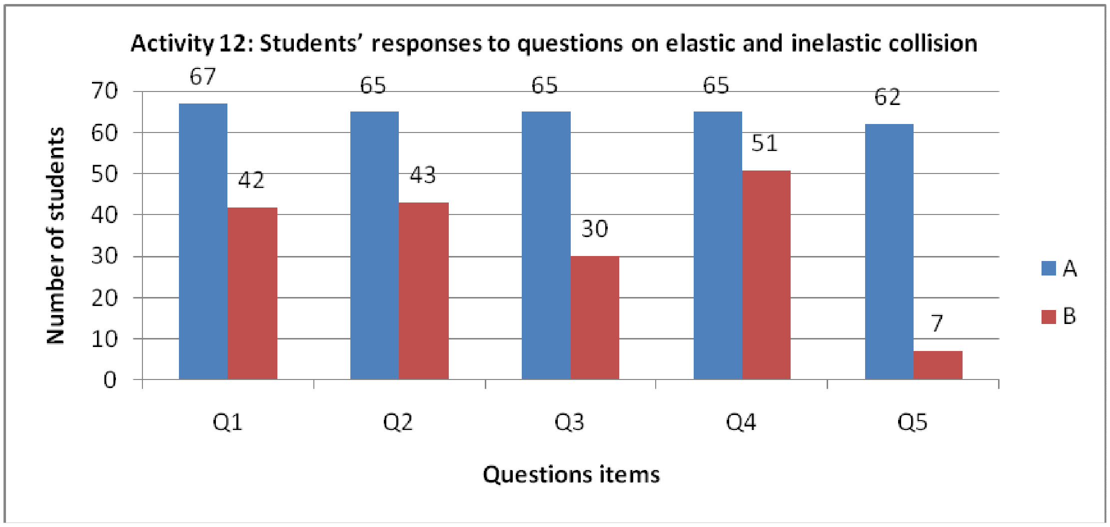


Figure 5.24: Students' responses to questions on elastic and inelastic collision

Legend:
A: Number of students who participated in answering the question.
B: Number of students who answered the question correct

When answering question 5, it seems students did not even look at the values on the table they filled for elastic and inelastic collisions.

5.2.13 Overall conclusions about WCD and CS activities

Generally , the results of WCD and CS activities suggest that both models have a greater potential of enhancing students' conceptual understanding of Newtonian mechanics. For example, in activity 1, WCD was effective in helping the students understand the difference between instantaneous speed and average speed, as well as to understand instances in which speed kills or not. The activities also revealed some of the misconceptions students have. CS helped students to understand the directions of velocity and acceleration, but failed when used alone, to help students to make reasonable predictions and conclusions in activities 11 and 12.

CHAPTER 6: ANALYSIS AND DISCUSSIONS OF RESULTS

6.1 FCI pre-and post tests results

In this section, both FCI pre and post tests were used in conducting t test and, in calculating the average normalized gain.

6.1.1 Descriptive Analysis of FCI post-test results

Table 6.1 indicates a descriptive summary of both the pre and posttest results. As shown on the table, pretest scores range from 2 (7%) to 12 (40%) while the posttest scores range from 5 (17%) to 16 (53%). That shows a slight increase in terms of the number of students who scored at least 17% after the intervention. The percentage class mean for both the pre- and posttests are 6 (21%) and 10 (32%) respectively. The percentage pretest mean is less than the pretest mean as expected from the literature. For example, the most typical class average scores for students entering an algebra-based introductory physics course in FCI pretest are between 30% and 45% (Redish, 2003). The pretest and posttest means were better when compared to means obtained in the pilot FCI results as shown in table 4.1.

Table 6.1: Summary of 2008 FCI pre/posttest results.

Variable	N	Mean	StdDev	Minimum	Maximum	Skewness
FCI Pretest	48	6.15 (21%)	2.66	2	12	0.45
FCI Posttest	48	9.52 (32%)	2.68	5	16	0.51

Below is an explanation of each of the columns above.
N: The number of participants for each variable.
Mean: The average value or the arithmetic mean for the variable.
StdDev: The standard deviation - an indication of how closely values are clustered around the mean.
Minimum: The smallest value obtained for a variable.
Maximum: The largest value obtained for a variable.
Skewness: An indication if the distribution of values are symmetrical or not

The skewness values of 0.45 and 0.51 in both pre and posttest respectively show that few students managed to score higher than the mean. The skewness value greater than zero, implies that both FCI pre and posttest were difficult to students. Looking at the frequency distributions of the scores in figure 6.1 it can be seen that only 12 (25%) students in the pretest, fall within Redish's scale (of between 30% and 45%) while 75% fell below 30% after intervention.

The FCI posttest's class average results of 32 % also did not fall in Redish's scale of between 40% and 50% even when the test was written after Newtonian mechanics was completed at the end of the second semester just before students write half yearly examinations. Figure 6.1 shows that only 9 (19%)students managed to score between 40% and 50% while only one student who scored more than 50% (53% to be exact) fell in the Redish's scale after intervention using WCD and CS models.

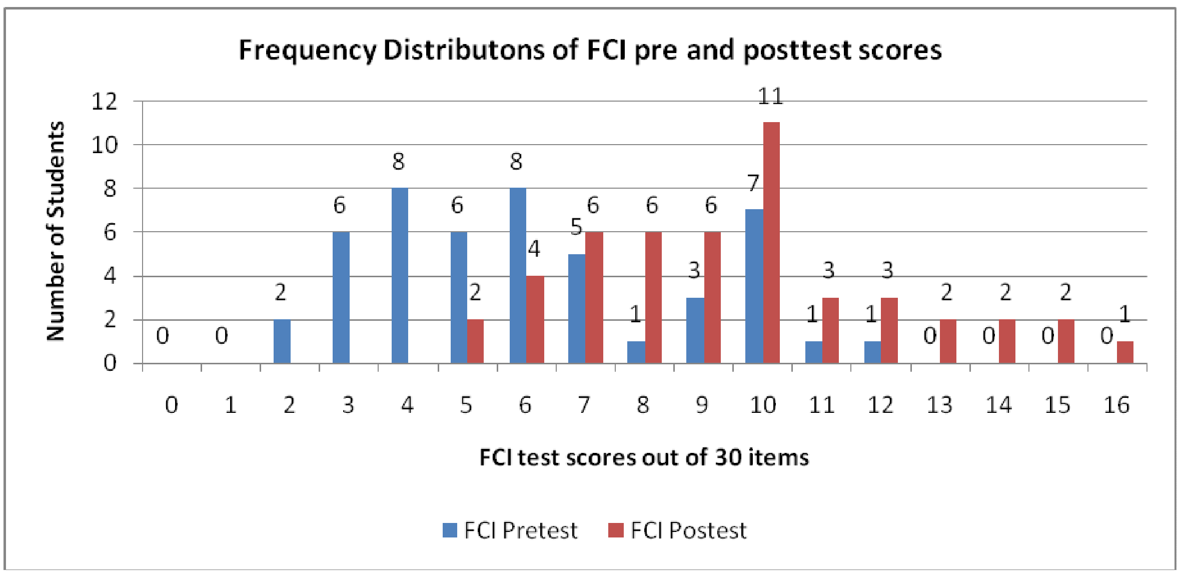


Figure 6.1: Frequency Distributions of FCI scores in Pre and Posttest

The analysis of frequency distribution of correct answers per question on FCI as shown in figure 6.2 indicated that:

- no change occurred in both the pretest and posttest (Questions 23 and 25)
- positive changes occurred in most questions (Questions1-4,7, 8,12 -16,20,21,24,26 - 30)
- negative changes occurred only in nine questions (Questions 5, 6, 9-11,17 -19, 22)

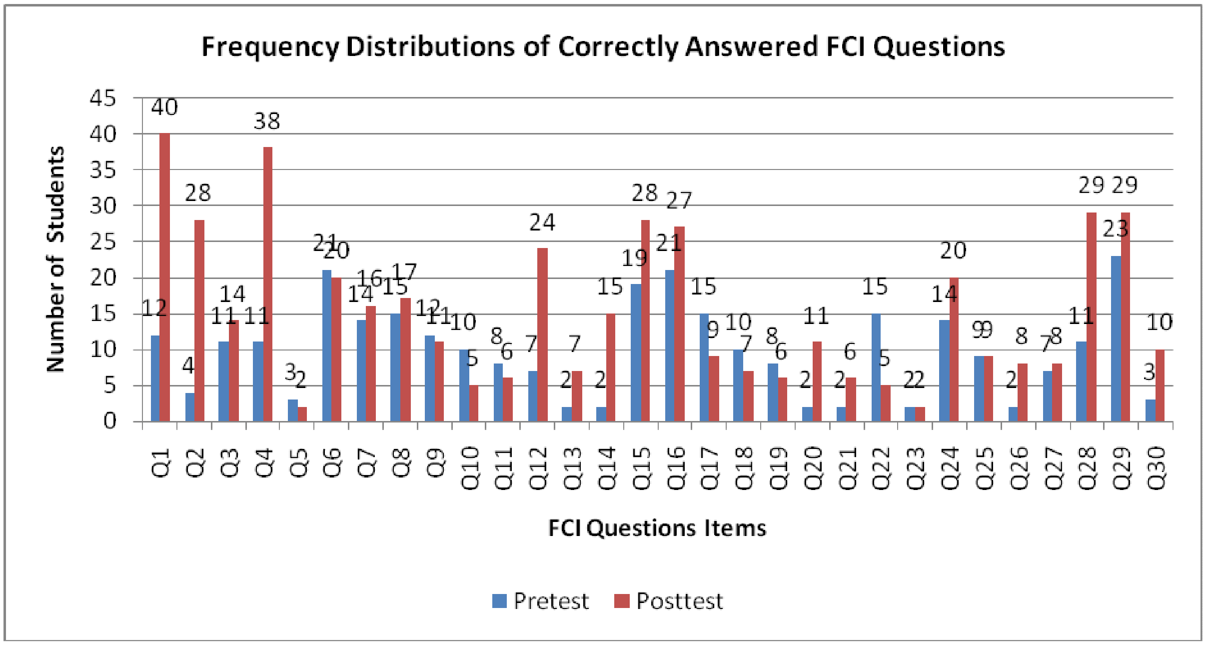


Figure 6.2: Frequency distribution of correctly answered FCI questions

The changes in the FCI scores in the pretest and posttest support the idea that the effect of distracters changes during the course of instruction (Rebello & Zollman, 2004). Rebello and Zollman (2004) further suggested that the analysis of incorrect responses to FCI questions may not be an effective way of identifying deficiencies in students' conceptual understanding of Newtonian mechanics. However, negative changes that occurred in some questions could have been caused by the fact that the related content was not covered during interventions, for example, circular motion. Since all students were English second language speakers, the study cannot rule out the impact of language on the FCI test items, as the other possibility of low performances by students. Pearce and Le Roux (n.d.) also reported the negative impact of language on FCI scores in South Africa.

Looking at the low scores both in the pretest and posttest, one could conclude that even after intervention using the WCD and CS which are interactive-engagement models, students still had some misconceptions, and hence the study supports the idea that misconceptions are mostly resistant to change and that conceptual change is not a quick and simple process (Grayson, 2004). Amongst physics education researchers, the general agreement is that, a low FCI test score indicates a lack of understanding of basic concepts in mechanics (Hake, 1998). Generally, the descriptive FCI results have shown that there was an improvement in average class performances because the percentage class mean changed from 21% to 32% after intervention using WCD and CS. The performance in the posttest was disappointing since only 3 students managed to get a percentage greater than or equal to 50. In other words, 94% of students scored less than 50% in the posttest.

6.1.2 The average normalized gain results

In order to interpret the results of the FCI pre and posttest better, Hakes (1998) suggested the use of the percentage average normalized gain <g> described in section 3.12.3. Table 6.2 contains the data used in calculating the average normalized gain. The calculations of the average normalized gain in the study using Hake's formula yielded $\langle g \rangle$ = 0.14 = 14%

Table 6.2: Data used to calculate <g>

	Mean (%)	StDev (%)
Pretest	20.5	8.86
Posttest	31.7	8.94
<G>	11.2	
<g>	15.0	

Where <G> is the actual gain, <g> the average normalized gain and StDev, the standard deviations from the mean.

Interpreting the average normalized gain using Hake's scale, a value of 0.15 (15 %) implies that this result is comparable to the results from settings where the models of instruction used were traditional in nature. This is in contradiction with the current study where interactive WCD and CS models were used. Fully interactive-engagement models of instruction are said to be associated with average normalized gains in a region greater than 0.7 or 70%. The low <g> for the FCI was also reported in South Africa by Pearce and Le Roux (n.d.) at the University of Cape Town's Department of Mechanical Engineering using both traditional and interactive-engagement models of instruction. The use of both traditional and interactive-engagement models is presumed to yield the average normalized gain of between 30% and 70% because they are classified under medium <g>

courses (Hake, 1998). Pearce and Le Roux (n.d.) suggested language as the possible cause for the low average normalized gain.

Comparing the FCI results with that of the pilot study (see figure 4.1) in which traditional teaching models were used, it can be seen that there is a slight improvement of the average normalized gain. The FCI average normalized gain in this study was very small when compared with other countries as shown in figure 6.3. In terms of the interpretation of <g>, the advice was to note that good performance on these tests like FCI should not be viewed as a sufficient condition for the attainment of proper conceptual understanding (O'Brien Pride, Voskos, & McDermott, 1988). The statement suggests that other factors need to be considered when making decisions about the implications of the results of <g>. The results on figure 6.3 were converted to the nearest percentage.

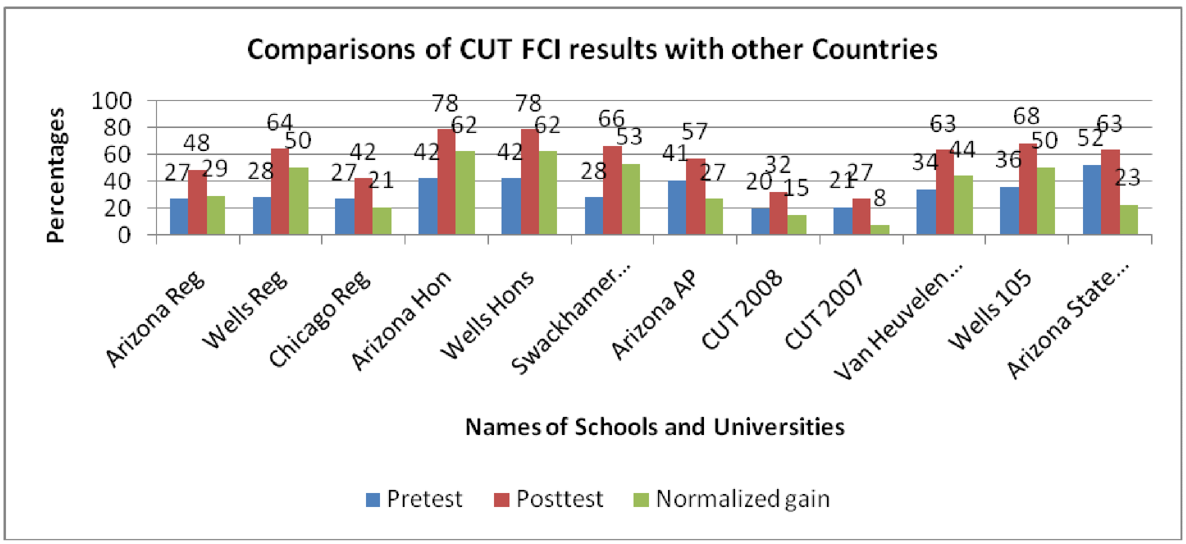


Figure 6.3: Comparisons of FCI results adapted from Table III (Hestenes, Wells and Swackhamer, 1992, p.6)

Since the normalized gain tells about the attainment of minimal conceptual understanding of mechanics (Hake, 2002), the study shows that both WCD and CS induced minimal conceptual improvement in Newtonian mechanics as measured by <g>. One of the reasons that could be the cause of the low <g> according to the literature, were the students' initial qualitative pre-knowledge and beliefs about motion and this is reported to have an impact on students' performance in physics (Halloun & Hestenes, 1985). For example, in the exercise about speed, students initially thought speeding in South Africa is traveling above 120km/h. That showed the lack of qualitative understanding of the concept speed. The low average normalized gain of FCI scores seems to support the idea that: "Teaching science for understanding is a complex issue" (Gabel, 2003, p. 75).

6.1.3 FCI Paired t-test results

A *t*-test was conducted on the overall pre and post-test data to examine the differences between the pre-test and post-test and the possible impact of instruction. In this study, at 1% level of significance, the p value was 0.000, which is smaller than 0.01. This suggests that there is a 99% or better probability that there was a statistically significant difference between the means of the pre and post-tests. The means of the tests are statistically significantly different at the 1% level ($t = 7.45 > 2.408$; $df = 47$; $p = 0.00$). There is a difference of 3.38 between the two means. The conclusion is that the mean difference between the paired observations is statistically significant.

Even when the average normalized gain is low, the t - test results calculated using the Moonstats program indicated that the change was probably due to intervention using Whole Class Discussions and Computer Simulations. The conclusion drawn from both the FCI average normalized gain and t-test suggests that both whole class discussions and computer simulations models enhanced students' conceptual understanding of Newtonian mechanics.

6.2 EBAPS pre-and post tests results

6.2.1 The Descriptive Analysis of the EBAPS Results

The overall summary of EBAPS results is shown in table 6.3. The overall class means before and after interventions respectively 1.87 (47%) and 2.36 (59%). The results suggest that there was an actual gain of 0.49 (12%). Another noticeable change was in the range of the scores. The pretest scores ranged from 1.40 (35%) to 2.46 (62%) while posttest scores ranged from 1.78 (45%) to 2.83 (71%). In terms of the distribution of scores around the mean, the pretest had a skewness of 0.15 while that of the posttest was -0.15. The change in magnitude of the skewness of the distribution from pretest to posttest indicates that an equal number of students who did not manage to score higher than the mean in the pretest scored higher than the mean in the posttest. That was a remarkable improvement which shows that both the WCD and CS had an impact in their beliefs about physics as a subject. A descriptive analysis of EBAPS shows that both WCD and CS managed to shift students' beliefs from less sophisticated towards more sophisticated beliefs.

Table 6.3: The Overall summary of EBAPS results

Variable	N	Mean	StdDev	Minimum	Maximum	Skewness
EBAPS Pretest	48	1.87	0.23	1.40	2.46	0.15
EBAPS Posttest	48	2.36	0.25	1.78	2.83	-0.15

Looking at the individual dimensions of EBAPS (see table 6.4), a remarkable change in percentages occur at the nature of learning and evolving knowledge dimensions.

Table 6.4: Summary of EBAPS pre and posttest results per dimensions

	Structure of knowledge	Nature of learning	Real-life applicability	Evolving knowledge	Source of ability	Overall
% Pre EBAPS Mean	41.95	45.31	53.58	31.08	58.75	46.74
% Post EBAPS Mean	50.64	64.17	57.49	55.53	71.87	59.03
% <G>	8.69	18.86	3.91	24.45	13.12	12.28
% <g>	15.31	34.42	8.42	35.48	31.81	23.06

where <G> is the actual gain and <g> the average normalized gain

That is where the actual gains were 19% and 24%. The average normalized gains for these two dimensions were 34% and 35% which is more than the overall normalized gain of 23%. The lowest normalized gain of 8% was seen in the real-life applicability dimension.

This is understandable since many students like physics mainly because of its real life applicability. As shown on table 6.4, students scored differently in different dimensions. The interpretation of results in table 6.4 could be that students had less sophisticated beliefs in one dimension and more sophisticated scientists-like beliefs in other dimensions. The results concurred with Mbajiorgu and Reid (2006). Mbajiorgu and Reid (2006, p. 8) note there are four areas where attitudes in physics are important, namely:

(a) Attitudes towards physics as a subject;
(b) Attitudes towards topics in physics;
(c) Attitudes towards the learning of physics and lastly;
(d) Scientific attitudes.

The results on table 6.4 support the view that epistemologies beliefs differs from one student to another (Trumper, 2006) and that students' interest in physics differs per area (Mbajiorgu & Reid, 2006). Conley, Pintrich, Vekiri and Harrison (2004) showed that students became more sophisticated in their beliefs about sources of knowledge and certainty of knowledge over time. Looking at table 6.4 , the average normalized gain of more than 30% were obtained under the columns which represent the dimensions of the nature of learning, evolving knowledge and source of the ability to learn and is in agreement with Conley, Pintrich, Vekiri and Harrison (2004) who indicated that students became more sophisticated in their beliefs in those dimensions. The overall average normalized gain is 23%. Since the models used in the study were interactive, an overall average normalized gain of more than 30% was expected. The interpretation can be that, WCD and CS models were not able to change students' epistemological beliefs to an expected acceptable level. The results is in agreement with Elby (2001), who claimed that even physics courses that helped students to understand concepts do not produce significant changes in students' epistemological beliefs. The four areas of attitudes towards physics (Mbajiorgu & Reid, 2006) which are in agreement with Trumper (2006) who claimed that the interest in physics is determined by a combination of different factors that vary from one student to another and could be the reason for obtaining the low overall average normalized gain in EBAPS.

6.2.2 The EBAPS t-test results

The t- test was computed using the Moonstats (2001-2002) programme. In this study, the p value was 0.000, which is smaller than 0.01. The results suggest that there is a 99% or better probability that there is a statistically significant difference between the means of the EBAPS pre and post-test. In other words, the conclusion could be that, the means of the EBAPS pre and post-test are statistically significantly different at the 1% level ($t = 9.54 > 2.407$; $df = 47$; $p = 0.000$). There is a difference of 0.491 between the two means. The t-test results show that both WCD and CS had a positive impact on the students' epistemological beliefs towards more sophisticated expert-like beliefs.

6.3 Comparison between FCI and EBAPS results

Attempts were made to correlate the FCI and EBAPS results using the Moonstats (2001-2002) program. The value of r is - 0.02. This could be considered a weak correlation. The p value is 0.909. This means that the correlation is not statistically significant. The conclusion could be that the FCI and EBAPS scores are not statistically significantly correlated ($r = -0.02$; $p = 0.909$). The weak correlation between epistemological beliefs and learning gains were also reported by Peng and Fitzgerald (2006). They found that epistemological beliefs had a significant but low relationship with conceptual learning gain. The results of this study support the view that epistemological beliefs and knowledge have a complex relationship which is not linear, but that at the same time, more sophisticated beliefs are said to be related to better learning (Bromme, Kienhues, & Stahl, 2008) which was shown by the slight increase in the FCI average normalized gain. In this study, students' beliefs were positively affected by the use of WCD and CS. However the results contradicted those of the study by Wendell (2005) as well as Ornek, Robinson and Haugan (2008) who claimed that students' beliefs about physics and learning physics typically do not change or become less expert-like after taking a standard introductory physics course, even when using a research-based curriculum. This study concurs with Ornek, Robinson and Haugan (2008) in terms of the timing of post-tests which is usually just before students start examinations. This results in low performance in post-tests due to the fact that students become more concerned with examinations than a survey. Both the FCI and EBAPS results of this study support the belief that “epistemological interventions could lead to better conceptual learning” (Lising & Elby, 2005; p. 381).

6.4 CS Questionnaire Results

The CS survey was completed by all students present at the time of writing because it was just a once-off activity done after the interactive interventions. All the students who completed questionnaire were considered for data analysis because they were also present in class during the intervention.

6.4.1 Descriptive analysis of Computer Simulations questionnaire data

Similar to what was done in EBAPS, the scores were converted to a scale ranging from 0 to 4 and different questions were scored differently. Table 6.5 shows a descriptive analysis of the CS questionnaire data.

Table 6.5: Descriptive Analysis of CS questionnaire results

	Mean	StdDev	Minimum	Maximum	Skewness
Overall	2.98	0.39	1.90	3.80	-0.46
Axis 1	3.37	0.90	0.00	4.00	-2.00
Axis 2	3.16	0.62	1.66	4.00	-0.35
Axis 3	2.73	0.64	0.66	3.83	-0.84
Axis 4	3.29	0.65	2.00	4.00	-0.38
Axis 5	2.25	0.53	1.00	3.50	0.02

Axis 1, 2 and 4 had an average mean of 3.37 (84%), 3.16 (79%) and 3.29 (82%) respectively. The high average means of these axes have shown that most of the students had a working knowledge of a computer from high school, believed that CS encouraged them to work independently and that they had positive attitude towards physics. The overall preferences for using simulations as shown by axis 5 on table 6.5 indicates that 2.25 (56%) of the students thought that computer simulations were helpful in enhancing their conceptual understanding of physics. Students' beliefs that computer simulations were helpful in enhancing their conceptual understanding of physics contradicted the results found in CS activities 11 and 12. The overall mean score of the CS questionnaire was 2.98 (75%) as indicated in table 6.5. where CS was not helpful in helping students to understand. The results of CS survey suggest that three-fourth of students believed CS helped them to improve their conceptual understanding of Newtonian mechanics and had a positive impact on changing their epistemological beliefs in physics as shown by the score of 82% in axis 4. Table 6.6 shows a description of how question item numbers were grouped into axes.

Table 6.6: The descriptions of the axes and CS questions items

Axis	Questions probed	Question item number
1	Knowledge of working with computer before	1 and 2
2	Clarifications of physics concepts	3 , 4 and 14
3	Encouragement of independent working	5, 6, 7, 8, 9 and 10
4	Beliefs in physics	11
5	Preference of when simulations can be done	13 and 14
Overall	Students' general feelings about the use of CS	

6.4.2 Overall: General feeling about CS

The overall results of the CS about the general feelings of the students suggest that about 75 % (as indicated by the overall mean results in table 6.5) felt that CS had a positive impact on their study of physics. The students further thought that CS encouraged independent working, helped to clarify physics concepts and increased their interest in physics. The results of this study about computer simulations concur Choi and Parker (2003) who reported the increase students' interest and Perkins and Wieman (2006) who claimed that CS generate a high level of engagement, exploration and understanding among students of diverse backgrounds and ages.

6.4.3 WCD and CS comparison questionnaire (Open ended questions)

Figure 6.4 indicates students' preferences of using WCD and CS. From the graph, it can be seen that 20 (31%) students prefer to be taught using WCD, another 20 (31%) prefer CS and 18 (28%) students prefer both. 7 (11%) students did not answer the question.

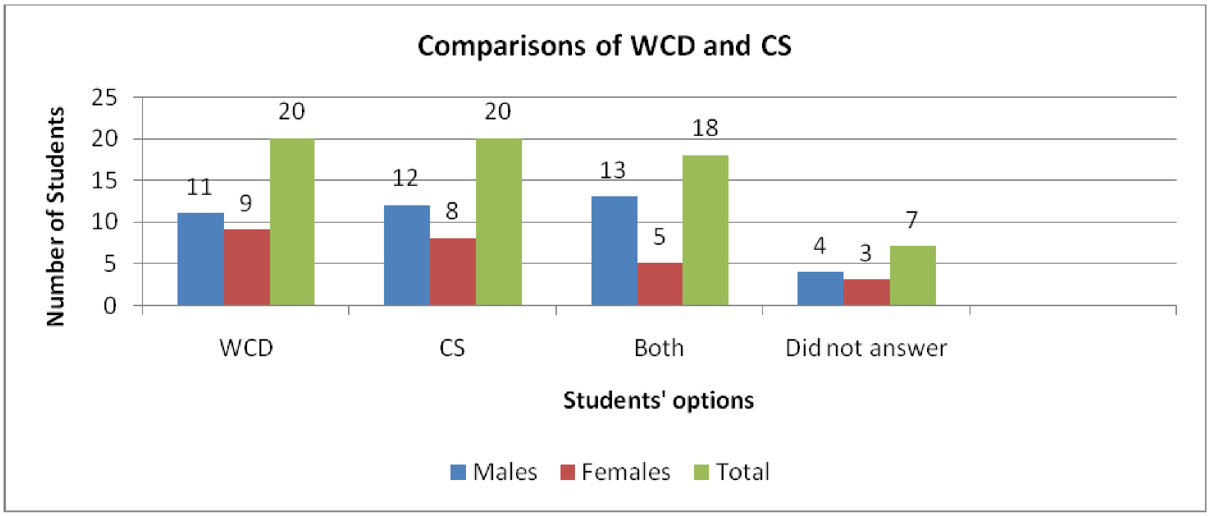


Figure 6.4: Comparison of WCD and CS questionnaires results

Some reasons given by the respondents who prefer WCD were the following:

Respondent 1: "In WCD you talk until you understand the lesson"

Respondent 2: "Everyone has his/her own view about physics and we master it by discussing most of the time"

Respondent 3: "One can ask questions and be able to get an answer at the same time".

Respondent 4: "Different ideas and opinions make me to choose the best answer".

Respondent 5:"Learning new things from others and share ideas for better understanding".

Respondent 6: "Simulations does not clearly explain how it gets to the answer".

Respondent 7: "It gives us some ideas that we don't know that can be helpful in the future".

Respondent 8: "Where we share our views with other students, obviously I can compare the feeling of others with mine".

In general, the results suggest that WCD seem to promote the following valuable skills:

(a) Respect for other people's point of view;

(b) Comparing different options;

(c) Sharing ideas and learning from others;

(d) Question asking skills;

(e) Argumentation and defensive skills.

These results uphold the claim in mathematics context that WCD can be effective when used for sharing and explaining different solutions (Grouws & Cebulla, 2000) and is also consistent with the constructivist view of learning where students interact with each other in the process of finding solutions

Some reasons given by the respondents who prefer CS were the following:

Respondent 9:"One can be able to see and observe a real situation which is better than using imagination in WCD which can be wrong".

Respondent 10: "Practical helps me to understand better than theory".

Respondent 11: "They explain better and chances of being wrong are too small".

Respondent 12: "We are talking about what we can see unlike in class discussions, we observe things that can be impossible to observe without".

Respondent 13: "To see what is happening using our naked eyes is very helpful".

Respondent 14: "In class discussions you may find other students joking".

Respondent 15: "I can see the immediate change when manipulating some values".

Respondent 16: "It helps students to do things on their own and able to follow instructions

Respondent 18: "It gives a clear picture and a straight forward answer".

Respondent 19: "A computer does not forget like when using WCD".

Respondent 20: "It is one of the technologies that any science student can rely on. It is user-friendly experiments are shown perfectly. It even expands software skills at the same time".

Respondent 21: "Makes me have more interest on computer and finding information on my own".

Respondent 22: "CS helped me a lot in analyzing a question and how things are done in real life situations like in elastic and inelastic collisions".

Respondent 23: "Clarifies everything and can observe and make deductions and conclusions on my own".

Generally the reasons given above suggest that CS can help students to develop the following valuable skills in physics and in life:

(a) Analysis
(b) Making deductions and conclusions
(c) Independence
(d) Computer skills

From the reasons given, the study seems to have confirmed McCorduck's assertion (as cited by Thomas , 2001, p. 30) that a computers increase students' usage of high order thinking strategies such as, being able to analyze and to make deductions during problem solving. Some reasons given by the respondents who prefer both WCD and CS were the following:

Respondent 24: "In WCD we mostly listen and in CS we do".
Respondent 25: "Computer shows calculations and diagrams whereas explanations are done in WCD".
Respondent 26: "Performing experiment and discussing help to acquire more knowledge".
Respondent 27: "Simulations help to rectify some of the mistakes done in class".

6.4.4 Overall conclusion about the use of WCD and CS

The results of the open-ended question differed slightly from the results found in section 6.4.2 but at the same time, consistent with the results found in section 6.4.3. The students who did not answer the questions were presumed to be confused and not knowing exactly which model they preferred. Based on this assumption and the interactions with students, the number of those students who did not answer the question was added to that of those opted for both.

To summarize the reasons given for both WCD and CS, the study has shown that both WCD and CS seemed to have the potential of improving some of the valuable skills that can help students to cope in an ever-changing world. For example, computer skills, analytical skills, being able to share ideas and questioning skills are applicable beyond the physics classroom. Analytical skills can also help in enhancing and understanding of different concepts in physics. Students suggested that the time they spent in CS activities should be extended and asked if it was possible for them to access the simulations program so that they could repeat what they have done in class in their own spare time. There were some students who said they did not have a background in computer applications and the they were being exposed to it for the first time and therefore needed to be given extra time. One student wrote: “I would like every chapter to have its own simulations and also to be used in other subjects”. The statement suggests that students are aware of the value of CS in enhancing their conceptual understanding of Newtonian mechanics and in improving their epistemological beliefs about physics.

The overall conclusions of results of the WCD and CS questionnaire suggest that when used hand in hand, WCD and CS have a great potential to enhance the students’ conceptual understanding of Newtonian mechanics. This study supports the broader belief that implementing a new technology like computer simulations with other models of instruction is the key to improving education (Thomas, 2001).

6.5 Interview Results

The structured interviews were conducted for the following reasons:

a) To gain an in-depth understanding of the impact of whole class discussions and computer simulations on conceptual understanding of Newtonian mechanics, epistemological beliefs about physics and the overall feelings about the students’ preferred models of instruction.
b) As a triangulation of the results obtained from FCI, EBAPS and CS surveys.

A structured interview consisted of six questions were conducted to a sample of 19 students randomly selected using a random calculator from MoonStats statistical software program which was found in a disk bought with a book by Welman and Kruger(2001). Those randomly selected sample of students represented 40% of those who wrote both the FCI and EBAPS pre and posttests. The questions selected from the FCI were regarded as challenging to students based on the researcher' experience in teaching those topics. The questions on EBAPS were selected because the researcher wanted to know how they learn the content in physics and also to find out if the organization of topics in textbooks has impact on learning. The interview questions were composed of two questions taken from FCI, two taken from EBAPS, a question about the reasons for choosing physics, the last one about their preferences between WCD and CS.

6.5.1 Question 1

Consider the situation: A large truck breaks down out on the road and receive a push back into town by a small car as shown in the figure below. While the car, still pushing the truck which one exerts more force during the process? Explain.

This question was taken directly from question 15 of the FCI test. In the FCI approximately 40% and 58% of the students answered correctly in the pretest and posttest respectively. The correct answer for the question was "*both will experience an equal force*" based on Newton's third law of motion. Figure 6.5 represents the results of this question.

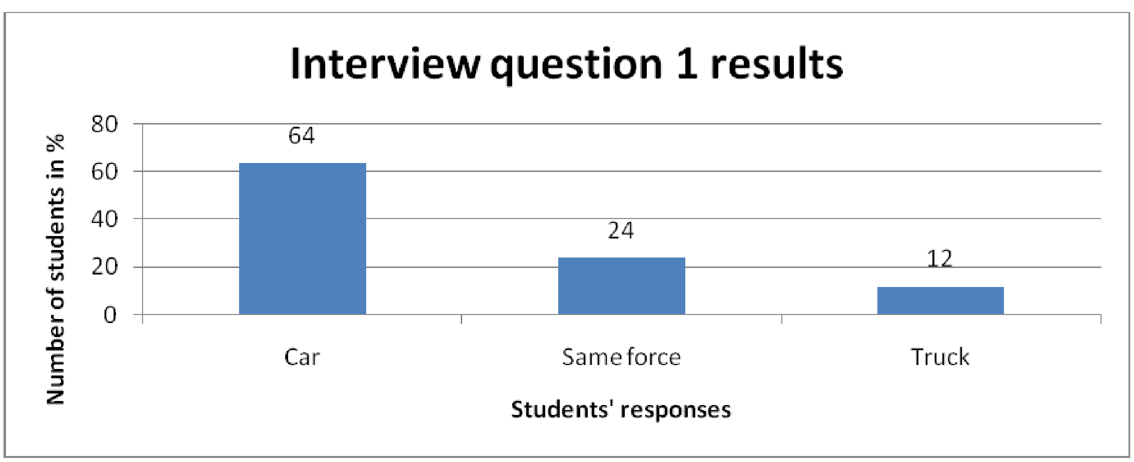
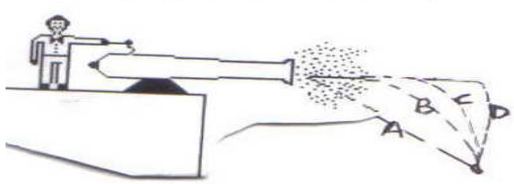


Figure 6.5: Results of interview question 1

The interview results of the same question gave a different picture. Only 24 % of the students answered the question correct by stating Newton's third law of motion. The rest had misconceptions which were ralated to "*the bigger the object, the greater the force it can produce*". One student mentioned that the small car must have a greater force because it made the stationary truck to move. In other words, 64% of the students in the sample believed that force is said to be directly propotional to mass. This contradicts Newton's third law.The results of this question show that students can still have misconceptions even after interactive engagement models were used to intervene.

6.5.2 Question 2

. A ball is fired by cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow? Give reasons for your answer.



Again, this question was directly taken from the FCI question item no 12 where the number of students who answered correctly in both pretest and posttest were 7 (15%) and 24 (50 %) respectively. A similar question was also dealt with using WCD and CS in Activity 8, the number of students who answered correctly were 24 (34%). Figure 6.6 represents the results of the interview.

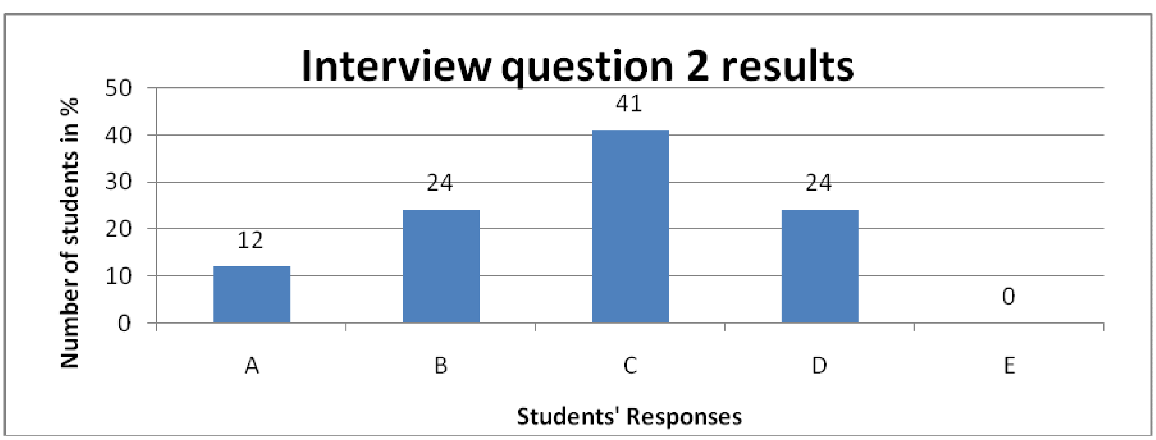


Figure 6.6: Results of interview question 2

The correct option was B. Only 24 % answered correctly and gave the correct explanations. C was the most selected answer. The reason given by those who opted for C was that the object first go straight and after a while gravity acts that is why it falls. The reason given by the group was similar to the findings of Halloun and Hestenes (1985). This again indicated the presence of misconceptions and that WCD and CS were less effective in handling these misconceptions. The results of this question again support the fact that some misconceptions are deeply rooted and can be very difficult to be replaced by the correct conceptions.

6.5.3 Question 3

Justin: When I'm learning science concepts for a test, I like to put things in my own words, so that they make sense to me.
Dave: But putting things in your own words doesn't help you learn. The textbook was written by people who know science really well. You should learn things the way the textbook presents them.
(a) I agree almost entirely with Justin.
(b) Although I agree more with Justin, I think Dave makes some good points.
(c) I agree (or disagree) equally with Justin and Dave.
(d) Although I agree more with Dave, I think Justin makes some good points.
(e) I agree almost entirely with Dave.

In this question, both A and B are prefferred answers based on agreement with experts and were awarded maximum points of 4. Combining the results of A and B implies that students interviewed had sophisticated expect-like beliefs about physics. That was indicated by above 88 % of the students who selected A and B. Elaborating on their reasoning behind opting for A and B, students have shown that they fully believe in explaining things using their own words to understand things better. Only 12% of the students selected D which was awarded a point of 1. The small percentage of these students who selected D indicated that WCD and CS models cannot change the perceptions and beliefs of each and every student doing physics, but that they can change the beliefs of the majorities of students.

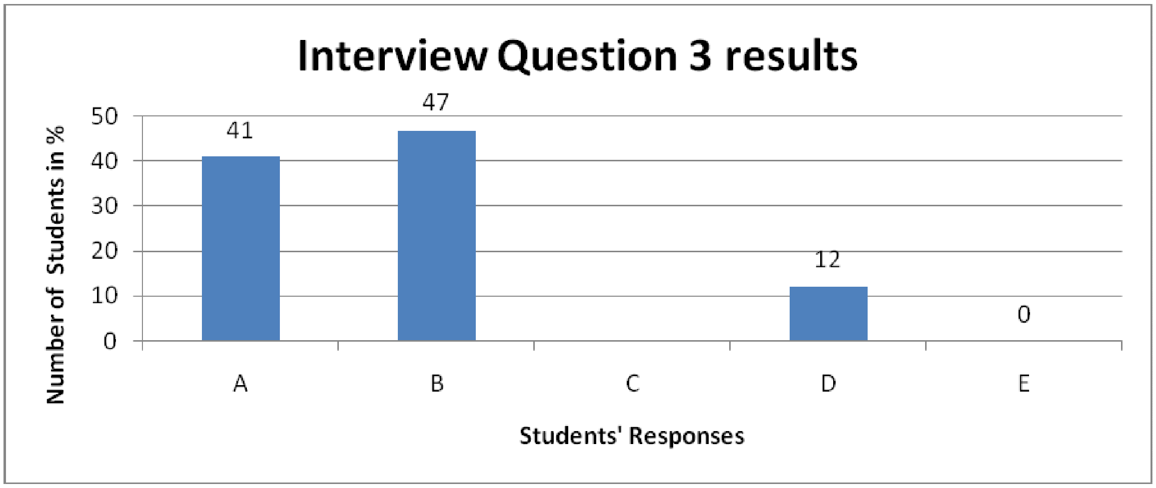


Figure 6.7: Results interview questions 3

6.5.4 Question 4

This question was also taken from EBAPS. This question was scored differently from question 5 because its option had its own score. For example, students who selected A were awarded a maximum score of 4 while those who selected E were awarded the least score of 0. The question differentiated between the most sophisticated beliefs and less sophisticated beliefs.

Brandon: A good science textbook should show how the material in one chapter relates to the material in other chapters. It shouldn't treat each topic as a separate "unit," because they're not really separate.
Jamal: But most of the time, each chapter is about a different topic, and those different topics don't always have much to do with each other. The textbook should keep everything separate, instead of blending it all together. With whom do you agree? Read all the choices before circling one.
(a) I agree almost entirely with Brandon.
(b) Although I agree more with Brandon, I think Jamal makes some good points.
(c) I agree (or disagree) equally with Jamal and Brandon.
(d) Although I agree more with Jamal, I think Brandon makes some good points.
(e) I agree almost entirely with Jamal

In this question, the most preferred option was A, followed by B. From figure 6.8, it can be seen that 77% of the students interviewed, believed that the material in one chapter should be related to that of other chapters. Only 6 % of the students believed that different chapters should not be integrated or related since each chapter has its own specific reasons. The results of this question suggest that WCD and CS drastically improved student's epistemological beliefs about physics.

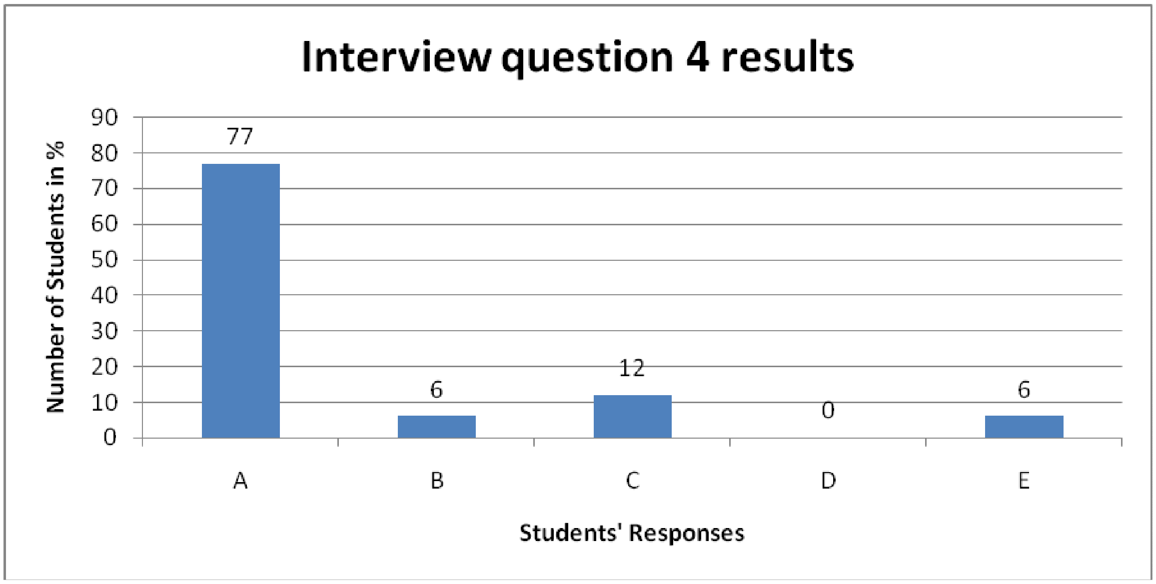


Figure 6.8: Results interview questions 4

6.5.5 Question 5

> **Interview Question 5:**
>
> In B.Ed (FET): Natural Sciences, you are allowed to select a minimum of two majors from Biology, Chemistry and Physics. What made you choose physics? Explain.

Students' verbal answers were classified under four categories; A, B, C and D. An explanation of each category is given on the table 6.7.

Table 6.7:Classifications of students' responses to Question 5

Category	**Explanation**
A	personally love and enjoy physics
B	peer pressure
C	Career Opportunities
D	practical applications and problem solving ability

Students mentioned various reasons for choosing physics as a subject. All the reasons given by students were counted under different categories and each reason a student gave was categorized separately. For example, one student mentioned the following three reasons:

A. I love the subject.
B. One of the scarce skills subject.
C. I want to explain and solve problems in nature because physics is everything.

From figure 6.9, it can be seen that students who loved and enjoyed physics constituted 59% of the sample and who had chosen physics because of its practical applicability in real life and that it helped in equip them with problem solving skills constituted 47 % Students who chose physics because of its competitive advantage in terms of career opportunities were 41%. Lastly, only one student mentioned peer pressure or followed what his friends had chosen as a reason for choosing physics as a subject.

The results of this question suggest that most students had a positive attitude towards physics and also knew exactly why they have chosen physics except for one student who was influenced by friends.

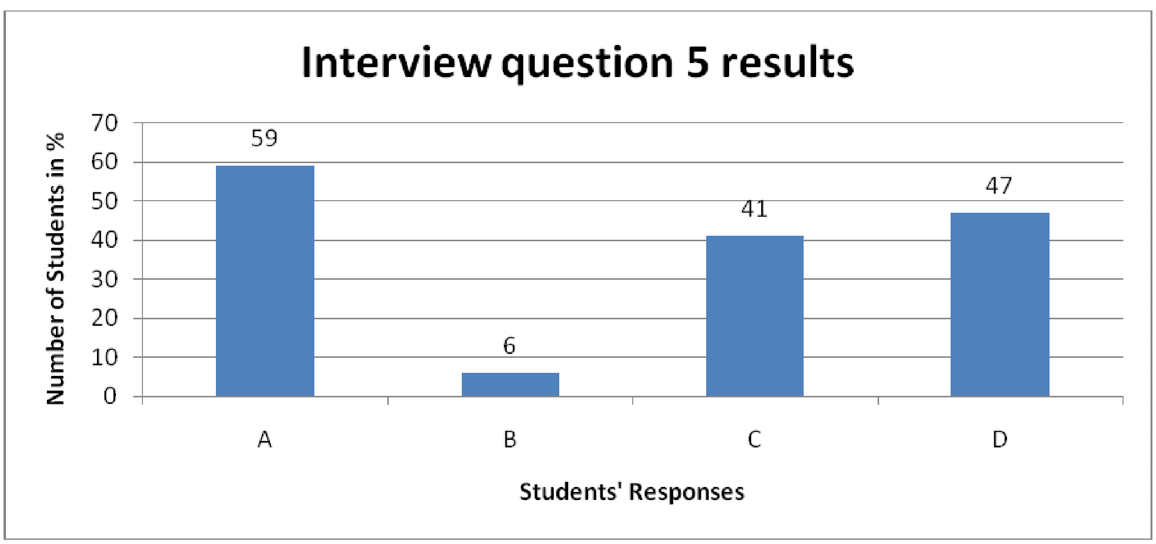


Figure 6.9: Students' responses to interview question 5

The results of this question are consistent with the results obtained in previous sections. The consistency of these results suggests that students did not guess at their answers when answering multiple-choice EBAPS questions.

6.5.6 Question 6

Interview question 2:
Whole Class Discussions and Computer Simulations were used as models for teaching and learning during the first semester. Which model(s) do you think helped you to understand physics better? Explain.

The question probed students' preferences of the models of instruction used. Figure 6.10 shows that 41% of the students preferred WCD to CS, while 24% preferred to use CS only. Those who preferred both models constituted 35%.

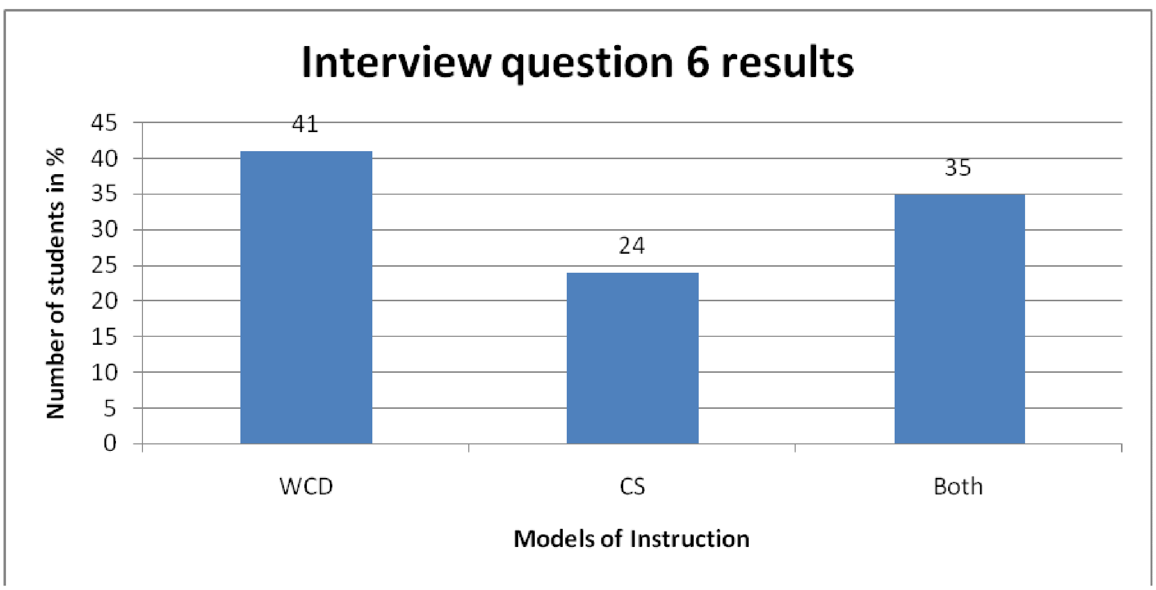


Figure 6.10: Results of interview question 6

The results of this question suggest that it would be advisable to use both models in order to cater for most students. The results concur with Jimoyiannis and Komis (2001), who found that CS can be used to complement or serve as an alternative to other instructional tools.

6.5.7 Overall conclusions about interview questionnaires

The interview results on conceptual questions 1 and 2 revealed some of the misconceptions like, bigger objects exert bigger force which contradicts Newton's third law of motion. Interviews on epistemological beliefs (question 4 and 5) indicated that there was a change from less sophisticated beliefs to more sophisticated expert-like beliefs in physics. That was evident when more students preferred that the material in one chapter be integrated with the material in other chapters. Most students said they have chosen physics because of the love of it (question 5) and prefer both models of instruction to supplement one another during the teaching and learning of physics (question 6). Generally, the results of concur with the results of EBAPS and CS questionnaires, but at the same time contradicted the results from FCI concepts tests because the reasons given by students were sometimes not consisted with accepted scientific view.

CHAPTER 7: SUMMARIES AND CONCLUSIONS

7.1 Introduction

The chapter provides a summary of the study, research findings and conclusions reached based on the findings. It further presents the limitations of the study and suggestions for future research.

7.2 Summaries of Findings

7.2.1 FCI tests

There was a slight change in FCI scores from pretest to posttest with the arithmetic mean changing from 20% to 31%. The average normalized gain on FCI tests was 14% which is not a gain typically achieved using interactive-engagement models. The paired t-tests have shown that the difference between the means of the pretest and posttest was significant. This can be interpreted as meaning that both WCD and CS had a positive impact on the students' conceptual understanding of Newtonian mechanics as measured by the force concept inventory. The results are in consistent with the constructivist view of learning. According to constructivism, students enhance their conceptual understanding when they interact with each other and the learning materials through interactive engagement models of instruction.

7.2.2 EBAPS tests

The overall mean score of EBAPS, changed from 47% in the pretest to 59% in the posttest with an actual gain of 12%. This is an indicative of an improvement in epistemological beliefs from less to more sophisticated expert-like beliefs. Like in section 7.2.1, the paired t-test has shown that the difference between the means of the EBAPS pretest and posttest was significant. Thomas (2001) has noted that students' conception of teaching and learning are key determinants of their actions and processes in the classroom. From that note, it follows that an improvement in their epistemological beliefs could have helped students to learn and understand physics better because they could emulate expert-like attitudes in solving problems. The study has shown an improvement in epistemological beliefs and hence, the conclusion could be that both WCD and CS had a positive impact on the students' epistemological beliefs about physics.

7.2.3 WCD and CS activities

The results of WCD and CS activities have shown that even after the same concepts were dealt with several times using different strategies, students still had some difficulties in understanding the concepts of speed, velocity and acceleration. Another important observation during WCD and CS was that "*being able to defining a concept does not necessarily mean that a student understands the concept"*. Students were able to define but unable to explain what they are defining. It was through the WCD model of instruction that created a smooth path in helping students from defining the concept to understanding it. Generally, in the study both WCD and CS helped in enhancing the students' qualitative understanding of speed. This was evident in the way they answered similar questions in the June examination. This study, which was grounded by constructivism theory, has shown that both WCD and CS helped in realizing the contemporary goals of science education which is "to provide students with opportunities to explore and understand workplace applications of science, to develop strategies for investigations, reflection and analysis to create and refine knowledge" (Thomas, 2001, p. 30).

7.2.4 The Computer Simulations questionnaire

The conclusion drawn from the CS questionnaire suggest that approximately 50% of the students think both WCD and CS can help them to understand physics better.

7.2.5 Interview results

A sample of 19 students representing 40% of those who wrote both FCI and EBAPS pre and posttests were taken through a structured interview consisted of six questions. In terms of conceptual understanding of Newtonian mechanics, the students had problems answering questions selected from FCI. On the other hand, their epistemological beliefs about physics became more sophisticated as confirmed by their explanations when defending their different choices in questions taken from EBAPS. The students' low performance in FCI questions during the interview suggested that their conceptual understanding of Newtonian mechanics and their epistemological beliefs about physics were not directly correlated. The results of the interview have shown that most students chose physics because of the love of it, being able to help in solving real life problems and also because of its competitive edge in terms of career opportunities. The interview confirmed again that the students preferred to be taught using both WCD and CS.

7.3 Conclusions

The main aim of this study was to establish the combined impact of two interactive-engagement models of instruction on first year physics student-teachers' conceptual understanding of Newtonian mechanics and, on their epistemological beliefs about physics. The initial assumption of the study which was based on constructivism theory was that: "Interactive-engagement models would yield positive results in terms of conceptual understanding and epistemological beliefs about physics".

The results of the study supported the initial assumption because both WCD and CS, as interactive-engagement models of instruction had a positive impact on student-teachers' conceptual understanding of Newtonian mechanics (as measured by FCI's average normalized gain) and, on their epistemological beliefs about physics (as measured by EBAPS). Both the t tests conducted on FCI and EBAPS results confirmed that the significant difference between the means of pretest and posttest was not due to chance, but the results of interventions using WCD and CS. However, the magnitude of impact on students' conceptual understanding of Newtonian mechanics was very small when compared normalized gains in other countries where interactive-engagement models were used. The FCI average normalized gain of 15 % in the study contradicted the claim that fully interactive-engagement models of instruction yield average normalized gain of more than 70% (Hake, 1998). The low average normalized gain in the study could have been caused by the fact that the posttest which was a week before mid-year examination. During that week, students were also requested to fill in questionnaires to assess their lecturers in all courses they have registered. Ornek, Robinson and Haugan (2008) claimed that students become more interested in studying for exams than answering questions in surveys.

The positive change in epistemological beliefs about physics in the study also contradicted the results of studies by Wendell (2005) as well as Ornek, Robinson and Haugan (2008) who claimed that there is either no change in the students' beliefs about physics or beliefs become less sophisticated after intervention. Again, the study did not show any direct correlation between the students' conceptual understanding of Newtonian mechanics and their epistemological beliefs about physics. In other words, the study supported the view that conceptual learning gains and epistemological beliefs have complex, but nonlinear relationship (Peng & Fitzgerald, 2006; Bromme et al., 2008).

7.4 Research Contributions from the study

It is envisaged that the findings of this study will have the following impact:

- Could help in the planning to improve the physics results of student teachers using interactive-engagement models of instruction. When these student teachers go out to schools their teachings will have a positive impact on their learners and these could result in improving the performance of physical science in the long run by students. The improvement of physics learning and teaching will in future produce more physicists that are needed to enhance the quality of life of its people (Mangena, 2007) and to compete technologically in the global and academic arena (National Research Foundation, 2007).

- Will inspire teachers to change from traditional teacher-centered models of instruction to learner-centered interactive-engagement models which take into consideration the epistemological beliefs of students which could lead to better conceptual learning gain (Lising & Elby, 2005) and lastly, to use the technological resources available in improving teaching and learning of physics.
- Lastly, in terms of aiming the physics curriculum towards conceptual understanding as suggested by Osborne (2007), the study partially contributed WCD and CS activities that have a potential of enhancing students' conceptual understanding of Newtonian mechanics. These activities can be adapted and used by other instructors in pursue of teaching physics for conceptual understanding.

7.5 Limitation of the study

7.5.1 The design

The disadvantage of the pre-test/post-test design used is that it is not impossible that the changes that occur are caused by other factors other than the event . It is particularly true if there is a long period between the tests (Bless & Higson-Smith, 1995). There are changes within the environment and those within the subjects like maturation where the attitude changes. Regression towards the mean was avoided by only considering those who wrote both tests when analyzing the FCI and EBAPS results. The t-test results also confirmed that the change was due to the intervention using interactive-engagement models of instruction.

7.5.2 The test-effect

Some researchers have argued that all pre- post-tests can bias a person's response (Bless & Higson-Smith, 1995). In the study, this possibility was minimized by not telling the students that the same tests (FCI and EBAPS) will be written again at a later stage and also the fact that a long period has lapsed before the posttests were written. For example, after the FCI posttest was written, few students recognized that they were writing the same test for the second time. They did not recognize it because it was first written at the beginning of the year before they started with instruction and repeated at the end of the second term before they started with examinations.

7.5.3 Experimentally mortality

The study was planned in such a way that all the students' work would be included in the analysis of the data. Due to unforeseen circumstances, some of the students who had registered for the course de-register after writing both EBAPS and FCI pretests, while other were absent when the posttests were written. It might happen that, perhaps the average normalized gain could have been better if all the students had participated.

7.6 Suggestions for implementation

Based on the challenges experienced while conducting this study, the following suggestions are given:

- The students should be prepared in advance for using interactive-engagement models (WCD and CS). The preparations could be in the form of explaining explicitly the main aim of using these models of instruction and their advantages during the process of teaching and learning to encourage voluntary participations.
- It should not be presumed that all students have the knowledge of operating a computer. There must therefore, be introductory computer activities familiarizing students with how to access the simulations programme and how to play around with different simulation activities.
- The instructor and the laboratory technicians must always carry a flash-drive with the simulations programmes installed for re-installations if other users erase the simulations programme erroneously from the computers.

7.7 Suggestion for future research

When conducting the study, it was expected that the average normalized gain of FCI will be in the region of at least 30% since interactive-engagement models of instruction were used. The results of the study showed otherwise. The unanswered question was “what could be the possible cause(s) of very low average normalized gain when interactive-engagement models were used as instructional models?”

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APPENDICES

A: Computer Simulation Questionnaire

QUESTIONNAIRE TO SCIENCE STUDENTS AT THE CENTRAL UNIVERSITY OF TECHNOLOGY, FREE STATE

The aim of this questionnaire is to assess your experiences of computer simulation experiments to which you have been exposed in the different physics classes. You are kindly requested to answer the questions as honestly as you can. The responses that you provide will be treated confidentially and will be used solely for the purpose of the investigation.

Respond to the following statements by placing a tick (√) at the appropriate space. You may strongly agree (SA), agree (A), be neutral (N), disagree (D) and strongly disagree (SD) with the statements that are provided regarding computer simulation experiments.

Computer Simulation Questionnaire

Statements	SA	A	N	D	SD
1. Before I came to the computer laboratory I knew the different parts of a computer (keyboard, monitor, etc)					
2. Before I came to the computer laboratory I could switch on the computer and follow instructions on my own.					
3. Computer simulations have helped to clarify some of the concepts I did not understand in class.					
4. Computer simulations have further confused me in understanding concepts I learn in class.					
5. When making use of computer simulations I expect the instructor to keep on helping me in each and every step.					
6. I do not need the assistance of the instructor all the time as I need to try out things on my own.					
7. I can read and understand what is taking place in the computer simulation on my own.					
8. I can interpret the results of the simulated experiment I am working on.					
9. I can make my own deductions and conclusions about the data that are presented about a particular experiment.					
10. If I have a personal computer at home and given the Computer simulation programme, I can do all the experiments without the help of the instructor.					
11. Computer Simulations have increased my interest in physics.					
12. I would like computer simulations to be used as a follow up on conventional experiments.					

13. Computer simulations have helped me to carry out experiments which could be difficult to perform in a normal laboratory.					

14. Is there any other information that you would like to share concerning computer simulations? Explain
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15. Comparing Whole Class Discussions and Computer Simulations, which model do you think help you to understand physics better? Explain.
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Thank you for your co-operation.

MN Khwanda