ALTERNATIVE CONCEPTIONS OF HIGH SCHOOL SCIENCE STUDENTS ON PROJECTILE MOTION

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ABSTRACT

The aim of this project was to research alternative conceptions that grades 11 and 12 high school physical science learners have about projectile motion. Their performance is compared with first year university physics students. A questionnaire was designed for grade 11 and 12 learners. The understanding of university students was assessed through *ex post facto* scrutiny of responses to a projectile question set in their mid-year examination.

The results of this study were analyzed through the responses of the learners and university students. The study revealed that the grade 11 learners performed better than their grade 12 counterparts, though the same questionnaire was used for both groups. Such differences may be associated with the fact that projectile motion is taught during the grade 11 year of study. Grade 11 learners may therefore have a better memory recall of the formal teaching of the topic and associated concepts. By contrast, grade 12 learners might have resorted to a “re-understanding” of the various concepts as they have been acquired in their own world: these are what the literature refers to as, *inter alia*, alternative conceptions or naïve ideas.

The performance of university students was also better than that of the grades 11 and 12 learners. This may be due to a maturity factor, as well as the way in which projectile motion was dealt with in their lectures. Arising out of our analysis, we shall make a number of recommendations as to how the topic might be better taught at the secondary level. Secondary educators need to be better informed about alternative conceptions research, and preventative and remedial activities that could be adopted.

DECLARATION

I declare that this is my own, unaided work. It is being submitted for the degree of Master of Science in Science Education in the Faculty of Science of the University of the Witwatersrand, Johannesburg. It has not been submitted to any other University.

ESE Hlatshwayo
10 February 2006

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CHAPTER 1

BACKGROUND TO THE STUDY

1.1. General introduction

A generally stated opinion is that in South Africa there is a shortage of qualified science educators. It is important that more science, mathematics and technically qualified students graduate from tertiary institutions, for the improvement of the economy of this country. This prompted the minister of education, Ms Naledi Pandor, to channel skills development funding to the training of mathematics and science educators to address the shortage of properly qualified personnel (Parliament Media Briefing: 14 February 2005). It is for this reason that the pass rates of learners from grade 12 to tertiary institutions is important.

Science and mathematics seem to trail behind all the other learning areas when matriculation results are analyzed. This is one of the worrying factors in education, as confirmed by the deputy minister of education, Mr. Mosibudi Mangena: "*Our statistics for the Senior Certificate continue to reflect a less than 1% pass rate for mathematics on the higher grade by African children. Apart from the poor qualifications of the teachers of science and mathematics, the dysfunctionality of many of our schools in the villages and townships largely contributes to the poor matric results generally, and of mathematics and science in particular*" (Mangena: Mathematics and Science Teacher of the Year awards, 2002: 3).

An important step to take therefore is to find out what problems are faced by grade 11 and 12 learners in science and mathematics. This study will focus on science learners. It will look particularly at the alternative conceptions that learners have in understanding and problem-solving in projectile motion.

As a matter of choice, the study will be grounded in the fundamental framework of the constructivist theory of learning. The theory is briefly discussed in Chapter 2.

1.2. Aim of the research

Unlike atoms and molecules, projectile motion is more concerned with tangible instances. Nevertheless, the study of macroscopic situations such as projectile motion still poses challenges and difficulties for some science learners. An in-depth study will be conducted into the problems that grade 11 and 12 science learners have about projectile motion. Projectile motion will be viewed from different frames of reference, to determine learners' understanding of Newton's first and second laws of motion (dealing with inertial and non-inertial motion).

1.3. Rationale for the research

Over the last decade there has been much research work on the nature and causes of alternative conceptions, as for instance the studies of Eryilmaz (2000), Millar and Kragh (1994), Hewitt (1993), Hood (1975) *etc*. However, the area of projectile motion has received little attention. We will investigate:

- what misconceptions predominate;
- how they may have arise;
- how they may be remediated, that is, what teaching strategies may be useful in teaching.

When discussing projectile motion, some learners confuse the different reference frames; others fail to apply Newton's laws, while others have a combination of both problems (McCloskey, 1983). Such discussions are important and typical for grade 12 final examinations. The study will, hopefully, alert the readers of this report about the existence of alternative conceptions and their possible effects in the teaching and learning processes. It may also assist educators to adopt the recommendations or suggestions stated in Chapter 5 of this study.

The study will focus on projectile motion in different frames of reference, and the relationship to Newton's first and second laws of motion (hereafter referred to as Newton I and II).

1.3.1. Motion

Motion is defined as "*the process of continual change in the physical position of an object*" (Collins English Dictionary). For an observer to conclude that an object is moving, the physical change in position of that object must be viewed relative to a certain reference frame ("*frame of reference is any set of planes or curves, such as the three coordinate axes, used to locate or measure movement of a point in space*.": Collins English Dictionary). This means that an object is moving if its position changes relative to another object in the vicinity. Motion is therefore relative to a reference frame.

Understanding of projectile motion requires learners to understand the reference frames being used. Projectile motion is referred to by Giancoli (1980: 53) as "*the motion of an object that is projected into air at an angle, near the earth's surface*". As the object is projected forward, it is also subjected to the downward gravitational acceleration. The object is therefore subjected to two motions simultaneously. The forward motion is due to the inertia the object has. Hewitt (1993: 41) defines a projectile as "*any object that is projected by some means and continues in motion by its own inertia*." The horizontal motion of the projectile is thus without any acceleration. Inertia is featured in this definition of a projectile, but what is inertia?

1.3.2. Inertial and non-inertial motion

Inertia is defined by Giancoli (1980: 69) as "*the tendency of a body to maintain its state of rest or of uniform motion in a straight line*." This concept clearly derives from Newton's first law of motion, sometimes referred to as the law of inertia. Newton's first law of motion states: "*every body persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by* *force impressed on it*." (Halliday & Resnick, 1978: 75). From this law, an object is expected to move incessantly, but because frictional force and/or air resistance are present (no matter how small they may be), the object will eventually stop. Although air resistance or frictional force is often important, in many cases its effect can be ignored (or, at an elementary level, is deliberately ignored to simplify the problem).

According to Newton's second law of motion, an object is accelerated in the direction of the resultant force. The accelerated motion is said to be non-inertial. This law states: *The acceleration of an object is directly proportional to the net force acting on the object, is in the same direction of the net force, and inversely proportional to the mass of the object* (Hewitt 1993: 59). According to this law a force is needed to accelerate an object. A falling object, for example, accelerates downwards due to the effects of gravity. In this case there is no horizontal motion. However, an object projected at a certain angle to the horizontal possesses both horizontal and vertical motions, that is, inertial and non-inertial motions respectively.

1.3.3. Projectiles as a combination of inertial and non-inertial motion

If an object is pushed along a horizontal surface over a short distance, it seems that the velocity is constant. But if this force is removed, it becomes evident that the velocity is not uniform, but gradually decreases until the object gradually comes to rest due to the effects of air resistance and friction. This means that inertial motion is an ideal situation, only approximated in real situations (Hood, 1975: 66).

If the object is projected horizontally from the edge of a surface, then the combination of both the forward and the downward motion of the object results in a trajectory, as shown in the following sketch (adapted from Swartz, 1981: 56):

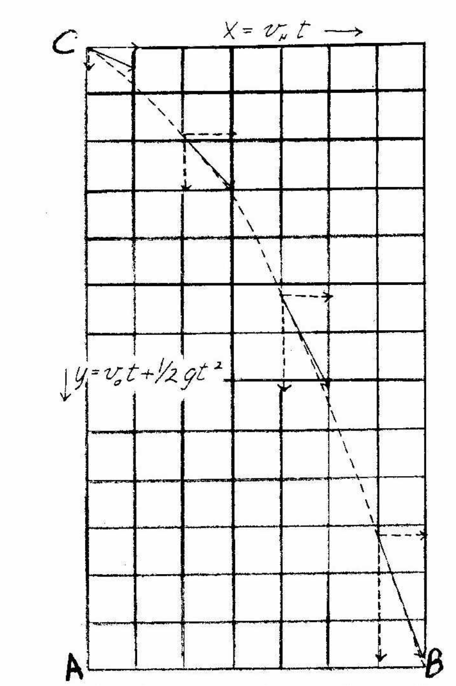


Figure 1.1: (x, y) trajectory of a falling object with an initial horizontal velocity

In this figure, the object falls from C to A, which represents the height, while it moves horizontally from A to B which represents the range. The horizontal arrows indicate the <u>horizontal component</u> of the motion (without acceleration, and therefore the velocity must remain <u>constant</u> if air resistance can be neglected). This forward motion of the object is an example of Newton's First Law of motion, which an object in motion tends to stay in motion. The vertical arrows indicate the <u>vertical component</u> of motion (under gravitational acceleration, and therefore the velocity <u>increases</u> with time). These two components are completely independent of each other.

In this discussion, the process by which an object is projected or thrown is not important. Only its motion after it has been projected and is moving freely through the air under the action of gravity will be considered. Gravity, an external vertical force, pulls the projectile towards the earth at a constantly accelerating rate. The acceleration of the object can therefore be attributed to the intensity of the gravitational field, i.e., the weight per unit mass, g = W/m = 9, 8 $N.kg^{-1}$ (often approximated to 10 $N.kg^{-1}$).

The following example by Swartz (1981: 56) is used to determine the trajectory of an object:

> *Suppose that you pitch a ball horizontally from a height of 1.6m with a speed of 30 m/s. The initial vertical component of velocity is zero, and so the vertical motion consists of a drop from a height of 1.6m with constant acceleration*.
>
> $y = y_o + \frac{1}{2} at^2$
>
> $0 = 1.6\text{m} + \frac{1}{2} (-9.8 \text{ m/s}^2)t^2$
>
> $t^2 = 0.326 \text{ s}^2$
>
> $t = 0.57 \text{ s}$
>
> *During this time, the ball's horizontal velocity carries it a distance*
>
> $x = v_H t = (30\text{m/s})(0.57\text{s}) = 17\text{m}$
>
> The trajectory is shown in the sketch below (Swartz, 1981: 56)

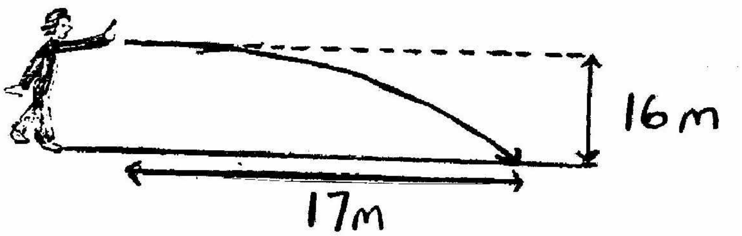


Figure 1.2: path followed by a trajectory

Hewitt (1993: 41-42) separately explains the horizontal and vertical components of motion as shown in the following pictures (p 42):

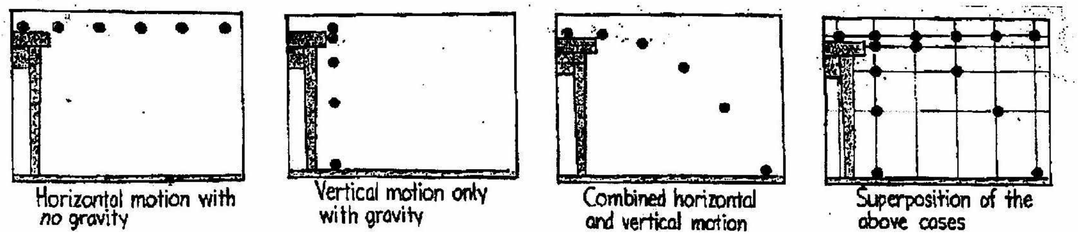


Figure 1.3: the combination of both horizontal and vertical motions of a trajectory

From the first picture, the ball's horizontal distance is the same at equal time intervals. This means that its acceleration horizontally is zero, that is, the horizontal component velocity is the same throughout. The horizontal motion is therefore inertial.

However, in the second picture, only the vertical component is shown, and the ball accelerates downwards, with an increase in its velocity. This constitutes a non-inertial or accelerated reference frame (Newton II). Only the effect of gravity is shown in this picture.

In the third picture, a parabola is shown. This is a combination of both the horizontal and vertical component of the motion. The fourth picture clearly shows the superposition of the two components. The parabola is the path that the ball follows as it is projected.

Other writers such as Halliday *et al*. (2001: 56), discuss the 4th picture in terms of a stroboscopic photograph. In that case the vertical path is for one ball while the parabolic path is for the second ball. These balls are released simultaneously; the first ball is dropped vertically downwards while the second ball is shot horizontally by a spring. The balls have the same vertical motion, both falling through the same height in the same time interval. "*The fact that one ball is moving horizontally while it is falling has no effect on its vertical motion*." (Halliday *et al*. 2001: 56).

It was Galileo who first accurately described projectile motion; he showed that it could be understood by analyzing the horizontal and vertical components of the motion separately. This is an innovative analysis, not done in this way by anyone prior to Galileo (Giancoli, 1984).

Galileo's statement which appears in his "*Two New Sciences*" (1638) regarding the analysis of a projectile is quoted by Arons (1990: 95) as follows:

> "…*I now propose to set forth those properties which belong to a body whose motion is compounded of two other motions, namely, one uniform and one naturally accelerated… This is the kind of motion seen in a moving projectile; its origin I conceive to be as follows: Imagine any particle projected along a horizontal plane without friction… This particle will move along this plane with a motion that is uniform and perpetual, provided the plane has no limits. But if the plane is limited and elevated, then the moving particle, which we imagine to be a heavy one, will, on passing over the edge of the plane, acquire, in addition to its previous uniform and perpetual motion, a downward propensity due to its own weight; so that the resulting motion… is compounded of one which is uniform and horizontal and of another which is vertical and naturally accelerated*."

Galileo was anticipating that projectile motion is a two-dimensional situation, but that the two motions are independent of each other, though they act on a single particle. The uniform motion is the horizontal motion which is in accordance with the principle of inertia (Newton I). It constitutes the inertial motion. However, the naturally accelerated motion is constituted by the vertical motion due to gravity. This motion is non-inertial (Newton II).

According to Giancoli (1984), a reference frame that validates Newton I is referred to as an inertial reference frame. In the case of a non-inertial reference frame, Newton I does not hold.

Consider the following situations described below, in which the two reference frames are discussed.

> *A person, in a hot-air balloon that is ascending at constant speed, releases a sand bag. What motion will be followed by the sand bag?* (Adapted from Van Zyl *et al*., 2000. Though projectile motion is taught in grade 11, it is a typical examination question for Grade 12)

The motion of the sand bag can be viewed from two reference frames:

a. The person in the hot-air balloon will see the sand bag falling straight down. This is because he/she is part of the moving balloon, as is the case with the sand bag. To him/her the sand bag seems not to have an upward motion (in contrast to Newton I). Instead, the sand bag seems to accelerate downwards. This is therefore a non-inertial reference frame.

(This is the path of the sand bag as viewed by the person in the hot-air balloon.)

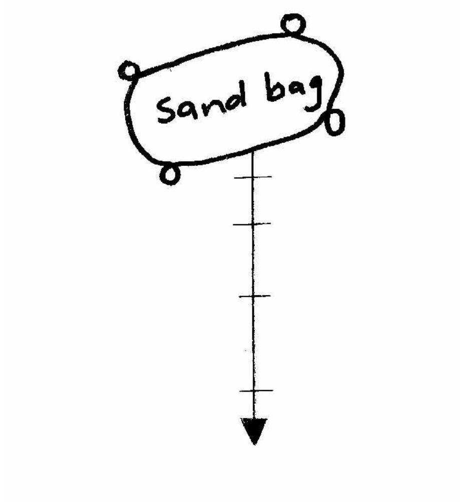


Figure 1.4: path of sand-bag observed from balloon

b. However, an observer on the ground will see the motion of the sand bag differently. To this observer, the sand bag will first move up for a short height before falling straight down (as shown in the diagram below). This means that the sand bag, though still moving upwards, will decelerate, stop and accelerate downwards. This is due to the effects of gravity. The reference frame is also non-inertial.

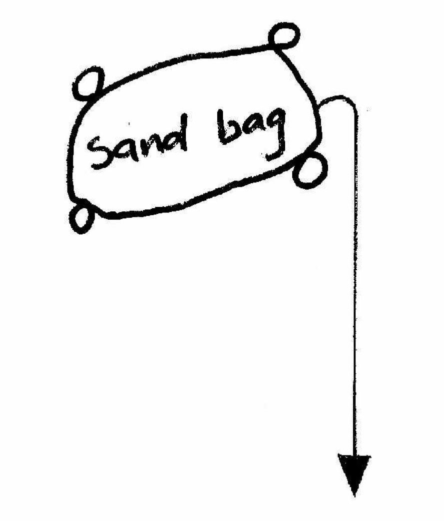


Figure 1.5: path of sand-bag observed from ground

Another situation is that of a boy who is running at uniform speed while holding a ball at shoulder height. If he drops the ball, he will see it falling straight down. This constitutes a non-inertial reference frame. However, an observer who is standing nearby will see the ball falling some distance ahead of the release point, forming a trajectory (as in **Figure 1.2** on page 6). This is because the ball has two motions, the vertical and horizontal motion. This constitutes a combination of inertial and non-inertial reference frames.

These observations from different reference frames are experienced daily. They tend to confuse some observers, and therefore result in incorrect conclusions being made about projectile motions.

1.4. Research questions

This research study is based on the alternative conceptions that students have about projectile motion. The following questions will guide this study:

(i) What are students' conceptions about projectile motion? And specifically,

(ii) Can they predict how a projectile will move, and provide an explanation thereof?

1.5. Brief overview of methods

Alternative conceptions on projectile motion have been studied spasmodically in the past years. These include researchers such as Hu and J Yu (2000), Hynd, Alvermann and Qian (1997), Bose (1985), Halloun and Hestenes (1985), as well as McCloskey (1983), to mention but a few. The alternative conceptions represent the way by which science students in secondary and tertiary institutions view projectile motion.

This study involves an in-depth probing of grade 11 and 12 science students' conceptions about projectile motion; and whether they can predict how a projectile will move, and provide explanations thereof. Although projectile motion constituted a relatively minor subsection in the “old” curriculum, it nevertheless incorporates valuable insights into the differentiation between inertial and non-inertial motion which are worthy of study.

A diagnostic test with multiple-choice questions was used as a tool for collecting data. The data collected was then analyzed in order to establish what the students’ conceptions on projectile motion were. A small group of university students was also involved on an *ex post facto* basis. In their case, their responses in an examination question paper (which contain some questions on projectile motion) were analyzed.

1.6. Outline of report

In this research report the following aspects have been dealt with:

- (**Chapter 1**) **Background to the study**: this chapter deals with the reasons for the study and its rationale, research questions that guide the study, as well as an overview of the research method to be followed.
- (**Chapter 2**) **Literature review and theoretical framework**: this chapter deals with some research findings related to projectile motion and the various components that form the processes of teaching and learning.
- (**Chapter 3**) **Research design and methodology**: this chapter deals with the methods followed when researching on alternative conceptions that some learners have on projectile motion. Included in the chapter is the sampling method, ethical issues and limitations of the study, as well as data collection and analysis techniques.
- (**Chapter 4**) **Analysis of results and interpretation**: this chapter deals with results of the test given to the learners and the analysis thereof.
- (**Chapter 5**) **Discussion of results**: this chapter discusses the results, the sources of alternative conceptions, and some recommendations arising from the research.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Review of literature dealing with projectile motion

Alternative conceptions on any topic can be problematic to both educators and students. In this study alternative conceptions on projectile motion will be investigated. Different researchers in different countries have studied students' ideas on projectile motion.

2.1.1. Some research findings on projectile motion and related concepts

Research in several countries reveals that students have alternative conceptions about motion. For instance, Millar & Kragh (1994: 27) reported that

> "*Many people hold the (non-Newton) view that an object will stop unless a force acts on it; they associate the force with motion, rather than with the change of motion. This understanding is, of course, constantly reinforced by everyday experiences of motion, where friction ensures that moving objects quickly come to rest once the applied force ceases*".

It should be emphasized that an understanding and application of Newton's laws of motion will assist students to better understand projectile motion. Teachers are challenged to utilize different strategies that will promote the applications of Newton's laws. Galus (2002: 48) argues that

> "*a challenge faced by physical science teachers is inspiring students to not just memorize, but also apply what they learned about these laws to any moving object. In order for my students to be motivated to understand and apply the laws of motion, we decided to play with toys*."

Such statements indicate the importance of understanding of Newton's laws and their application to various forms of motion. Some researchers believe that applying Newton's laws will help alleviate alternative conceptions that students have about motion, and so enhance better understanding of key concepts. This may be difficult, particularly because alternative conceptions are often acquired through everyday experiences. When so acquired, teachers are not present to correct any non-scientific ideas.

Hsu (2001: 206) argues that teaching students about Newton's laws first, will have positive effects when projectile motion is taught. He argues that "*one advantage of teaching students Newton's laws before projectile motion is that it allows a better treatment of the constant gravitational acceleration*." These views are also shared by McCloskey (1983: 114) when he claims that

> "*Recent studies on the nature, development and applications of knowledge about motion indicate that many people have striking misconceptions about the motion of objects in apparently simple circumstances. The misconceptions appear to be grounded in a systematic, intuitive theory of motion that is inconsistent with fundamental principles of Newtonian mechanics*."

He further suspects that "*intuitive beliefs about motion play a role not only in people's thinking about hypothetical situations but also in their interactions with real objects*" (p. 114). In this case also, McCloskey is referring to people's daily experiences of motion.

Though this study is based on projectile motion, it is worth mentioning beliefs some students have on curvilinear motion. In an investigation of children's conceptions on curvilinear motion (Kaiser *et al*., cited in Pine, Messer and St John: 2001), children were shown a drawing of a tube curved like a spiral. They were asked to imagine that a ball was traveling inside the tube from the centre outwards. They had to indicate the path they thought the ball would follow as it left the tube. Kaiser *et al*. found that only 25% of school children (mean age 7 years 11 months) correctly predicted that the ball's path would be a straight line. The remaining 75% predicted incorrectly that it would continue on a curved trajectory (Pine *et al*. 2001: 81). As with projectile motion, the root cause of the alternative conceptions is deeply seated misunderstandings of the difference between the tangential inertial motion and the inwardly-directed non-inertial acceleration.

McCloskey (1983: 114) discovered that one subject in their studies told them that the first time he threw a stone with a sling he broke a window. This happened because after the stone was released it did not curve as he expected it to. This is an indication of the subject's understanding regarding motion in general.

Hynd, Alvermann and Qian (1997: 3) identify the following as some of the alternative conceptions associated with projectile motion:

1. Many people believe that a cannonball will move forward for a while and then begin to deviate downward, saying the cannonball's forward motion must be "used up" because it overpowers the effects of gravity.
2. Many people fail to ascribe movement to a carried object, because it appears to be at rest to the person carrying it. Therefore, if released, they believe a carried object will fall straight down.
3. They also do not believe that a dropped object will land on the ground at the same time as a horizontally projected object, given identical release times.
4. They believe that the forward motion either speeds up or slows down the vertical motion. They often describe the path of an object, not as an arc, but as straight out and then curved down.

Bose (1985: 175) mentions that "*for an ideal projectile (i.e. in the absence of air resistance) maximum range is achieved when the initial and the final velocities are perpendicular. It is natural for students to ask why this is so*." The discussions in this subsection are an indication that many learners have alternative conceptions regarding projectile motion. This problem is commonly experienced at schools, when this concept is being taught. It is important for educators to find some kind of solution these to problems such that a better understanding of projectile motion is ultimately achieved by learners.

Several aspects that will promote understanding of scientific concepts are important to consider in a teaching-learning situation. Among these are learning theories, which represent the beliefs that theorists hold, regarding successful teaching and learning. Some components and theories of teaching and learning in science are discussed hereunder.

2.2. Theoretical framework

The learning and teaching processes are composed of various components. The following discussion will be based on some of these components, namely:

- Conceptions
- Alternative conceptions
- Conceptual change
- Constructivism and related components

In most learning situations, there are three factors that are important, namely, the learner, the educator, and the subject matter to be learnt.

2.2.1. Concept: its definition and how it is acquired

An understanding of a concept results in a build up of knowledge. Science concepts are a standard form of knowledge against which learners' knowledge of natural phenomena is compared especially after instruction in class. For a learner to acquire knowledge, he/she must make sense of a concept, phenomenon or event, no matter how easy or difficult that knowledge is. "*Even for relatively simple concepts, learning is not a quantum jump from zero to mastery, while for high level concepts the processes of clarification, extension, generalization and linkage may last a lifetime*" (McClelland 1984: 2) This makes concepts to be subordinate to knowledge, or knowledge to be superordinate to concepts.

To understand how concepts are acquired, it is important first to define a concept. Each individual learner at school understands a concept differently, depending on his experiences. Thus a meaning of a concept is idiosyncratic. Generally a concept can be defined as an idea about a word, a subject, a phenomenon *etc*. perceived in a certain context. According the Collins English

Dictionary (2003: 350), a concept is "*an abstract idea; is a general idea or notion that corresponds to some class of entities and that consists of the characteristic or essential features of that class*." It is in this sense that a concept is regarded as having a contextual character.

Novak (1977: 454) defines concepts as "*inventions of man used to describe observed regularities in events*." According to Stanton (1990: 28) concepts are "*constructs of the human mind, organized around perceptions of objects and events*." He further argues that "*perception is not reality, but the observer's observation of that reality, while organization is a mental process whereby the thinker analyzes, reorganizes, categorizes and synthesizes, in order to grasp meanings*" (Stanton, 1990: 28). These definitions confirm the fact that a meaning of a concept is idiosyncratic or *sui generis* to an individual child.

A learner in his world has his own understanding of events that is guided by his experiences within a particular context. "*Concepts are thus peculiar to the individual, and are also subject to change, both within the history of science… and within the life-history of the individual*" (Stanton, 1990: 28). Some learning theories that may assist learners to change their understanding of a concept will be discussed later in this chapter.

Acquisition of a concept

The acquisition of a concept is a gradual process in which a learner integrates a meaning of a concept with other relevant concepts in order to build up knowledge. Novak (1977: 455) argues that "*since all concepts have at least some remote relevance to other concepts, the total mass of specific concepts acquired over a life span will influence the acquisition and use of the concepts*." In this way scientific knowledge is built on existing knowledge or concepts. This process is referred to as learning.

2.2.2. Alternative conception

There is confusion surrounding the terminology used to label students' conceptions in science. Some researchers refer to them as misconceptions, while others call them alternative conceptions. Nesher (1987) regards calling of alternative conceptions errors, mistakes or incorrect opinions as inappropriate terminology. An error or mistake refers to a condition of deviating from accuracy or correctness.

Gunstone regards misconceptions as an incorrect label. "*One can correctly assume that a researcher's use of this term implies a view of student conceptions as "wrong"*" (Gunstone 1989: 643). This view is also held by Abimbola (1988) who regards the terms, 'wrong knowledge'; 'erroneous conceptions'; 'misconceptions' etc., as inappropriate to use in describing students' science conceptions.

Nesher (1987: 35). also discourages the use of words such as 'error' or 'mistake' instead, prefers the word 'misconception.'

> "*The notion of misconception denotes a line of thinking that causes a series of errors all resulting from an incorrect underlying premise, rather than sporadic, unconnected and non-systematic errors."*

The most appropriate and widely accepted label learners' pseudo-scientific conceptions are 'alternative conceptions'. This is in accordance to what Abimbola maintains. According to him the term 'alternative conceptions' refers to "*particular conceptions that are held strongly and persistently by the students*" Abimbola 1988: 180).

Alternative conceptions are a representation of what a learner thinks about a concept or phenomenon. Such thoughts are connected to a particular system of knowledge. Alternative conceptions therefore do not occur randomly, nor are they created arbitrarily. They are connected to a certain system of thought or knowledge or "*actually derived from previous instruction*" (Nesher 1987: 35).

The learner's line of thinking may, in some cases, reveal how systematic and consistent it is. This may not be easy to detect, though it is very useful to do so. It is this line of thinking that may guide the educator to the origin of the alternative conception, and consequently to its possible solution. Alternative conceptions therefore need not be discarded, for they are useful in the teaching and learning processes.

The educator has a responsibility of probing deeper in order to find the meaning system upon which an alternative conception is based. It is this meaning system that may guide the educator to finding solutions to the alternative conceptions. This view is also held by Abimbola (1988: 176):

> "*As existing concepts yield to the force of new concepts, the existing concepts undergo some reorganization which could lead to a new view of the world. Progress in science comes about as a result of this reorganization*."

In some instances the alternative conceptions may persist even after the educator has attempted to eradicate them. This may be the result of an incorrect diagnosis of the alternative conception by the educator, or an incorrect strategy used to eradicate it. It is the responsibility of the educator to create dissonance between the prior knowledge of the learner and the new knowledge to be acquired in class. "*Without dissonant experience there is no motivation to know*" McClelland (1984: 1). This will encourage the learner to change his alternative conception and adopt a scientific conception. "*The cognitive organism tries to make sense of experience in order better to avoid clashing with the world's constraints. It can actively modify ways and means to achieve greater viability*" (Von Glasersfeld, 1988: 324).

The learner's attempts to change his/ her alternative conception, marks the process of learning. The learner has then, through experience, acquired the scientific conception. Von Glasersfeld (1988: 324) maintains that "*to have 'learned' means to have drawn conclusions from experience and to act accordingly. To act accordingly, of course, implies that there are certain* *experiences which one would like to repeat rather than others which one would like to avoid*."

In addition to the previous discussion, knowledge and understanding of the learning theories may also help the educator in adopting better strategies for teaching. The theories of learning that an educator may use as part of his/ her teaching strategies are discussed hereunder.

2.2.3. Conceptual change

As mentioned earlier, prior knowledge, intuitive belief or thoughts play a vital role in the acquisition of new concepts. This is regarded as an interaction between what the learner is taught and his/ her current ideas or concepts.

Posner, Strike, Hewson and Gertzog (1982) regard the acquisition of knowledge or learning as an activity composed of the following characteristics:

- Learning is a process of comprehending and accepting ideas because of their intelligibility and rationality. Novak (2002: 562) views "conceptual change" as the necessity for meaningful learning to occur.
- Learners make judgments on the bases of available evidence. For learners to accept that their intuitive beliefs or thoughts are incompatible with the new knowledge to be acquired there must be appropriate convincing evidence. Motivational and affective variables do play a role in the acquisition of new knowledge. "*Changing their 'conceptual ecology' requires that the learners recognize explicit ways where their concept/ propos ional frameworks are limited, inappropriate or poorly organized into hierarchies*" (Novak 2002: 562).
- Learning is concerned with ideas, the structure of these ideas and evidence for them. Therefore learning is not a verbal repertoire or a set of behaviours.
- Most importantly learning has to do with conceptual change.

Posner *et al*. (1982) further identify two phases of conceptual change, and these are discussed briefly in the following paragraphs.

2.2.3.1. Central commitments

Central commitments define problems, organize research, indicate strategies for dealing with the problems and specify criteria for what counts as solutions. Central commitments are regarded by Lakatos (in Posner *et al*., 1982) as the ‘theoretical hard core.’

2.2.3.2. Modification of the central commitments

It is in this phase where patterns of conceptual change occur. Learners use their existing knowledge or concepts to deal with the new phenomena. This is one of the patterns of conceptual change and is termed assimilation.

In most cases, however, the learners existing knowledge or concepts tend to be inadequate to successfully assimilate new phenomena. Then learners are forced to abandon the old knowledge or concepts and acquire the new phenomena. This process is termed accommodation. The two concepts, assimilation and accommodation are part of the equilibration process in Piaget’s constructivism theory.

2.3. Constructivism

Matthews (2000: 494) mentions three major types of constructivist traditions, namely, educational constructivism, philosophical constructivism and sociological constructivism. Of importance to this study is educational constructivism, discussed hereunder.

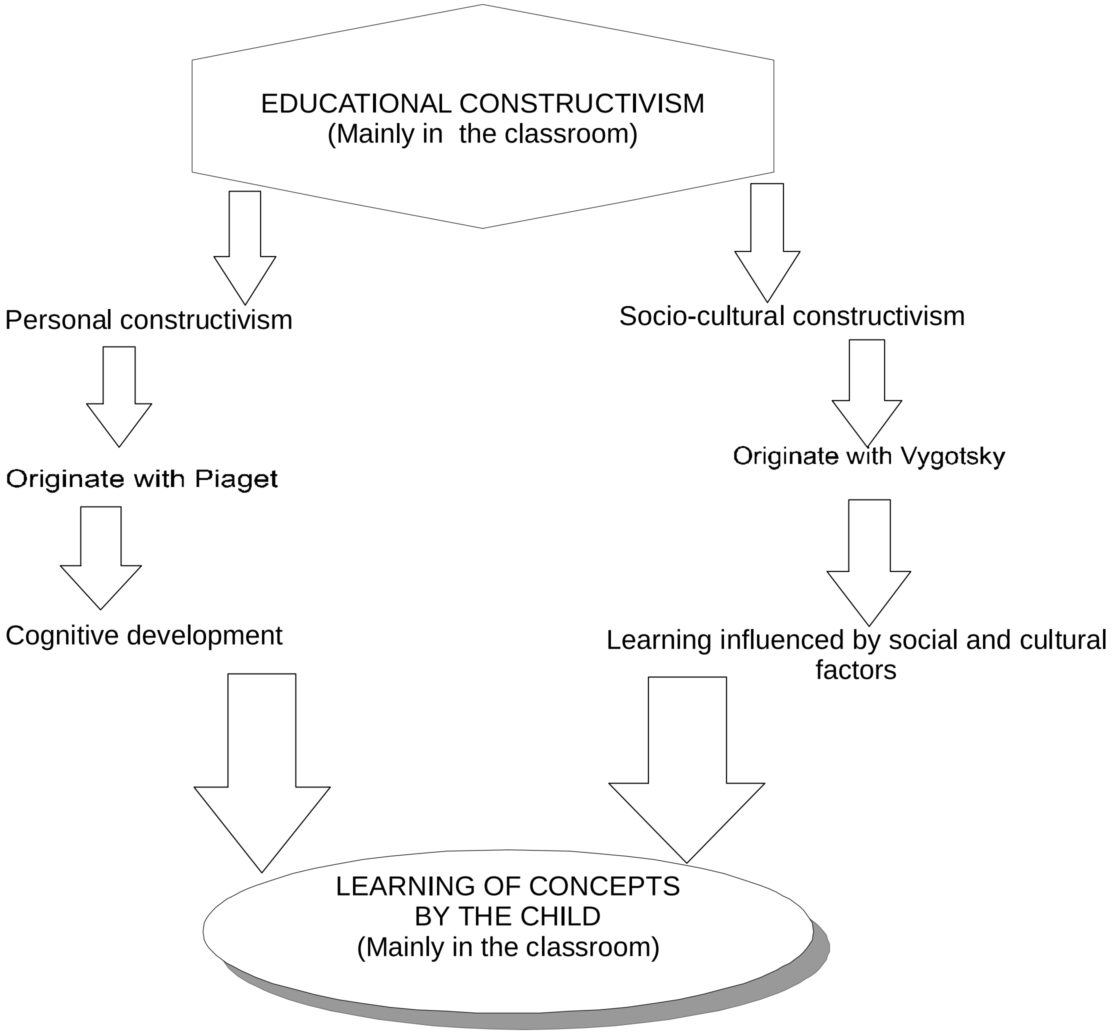


Figure 2: Constructivism

Constructivism explains how knowledge is developed cognitively by learners. Prior learning or pre-knowledge plays a vital role in the construction of knowledge. This is one of the important components of constructivism. When considering prior knowledge that learners have regarding a certain topic, alternative conceptions about that topic may, most probably, become evident. It is this prior knowledge that educators use that may act as a guide to their teaching of the topic, and assist learners in the construction of new knowledge.

Construction of knowledge happens when a person (learner) builds up new knowledge on existing knowledge. It is important to note the dichotomy that exists between the notion of “constructivism” as a learning principle and “conceptual change” as the desired outcome of a teaching and learning process. “*The basic notion of constructivism is that the student has an essential role to play in the process of constructing knowledge, as scientists do in their constructions*” Helldén and Solomon (2004: 886). Conceptual change involves changes in the learner’s fundamental assumptions about the world, about a phenomenon, about a certain concept, about knowledge *etc*.

Matthews (2000: 495) argues that “*Constructivism’s paradigmatic case of knowledge is the individual confronting the world and making sense of their experiences: socialization, enculturation and language is pushed into the background*.” Learners are active participants in the construction of knowledge. Von Glasersfeld (1993), quoted by Morrison and Lederman (2003: 850), states that:

> *“knowledge is the result of a constructive activity and cannot simply be transferred to a passive receiver. Knowledge has to be built up by each individual knower. According to this theory, all knowledge must be individually and socially constructed and based on the learner’s existing knowledge and experience; therefore, it is essential for a teacher to be aware of students’ prior knowledge of science concepts.”*

The process of acquiring knowledge happens both inside and outside the classroom. “…*we all construct our own knowledge. We do not passively receive it from our environment. Taylor and Campbell-Williams (1993) point out that this is well known and often perceived in the Ausubelian form ‘that the learner’s new understandings are dependant on prior knowledge and experiences*’ (Jaworski 1994: 16).

There are many aspects that influence learning, whether formal learning (in class) or informal (in communities). Aspects such as economic demands; politics and its changes; religious and other beliefs *etc*. all influence the construction of knowledge. Morrison and Lederman (2003: 850) maintain that students enter their classroom with ideas about science that have been influenced by their prior experiences, textbooks, teachers’ explanations, or everyday language.

Outside the classroom the teacher has no control on what knowledge is acquired by the child or how it is acquired. Instead, social changes, cultural beliefs and language within the social community influence the construction of knowledge by the child. Trowbridge and Bybee (1990: 89) argue that "*In the first view there are forces and pressures in the external environment that impress themselves on the student's mind. Knowledge has an exterior origin. Learning is a copy of reality*." This knowledge which is pre-conceived conflict with what is scientifically correct. This belief is also held by Carr *et al*. (1994: 149) "*A further complication when considering learning in science is the developing realization that individual students hold many, often conflicting, concepts about their world, some of which they use in the school classroom, others in the world outside*."

The following are other important components of constructivism, and are worth discussing in the following sections:

- 2.4. Development and its associated concepts
- 2.5. Learning
- 2.6. Some critic's ideas on constructivism

2.4. Development and its associated concepts

2.4.1. Definitions

Piaget (Piaget, 2003, originally published in 1964) distinguishes between **development** of knowledge structures and **learning** of concepts. According to his theory development occurs spontaneously and is a process which concerns the totality of the structures of knowledge. However, learning does not occur spontaneously, but it is provoked by situations. In addition, it is limited to a single problem or structure. To Piaget development explains learning (as opposed to the widely held view that development is a sum of discrete learning experiences). This implies that the two processes, development and learning are indispensable.

According to Piagetian theory (Trowbridge and Bybee, 1990: 83; and Good, 1977: 151) there are four developmental stages through which a child passes, namely, **the sensori-motor stage** (the active child: 0-2 years); **the preoperational stage** (the intuitive student: 2-7 years); **the concrete operational stage** (the practical student: 7-11 years); and **the formal operational stage** (the reflective student: 11years to adulthood). In this study high school learners, with ages ranging between 15 and 19 were involved. It is therefore to focus on the fourth stage of development, **the formal operational stage.**

Formal operational stage (The reflective student)

This stage is regarded by Piaget as the intellectual gateway for the child to adulthood. At this stage the child can now reason about hypotheses, and not only on objects. The child is now capable of constructing new operations of propositional logic, and not on simply the operations of classes, relations, and numbers. Von Glasersfeld (1988: 327) claims that "*Operative knowledge is constructive and, consequently, is best demonstrated in situations where something new is generated, something that was not already available to the operator*." The child at this stage is able to better use his/ her mind to interact more effectively with both the physical and social environment (the social environment is composed of certain cultural and religious beliefs; economic status and demands *etc*.).

A student who has reached this stage is referred to as the reflective student. This means that the student has the ability to do reflective thinking. He/she reflects back to what has been done, how it was done, and how can it be improved (or what obstacles may hinder any envisaged improvement). He/she "*is able to think back on a series of mental operations, that is, reflect on them. In other words, students can think about their own thinking*." (Trowbridge and Bybee 1990: 88)

This is also a stage at which the child is able to reason inductively and deductively. Deductive in this case refers to reaching conclusions about something through reasoning, or making conclusions or inferences after considerable reasoning about something. Inductive, on the other hand, refers to influencing possibly a decision through reasoning. "*Possibilities become real rather than reality determining what is possible. This is one way of expressing the fact that formal thought transcends the concrete situation*." (Trowbridge and Bybee, 1990: 88)

2.4.2. Factors affecting development (extracted from Piaget, 2003 and White, 1988)

It is at the formal operational stage that the child's development and learning becomes more pronounced. This occurs as the child <u>matures</u>; <u>experiences</u> more through handling physical objects that may be used to explain science principles and concepts; and also as the child <u>socially interacts</u> with others in science projects within the school, or as they play or discuss within their niche. In some instances the child may face new knowledge or situations that are, most likely, in conflict with what the child already knows. Such novel situations or knowledge challenges the child to establish equilibrium between these novel situations or knowledge and the preconceived knowledge. This process is referred to by Piaget as <u>equilibration</u>. The underlined concepts in this paragraph constitute what Piaget refers to as factors that affect the different developmental stages through which any person pass in his/ her life. Only those factors deemed important will be discussed in the next paragraphs.

<u>2.4.2.1. Experience</u>: a child develops his cognitive structures through physical handling and manipulation of objects. This is termed by Piaget as the **physical experience**. According to this theory, this factor, like maturation, does not explain everything regarding the development of a child. It suggests, for example, that the subjects must practically demonstrate to each other how a projectile will move using physical objects. This enables them to gain experience through demonstration or experimentation. Such experience may assist them in the development of the conceptual structures based on projectile motion. This view is also held by Von Glasersfeld (1988: 320) when he maintains that "*What determines the value of the conceptual structures is their experiential adequacy, their goodness of fit with experience, their viability as means for the solving of problems, among which is, of course, the never-ending problem of consistent organization that we call understanding*."

2.4.2.2. Social transmission (linguistic or educational transmission): this factor, according to Piaget, is also important in a sense that a learner or child receives valuable information via language or education.

The subjects in this study are English Second Language speakers. This is a problem as, in many cases, information that is transmitted in English is not fully received by the learners. The language is therefore a barrier that these learners have to contend with in their studies. It is therefore no surprise that they do not perform well in their science lessons (Solomon 1992). (Language problems are discussed briefly in Chapter 4).

According to this factor, a learner must have a structure, the language of science, which enables him/her to assimilate information. Explaining one science concept may in many instances require reference to, for example, a science concept dealt with previously. All the other concepts associated with the previously learnt concept form a structure upon which a new concept is built. In this study, the understanding of projectile motion requires background knowledge on Newton's laws of motion and inertia. This means that the laws of motion and inertia constitute the structure upon which the concept projectile motion is based. Because of this language disadvantage, this structure may not be well established in some of the learners, thus making the learning of science a problem (Solomon 1992).

2.4.2.3. Equilibration: this is an important factor which a learner who interacts with unmatched situations or information, must strive to be at equilibrium with what is new to him/her. This is a process of self-regulation. This factor is regarded as an active process in which operational reversibility prevails. Piaget maintains that at this stage transformation in one direction is compensated for by transformation in the opposite direction (Piaget 2003).

Trowbridge and Bybee (1990: 89) explain equilibration as "*the process that explains the simultaneous maintenance and change of the intellectual structure. Maintenance and change occur through organization and adaptation respectively*."

2.4.3. General features of development

As learners interact with unmatched situations or information, feedback and feedforward processes prevail until the new information is properly linked with the knowledge that already exists (Trowbridge and Bybee 1990). This brings about equilibration. For equilibration to occur, the learners' prior knowledge must be challenged with new knowledge. It is therefore the onus of educators to ensure that there is dissonance between what the learner already knows and the new or unmatched knowledge. This challenge will result in learners wanting to reach equilibrium, as they merge new knowledge with the old. This fact is supported by Piaget's statement (2003: S17): "*The internal reinforcements are what enable the subject to eliminate contradictions, incompatibilities, and conflicts. All development is composed of momentary conflicts and incompatibilities which must be overcome to reach a higher level of equilibrium*." Equilibration process should therefore be viewed as the most important feature of knowledge development.

Piaget further uses two concepts, *assimilation* and *accommodation*, to show that a person assimilates new experiences and then accommodates them to the already existing knowledge. However, it should be noted that what is assimilated does not entirely depend on the environment but also on the experiences of the person. This also does not guarantee that the newly assimilated knowledge is scientifically acceptable. In some instances it may be inappropriate. This is the case when alternative concepts originate, particularly when what is experienced confirms to some extent what has already been learnt by the child.

To the subjects in this study, their prior knowledge (what they have experienced about projectile motion) must be at equilibrium with what is scientifically acceptable. This implies that there must be the first level upon which prior knowledge coexists with new knowledge at equilibrium. The second level is built upon the first, that is, the newly acquired knowledge in the first level becomes prior knowledge for the second level. For example, knowledge on circular motion may be built upon knowledge on projectile motion in the sense that there is a combination of inertial and non-inertial motions in perpendicular directions. This makes projectile motion the basis for understanding circular motion. The new knowledge must be in equilibrium with the old. The third level is similarly built upon the second and so on. This process will ultimately form a convoluted knowledge structure on motion in general. Piaget refers to this as sequential levels of equilibrium, in which succession of levels occurs. Prior knowledge can therefore be regarded as another important feature of knowledge development.

As mentioned earlier, science educators have a responsibility to identify existing knowledge that learners bring into the classroom. Not being aware of the existing knowledge may result in undesired learning outcomes. Gilbert *et al*. (1982) discuss possible arrangements of outcomes of science teaching between what they termed Teachers' Science' and 'Students' Science. They show that there are at least five possible arrangements, namely

- The *undisturbed children's science outcome* where the 'Students' Science' view is not modified by 'Teachers' Science',

- The *two perspective outcome* where the ‘Teachers’ Science has been taken only for the purposes of evaluation, while the student holds on to his own ‘Students’ Science’ to explain any other situation,
- The *reinforced outcome* in which the ‘Teachers’ Science’ viewpoint is used to explain a particular situation while the ‘Students’ Science viewpoint remains internalized by the student,
- The *mixed outcome* in which both ‘Teachers’ science’ and ‘Students’ Science’ coexist, and
- The *unified scientific outcome* where ‘Teachers’ Science’ is completely accepted by the student, to form an acceptable scientific viewpoint.

The last outcome is the most desired for which any science educator must achieve. In this outcome the ‘Teachers’ Science’ which is scientifically accepted has been completely accommodated by the student. Learning outcomes are also important features of knowledge development.

Another responsibility for science educators is to assume that the majority of learners will be in a transition from concrete to formal reasoning patterns. This is the case because it is not easy to determine at which age learners develop formal reasoning patterns. Substantial numbers of adolescents do not use formal reasoning patterns. They avoid critical thinking (Trowbridge and Bybee 1990). These authors further maintain that

> “*Science teachers should realize that adolescents do not automatically employ formal patterns of thought. Most students in secondary schools are capable of formal thought, but most students do not demonstrate this level of thought. Any number of factors can influence adolescent performance; for instance, motivation, self-esteem, and peers. With this caution, science teachers are advised to view formal reasoning as optimum patterns of thought*.” (Trowbridge and Bybee 1990: 88-89)

A similar idea to that of Trowbridge and Bybee that Karplus (2003: S55) claims is that

> “*Teachers need to concentrate on identifying their students’ reasoning patterns and should not expect that each student’s entire behavior can be classified neatly as reflecting either concrete or formal thought. Most important is the teacher’s willingness to accept the conclusion, documented in recent*

> *studies that a large fraction of students will use concrete reasoning patterns extensively*."

The developmental stages of learners may also be regarded as important features of knowledge development.

2.5. Learning

2.5.1. Definitions

Learning can be defined as a process in which a child (or any person) builds up knowledge on what they already know. Preconceived ideas play a vital role in learning. Ausubel (1968) quoted by Osborne and Gilbert (1980: 376), states that "*The most important single factor influencing learning is what the pupil already knows. Ascertain this and teach accordingly*." This view is also held by Hewson and Hewson (2003: S86), when they state that "*One of the factors affecting students' learning in science is their existing knowledge prior to instruction. The students' prior knowledge provides an indication of the alternative conceptions as well as the scientific conceptions possessed by the students*." Preconceived ideas, as mentioned earlier in this document, assist the educator in planning his teaching.

2.5.2. General features of learning

Exploring prior knowledge of learners is important for an educator to start the process of learning. The knowledge structures that the learner already has, should, not be regarded as isolated ideas, but rather as conceptual structures which provide a sensible and coherent understanding of the world from the learner's point of view. As mentioned earlier, development precedes learning. Knowledge structures already developed provide learners with the background to learn further. Learning should then be viewed as a process in which an existing concept is modified due to the presence of new knowledge that influences this modification. Learning can therefore be described as a process in which alternative conceptions are changed to scientific conceptions. This is in line with Osborne and Gilbert's (1980: 376) statement

> "*It might therefore be reasonably argued that the more teachers know about and appreciate the cognitive structures of their students, the more they will provide learning experiences whereby these structures might be modified. From this perspective science learning involves modifying a student's cognitive structure in such a way that the student can explain things both better and more scientifically*."

Hewson and Hewson (2003: S87) also hold this view, as they maintain that "*learning is not simply the addition of new bits of information, but involves the interaction of new knowledge with existing knowledge in order that the new may be reconciled with the existing, if possible. The process of reconciliation may involve the rejection of some conceptions*."

Shaw and Thomas (1979) in Osborne and Gilbert, suggest that "*to an observer learning may appear to be the achievement of certain behavioural objectives. However, for the learner, learning is the revision of his or her own cognitive structure, that is a shift in the way he or she perceives and construes vent and behaves in situations*." (Osborne and Gilbert: 1980: 379). Trowbridge and Bybee (1990: 92) argue that "*It is important to remember that development explains learning; that is, the student has a cognitive structure that will be applied and modified in the learning situation*." They further regard learning as an adaptation and organization of experience. Prior knowledge, as was the case with development, is an important feature in learning processes.

Another important feature of learning involves the stimulus and response schemata. Some science educationists believe that learning is based on stimulus-response schema, a linear arrangement. However, Piaget regards the arrangement of stimulus and response not as a one way street, but in a circular form. This implies that when explaining, it will be better to start from any point, and not necessarily to start with stimulus and then response. He supports his argument when he says "*The stimulus is really a stimulus only when it is assimilated into a structure and it is this structure which sets off the response*." (Piaget 2003: S14)

Whichever way one looks at learning, is not too important for this study. Learning will always involve stimulus and response. In the process of learning, the child is an active participant. The child actively assimilates information. As indicated earlier, development encompasses learning, and the two are inseparable. Together they are responsible for the construction of knowledge, an important process in learning activities.

2.5.3. Factors affecting learning

When learning occurs, it is affected by certain factors, either positively or sometimes negatively. Sometimes learners confront situations that are not conducive enough for them to concentrate and thus learning is hindered. Examples of such hindering factors that are common at schools are hunger, emotional disturbance due to problems at home or in community, crime, pregnancy, etc.

White (1988) identifies and classifies other factors that affect learning:

2.5.3.1. State of the learner

a) Attitude: learner's attitude plays a crucial role in the learning process. White (1988: 16) maintains that "*the learner's attitude towards a topic, for instance, affects the attention given to instruction about it and consequently the amount of knowledge that is acquired*." Though this is not easy, it is the responsibility of educators to motivate learners to acquire a positive attitude towards a particular, discipline, topic and education in general.

b) Abilities and knowledge: some learners' prior knowledge or skills enable them to acquire some new knowledge or skills, though in many cases this may not be possible. Prior knowledge that learners bring to a learning situation may contain both alternative and scientific conceptions. This depends on their home background and available resources for them to reinforce knowledge acquired at school. In many instances alternative conceptive prevail. This implies that learners may be able to explain some concepts correctly or incorrectly, depending on their knowledge they have based on that concept.

Prior knowledge is also acquired at home through the help of adults and parents, with the intention of assisting and supplementing in what is learnt by the child at school. Bernstein (1996) in Taylor and Vinjevold (1999) regards this knowledge acquired at home as everyday knowledge, and that acquired at school as school knowledge.

The research work of Bernstein (1996) as discussed in Taylor and Vinjevold (1999) reveals that a difference exists in terms of everyday knowledge between learners, due to their class backgrounds. Learners from middle-class backgrounds are exposed to a number of learning resources such as libraries, books, computers with internet, television (possibly showing learning channels even from outside this country), which their parents can afford. The knowledge and abilities of these learners are greatly improved.

Learners who come from working-class backgrounds (as is the case with the subjects in this research report) do not have full access to all such resources mentioned above. Libraries, if available, are far from them in most cases. It is for these reasons and others not mentioned in this discussion that such learners are unable to reach the level of achievement that is often reached by the learners from middle-class background.

The situation for working-class learners is made even worse when one considers the fact that most of their parents are not only poor, but they are also illiterate and cannot assist their children in their school work and projects given to them at school. This gives added advantage to middle-class learners whose parents are mostly literate and can assist them with their school work and projects.

It is evident then that the sociological nature and status of learners has an influence on everyday and school knowledge. For working-class learners, the gap between everyday and school knowledge is much wider when compared with their counter-parts from the middle-class. Learners in previously disadvantaged societies and schools will, to some extent, remain disadvantaged, no matter how much the government may provide for school. This problem will persist for as long as there are learners who come from poor backgrounds.

2.5.3.2. The influences that determine the state in which learners are found

a) Physical state of the learner: learners in good health are likely to learn better than those who are ill. This may lead to disturbances in what is being taught in class. In such situations the child will not comprehend fully and easily what is taught in class.

b) Needs: White uses Murray's theory of needs to explain this factor. "*Murray recognized a set of what he called psychogenic needs, including needs for achievement, blame avoidance and affiliation. It is simple to incorporate these ideas into a theory of motivation to learn*" (White 1988: 18). White further argues that "*… in a school setting, an able child who has developed confidence through steady experience of success may have different needs from one who has suffered many failures and consequently has a different attitude to learning*."

2.5.3.3. The circumstances in which the learner is placed

a) Context and its perception: This is determined by the setup of a learning situation and all other factors. This is an important factor in that it can influence learning greatly. White (1988) argues that

> "*The model stresses that context influences performance only through the individual's perception of it… Their perceptions of the context are determined by their physical and mental states*." (White 1988: 19)

White also maintains that how learners perceive context is important in learning because it determines what the individual thinks is the purpose of learning. "*If the* *general context of schooling is seen as authoritative and repressive, a different style of learning will develop from that fostered by a situation seen as liberal and helpful*" (White 1988: 20). This challenges educators at school to create and maintain a context that is good enough and normal for learning to occur.

b) <u>Teaching</u>: this is central in all learning situations. Teaching forms part of the learners' surroundings. Teaching and learning are two processes that are, in most cases, intertwined. A good educator will create an environment for both teaching and learning to proceed. It is therefore imperative for an educator to acquire the skills necessary for teaching, for learning to occur optimally.

2.6. Some critics' ideas on constructivism

Constructivism is viewed differently by different researchers. Others criticize it while others agree with its principles. It is upon the individual reader of this report to decide whether to follow what the critics of constructivism say, or to follow what the constructivists believe in.

Jenkins (2000), one of the critics of constructivism, quotes some researchers as follows:

> "*The constructivist view of teaching and learning has proved to be a powerful model for describing how conceptual change in learners might be promoted*. (Keogh and Naylor 1997: p12)"

In criticizing the view of Keogh and Naylor, Jenkins argues that

> "*A theory of teaching (however that may be defined) is necessarily more complex than a theory of learning, not least because it must accommodate what is known about a range of matters not embraced by studies of how students learn. In addition, while the large volume of empirical data about students' understandings of a range of scientific phenomena … is of interest, comparatively little is known about how teachers can most effectively respond to it*." (Jenkins 2000: 602)

There are some learning theories that have been studied and may be effective in teaching. Some of these are situated learning (Hatano 1996 and Brown *et al*.

1989); socio-cultural learning Hewson and Hewson (2003), constructivism (Piaget 2003) *etc*. These theories can be used to guide teaching, that is, they may serve as teaching theories. In this sense teaching theories can be viewed as equally complex as the learning theories. According to Jenkins' previous statement, teaching theories can therefore be viewed as at the same level of complexity as the learning theories.

Another important point mentioned by Jenkins is that if students' understandings of natural phenomena are wrong, science teachers argue that they are to be corrected. This is really important to consider during teaching process. However, Jenkins argues that constructivism offers little in the way of guidance about how this may best be done, despite the fact that a range curriculum materials supposedly based on constructivist principles (for example, the Nuffield project kits developed in the UK in the 1960s) have been produced.

The argument in the previous paragraph is not necessarily correct according to the study by Jenkins. Erylimaz (2002) discusses steps from the programs that Brouwer (1984) developed. The steps may be used to correct what the educators regard as wrong about a scientific phenomenon that a learner is trying to explain.

The following are steps that Eryilmaz (2002: 1003) discuss from the programs that Brouwer (1984) developed (Problem-Posing Physics Program). These may assist in dealing with alternative conceptions in general. The programs

i. ensure that the students are aware of their preconceptions;
ii. allow students to make their own conceptions or hypotheses explicit and test them;
iii. confront students with situations where their preconceptions cannot be used as explanations;
iv. let student become aware of this conflict. This means that educators must set up a teaching-learning situation that will reveal dissonance between what the learners have as

alternative conception and what is scientifically correct. In this way learners may be forced by the situation to change their alternative conceptions to what is acceptable in class. McClelland mentions that:

> *"Without dissonant experience there is no motivation to know more. The most elaborate is piecemeal explanation where notions about different phenomena are incompatible without this being apparent, or where circumstances in which inconsistencies become apparent are not sufficiently salient for an effort at reconciliation to seem worth the effort."* (McClelland 1984: 3)

v. help students to accommodate the new ideas presented to them;

vi. make students conscious of the fact that their new knowledge is more powerful than their previous ideas by applying the model in familiar and new situations;

vii. give the students a feeling of progress and growth in mental power and help students develop confidence in themselves and their abilities; and

viii. test scientific understanding both conceptually and qualitatively.

Gilbert, Osborne and Fensham (1982) differentiate between 'student's science' and 'teacher's science' by the outcomes of teaching. This may serve as a precaution to educators that 'teacher's' will not always be achieved. Some learners' alternative conceptions may persist even after thorough teaching by the educator. There is no teaching method that is absolutely perfect.

Jenkins also criticizes common sense or everyday knowledge that it should not always be valued over scientific knowledge, or that all forms of knowledge are always of equal worth.

> "*Common sense or everyday knowledge is sometimes wrong and occasionally dangerously so. The particular point is simply that each of us, in our everyday activities, is usually content to use a model which seems adequate for the purpose we have in mind. The model may draw upon a variety of sources but it will always be tested against experience. This, of course, does not make 'true,' even though, because it works, it may seem so. As noted above, it is on*

> *this issue that those who equate constructivist science education with helping students to 'make sense' of the natural world run into some difficulty*."
> (Jenkins 2000: 606)

As mentioned, prior knowledge plays a vital role in the identification of alternative conceptions. It is this knowledge that informs the educator about the learner's understanding of the concept to be taught. The educator in turn exploits this knowledge in order to create dissonance in class, thus encouraging for conceptual change by the learner.

The views of the critics of constructivism may be important to consider. Though this is the case, constructivism and its principles form the framework on which this study is based.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

The reader is reminded of the research questions of this study, namely,

(i) What are students' conceptions about projectile motion? And specifically,

(ii) Can they predict how a projectile will move, and provide an explanation thereof? (refer back to page 10).

In order to provide a research-based answer to these questions, it was decided to use a case study. A case study is characterized by observing or probing "*the characteristics of an individual unit- a child, a clique, a class, a school, or a community*" (Cohen & Manion, 1980: 120). Cohen & Manion, (1980: 120) regard the purpose of observing as intended "*to probe deeply and to analyze intensely the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalizations about the wider population to which that unit belongs*"

In order to execute the project, a small number of grade 11 and 12 science learners were given a test with the purpose of probing deeply into their beliefs regarding projectile motion. The following characteristics of case studies as a research method were extracted from Dyer (1995: 48). Dyer regards a case study as:

1. **A descriptive method**. The research describes pieces of behaviour or a problem that is encountered in learning, for example, inconsistent beliefs that learners have regarding a certain concept or phenomenon.
2. **Narrowly focused**. A small group is used as sample for a larger group. The results found will then form a general belief, impression or feeling of the larger group.
3. **Highly detailed**. The researcher probes deeper in order to get more details regarding the problem under scrutiny.

4. **Combines objective and subjective data**. The information collected in a case study represents almost any combination of objective and subjective data. Alongside the objective description of behaviour and its context, the case study can equally include details of the subjective aspect, such as feelings, beliefs, impressions or interpretations.
5. **Process oriented**. The case study enables the researcher to explore and describe the nature of processes which occur over time.

3.1. Sampling

As mentioned earlier, some grade 11 and 12 science students have problems in understanding projectile motion and concepts related to it. Research was conducted in three science classes in one conveniently chosen high school: one grade 11 (25 learners out of 103) and two grade 12 classes (42 learners out of 111).

In addition to the three classes at high school level (the main study), the mid-year examination scripts of a first year physics university class were also assessed through *ex post facto* scrutiny. In the examination some questions were assessing the student's level of understanding on projectile motion. This supplementary study was undertaken to see if students' understandings changed in any significant way at the tertiary level.

3.2. Ethical issues

The objectives of the study were made clear to all the learners and other colleagues. Permission was obtained from the Gauteng Education Department, Headmaster of the school, learners and their parents, as well as the educators in the science department within the school.

It is important to mention that participants were allowed to withdraw from the study at any point. The examination scripts of university students were perused with the permission of the lecturer concerned.

3.3. Data collection and analysis techniques

Diagnostic test

A diagnostic test was used to collect data during a science double-period (1 hour). Preference was given to the end of the day. This was intended to allow for more time to complete the test outside teaching hours, in case one hour was not enough. Time was also afforded to explain some questions in case students encountered difficulties with the test.

The test was designed such that students would write their responses on the instrument. Appendix A is a sample of the diagnostic test. Appendix B are the questions designed for Physics I University Students (extracted from the mid-year examinations)

3.4. Justification for the use of diagnostic test

As the name suggests, a diagnostic test is used in this case to diagnose or probe deeply on problems regarding comprehension of projectile motion and the concepts associated with it. Diagnosis is a *thorough analysis of facts or problems in order to gain understanding and aid the future* (Collins English Dictionary).

The structure of the diagnostic test contains multiple choice items whose responses represent the conceptions and alternative conceptions that students have regarding projectile motions. The alternative conceptions serve as distractors in the test. This is in accordance with the innovative work by Tamir, quoted in Treagust (1988: 160) as saying "*These alternative responses being representative of typical conceptions and misconceptions of students have a distinctive advantage as compared to regular test items for which professional test writers provide the alternatives*."

3.5. Limitations

- The main study will be limited to grade 11 and 12 science learners in a single school. (Although a small sample of first-year University students will also be investigated).
- The results are not generalizable.

3.6. Rigour

Setting good questions for a diagnostic test required considerable skill and care. It was therefore necessary to pilot (and re-pilot when a need arises) the diagnostic test in order to improve its rigour. When piloting the test, the following were important to consider:

- Readability of the test (font size and type)
- Language usage. Terms used in the test must not be difficult, as the test will be written by English Second-Language users.
- Diagrams must be easy to understand and analyze. Students will be referring to diagrams for answering most of the questions in the test.
- Time allocated for the test must be sufficient for its completion.
- For the purpose of piloting the diagnostic test, two science educators from different schools were provided with the test and asked to utilize it in their classes. According to their feedback, the test was testing mainly what it was intended to test.

The supervisor was requested to assist in piloting the test.

CHAPTER 4
TEST RESULTS AND ANALYSIS

4.1. Analysis of results of grade 11 and 12 questionnaire

4.1.1. Questions 1 and 2

In these items the car is moving forward with constant velocity and the top of the car is closed. The expected responses for question 1 are **C** and **ii)** for a reason, while the correct response for question 2 is **A**.

Question: 1

Most grade 11 learners (44%) opted for **C** as the response and 40% for **ii)** as the reason, while only 7% of grade 12 learners chose **C** as the correct response and 18% for **ii)** as the reason. This is no surprise as the grade 11 learners have recently studied the topic and the correct facts may still be dominant in their minds.

Grade12 learners studied projectile motion in the previous year. Perhaps they have resorted back to their alternative conceptions regarding this topic. This is shown by the highest percentage (56%) for **A** in question 1. This implies that most of them believe that ball will simply fall straight down, that is, it only has vertical motion and no horizontal motion. This is further supported by the fact that most of them (60%) chose **iii)** as their reason in question 1. This is an idea that may be regarded as naïve. It may persist throughout life.

Question: 2

Grade 11 learners still show better results when compared with grade 12 learners. For the correct response (**A**) grade 11 learners obtained 28%, better than grade 12 learners who obtained 19%. The same reason may be applicable, that in the case of grade 11 learners, the information on projectile motion is still fresh in their minds.

Both groups obtained the highest percentages for option **C**, 64% for grade 11 learners and 45% for grade 12 learners. This may suggest that they have problems in believing what is correct. The grade 11 learners are showing signs of being confused in choosing what they are expected to choose. In question 1 (in which the response was in writing) they obtained good answers. In question 2, the questions are similar to question, except that the responses are by means of lines. In this case the trend to their responses changes. Most of them opted for incorrect responses.

Reasons for question 2

In this case learners are expected to provide their own reasons for the choice they made. Some of the reasons worth quoting are tabulated, and comments thereon are made:

Misinterpretation of reference frames

Response	Comment
1. *"Simply because the ball is not part of a moving car, no matter where the car was moving to any direction the ball will just go down and I think the reason for that will be the gravity."*	This is a belief among some learners, that if an object is dropped, it will always fall straight. The vertically downward motion, according to this belief, seems to be the only one that exists, irrespective whether an object is projected at a certain angle to the ground or is released from a certain height. This is in line with what Hynd *et al*. (1997) identify as a common alternative conception associated with projectile motion (alternative conceptions by Hynd *et al*. written on page 14 of Chapter 2 in this research report).
2. *"Because immediately you throw it, it will go vertically downwards."*	
3. *"It is because it will not be affected by the forward motion of the car."*	
4. *"Because of the gravitational force which attracts objects."*	
5. *"It is because, if the car is at a constant speed it is a same as if the car is not moving that is why the ball will directly go down because it is not acceleration."*	

4.1.2. Questions 3 and 4

For these two questions, the car is open at the top. The expected responses for question 3 are **C** and reason **ii)**. For question 4 the correct response is **A**. The reason for this response is that the ball has both the forward and downward motions. It will thus follow a parabolic path as shown in **A**.

Question 3

In both grades, most learners regarded **B** (instead of **C**), as the correct response. The fact that the car is open at the top influenced their thinking. They believe that the ball will fall behind the release point due to air resistance. The fact is that even though air resistance may be present in this situation, it is insufficient to overcome the forward inertial motion.

Only 24% of grade 11 learners had the correct response. Grade 12 was even poorer (12%). This again may be attributed to the fact that grade 11 learners have recently studied the topic, while grade 12 learners studied it the previous year.

Reasons for question 3

Most grade 11 learners (36%) chose ii) as the reason. This is almost twice the percentage for grade 12 learners (20%). A high percentage (33%) of grade 12 learners provided their own reasons in this case.

The reasons provided by the grade 11 and 12 learners reveal some alternative conceptions, or lack of understanding of the topic. Some of the reasons (unedited) are listed below:

Incorrect understanding or air-resistance and frictional force

Reason	Comment
1. *"It will be disturbed by the air resistance so it will land after the release point."*	The understanding of air resistance of one of problems that some science learners encounter. In fact, it may be possible that there is no much that is taught regarding air resistance and its effects at high school level. It is no surprise therefore that in these reasons the effects of air resistance are incorrectly interpreted. It is a fact that air resistance does have an effect, to some extent, on moving objects (refer to reason 3 in this table). However, the forward and downward motion, are the main determining factors affecting the path that will be followed by the projected object. Reason 3 is therefore correct, though not complete. For some learners, air resistance is regarded as the only factor that determines the path followed by the ball in Question 3 of the diagnostic test.
2. *"Because air masses are there which will disturb the ball."*	
3. *"I think the ball will be affected by air while the car is moving forward, so the air will push it back."* (refer to the fourth alternative conception extracted from Hynd *et al*. and mentioned on page 13 of Chapter 2 in this research report)	
4. *"Because of air friction the speed of the ball decreases a little."* (refer to the fourth alternative conception extracted from Hynd *et al*. and mentioned on page 14 of Chapter 2 in this research report)	
5. *"Reason, the ball will land some distance behind the release point because there is a force of air which is acting against the car or in opposite direction."* (refer to the first alternative conception extracted from Hynd *et al*. and mentioned on page 13 of Chapter 2 in this research report)	
6. *"There is an unbalanced force of air friction the speed of the ball will behind the release point."*	

Question 4

In this question most grade 11 learners opted for **C** (64%) and only 16% got **A** as the correct response

In the case of grade 12 learners, however, most of them, 69%, regarded response **D** as correct and only 12% opted for **A** as correct.

The trend here is that the grade 11 learners still hold the idea that the ball will fall straight down, irrespective of whether the car is open at the top or not. From the graph and the table, they obtain 64% for in both questions 2 and 4.

However, most grade 12 learners (69%) opted for **D** as correct in this question, whereas in question 2 the majority of them (45%) opted for **C**.

As noted before, **A** is an expected response in this question. More grade 11 learners (16%) responded correctly than grade 12 learners (12%).

The following are some of the reasons provided by the learners in both grades:

Misinterpretation of the reference frames

Reason	Comment
1. “The gravity will attract the ball to fall down.”	In this category only the second reason is correct. In the remaining reasons the learners misinterpreted the reference frames. This is due to the fact that it is the inertial motion that is commonly observed in daily life. According to some science learners the non-inertial motion does not exist, even though scientifically projectile motion possesses both motions.
2 .“The ball is the part of the moving car, therefore will land in front of the point of release.”	
3. “When a ball is thrown upwards it will simply fall by changing direction so as for the observer will be seeing of that released ball.”	
4. “The ball is not part of the car and is therefore not moving with the car.”	
5 .“Just because the car is open it doesn’t mean it will change, it will still go down in a straight line because of the way he released it.”	

4.1.3. Question: 5

In this question learners are expected to imagine themselves piloting an aeroplane with a bomb attached below it. The correct response is that the bomb should be released some distance before passing the target (Option **B**). The reasons for this answer is that the bomb will continue with forward motion while it falls, thus allowing it to fall some distance ahead of the release point (reason **ii**).

48% of grade 11 learners got **B** as the correct response and for grade 12 it was 62%. In this case the performance of the grade 12 learners is better than those in grade 11. The question is more challenging when compared to the others already dealt with. The fact that the bomb is attached below the flying aeroplane poses many challenges. This might lead to some confusion. They thus concluded that it must be released some distance **after** the target, (and not **before** as is the correct option). Such confusion is more pronounced in the grade 11 group than in grade 12

The following are some of the unedited reasons provided by the learners in both grades:

Misinterpretation of forces acting on the bomb

Reason	Comment
1. "There is backward force acting on a bomb and aeroplane. Therefore the bomb will hit the target after passing.	In the reasons provided the learners misinterpreted air-resistance as well as the forces acting on the bomb. Of particular is the last reason. The learner believes that heavier objects are less affected by air-resistance than lighter objects. He/she also regards air-resistance as 'wind'. These are some of the most common alternative conceptions that some learners have on motion in general.
2. "Release the bomb some distance after passing the target because of the unbalance opposite force will act on the ball after release."	
3. "My reason it will depend on the weight of the bomb if it is more or having more kilograms I will release the bomb after I pass the target. Light bomb will be push backwards by wind and heavy one will not."	

4.1.4. Question: 6

The concept inertia is mainly dealt with in grade 11. In this question the two groups of learners are expected to define inertia. Three options from which to choose the definition are provided. The correct option in this case is **B**. Most learners in both groups got the correct response, 60% for grade 11 and 62% for grade 12. This high performance in this case can be attributed to the fact that they remember correctly the definition of this concept. However, linking this concept to projectile motion seems to be problematic.

In the previous questions, they were expected to apply the concept so as to explain projectile motion. Example, in Question: 5 the aeroplane is flying forward with the bomb. When the bomb is dropped, it will continue with the forward motion while simultaneously falling. For it to continue with the forward motion is due to its inertia. This then leads to the fact that the bomb has to be released some distance before the target for it hit it.

Alternative ideas about inertia are quoted below:

Incorrect definition of inertia

Reason	Comment
1. “The tendency of object moving at constant velocity.”	Inertia is among others, a science concept that is not constantly encountered by science learners in their studies. Discussion on this concept which, occurs mainly in grade 11, is often minimal, and learners do not get enough opportunity to grasp its meaning to apply it in some situations outside the classroom. It is therefore no surprise to find these incorrect definitions of the concept.
2. “Is the force that keeps an object in the same position or state of movement until it is moved or stopped by another force.”	
3. “This is due to the property of the body known as inertia.”	
4. “Inertia is that property of matter which opposes change in motion of the object.”	
5. “When you traveling in car, there is a tendency to turn to left when the car is turning to the right side.”	

4.1.5. Question: 7

The explanation of inertia relates to the explanation of Newton’s first law. The law states: “*A body retains its state of rest or uniform motion in a straight line unless an unbalanced resultant force acts on it*.”

This is a stand-alone question that was intended to check if learners do have a good background understanding on Newton’s laws of motion. The expected response in question is **A**. Most learners in the two groups got the correct response, 84% for grade 11 and 93% for grade 12. This performance is also linked to the fact that Newton’s laws are handled in both grades, and in more detail in grade 12, where they are applied in everyday situations. As is the case with inertia, some learners fail to link this law with projectile motion.

4.1.6. Question: 8

In this question the learners are expected to state Newton’s first law. The correct response for this question is **A**. Grade 12 learners’ performance is better than that of grade 11, 88% and 28% respectively. As cited earlier in this discussion, the law is dealt with in more detail in grade 12 than in grade 11, hence the difference in the performance.

Some learners in both groups confuse the three laws and only one learner came with his/her own (unedited) statement of the laws as quoted below:

"*Because when a resultant force is applied to the projectile it does not produce acceleration*."

4.1.7. Question: 9

Grade: 11 (25 learners)

Correct responses	Incorrect responses
8 (32%)	17 (68%)

Grade: 12

Correct responses	Incorrect responses
5 (11.9%)	37 (88.1%)

Others define projectile motion in their own (unedited) words as quoted below:

A. Forces only are involved in projectile motion

Definition	Comment
1. "It is a force from an object that is thrown."	It is a fact that certain forces are involved in the motion of objects. This is an idea that learners. Unfortunately they incorrectly involve forces in the definition of projectile motion.
2. "It's any force coming from an object that has been thrown from may be a building."	
3. "It's any force coming from object that has been thrown from may be a building will go down."	
4. "It is a powerful motion e.g., weapon with large amount of speed."	
5. "It is something that is capable of being projected by force e.g. bullet."	

B. Explanatory statements

Definition	Comment
1. “A projectile motion is a motion moves in a straight line.” *“Projectile motion is about objects moving anywhere above the surface of the earth.”*	In this category the learners wrote <u>any</u> statement that they <u>think</u> closely defines projectile motion.
2. “Projectile motion is about objects moving anywhere above the surface of the earth.”	
3. “A projectile motion is something which you throw it can be a stone, pen, or an empty tin.”	
4. “It is the free fall motion where a body is projected upwards or downwards at a certain initial velocity, or from rest.”	
5. “It is the motion that has been created by a person to throw an object.”	
6. “It is the movement of the object from the starting point to the end point.	
7. “It is the movement of an object when it reaches the initial then it turns back from where it started.”	
8. “Is the motion that an object move at a straight line and immediately change the direction like the missiles.”	
9. “Projectile motion is the motion that the initial velocity of which is given by throwing/ firing or in a vertical direction.”	
10. “It is a movement of a missile or a rocket.”	
11. “Is whereby an object or something designed to be shot forward of which it’s motion is fast as a bullet.”	
12. “It is the up going motion and the down going motion changing directions from the starting point to the ending point.”	
13. “Projectile motion is the movement of missiles.”	

C. Explanations that incorrectly involve other concepts (or definitions thereof)

Definition	Comment
1. "The tendency of object will remain at rest."	In this category learners define the concept and from meanings of other concept that are associated with motion such as inertia and acceleration. Even though this is the case, their definitions are incorrect.
2. "Is an object moving from 0km to 100km in less than 2s, e.g. rockets."	

4.1.8. Question: 10

Grade: 11

Only two learners did not respond to this question in this grade. Most responses include cricket, javelin throw, (lawn and table) tennis, soccer, baseball, shot-put throw, volley-ball, netball, target-shooting, rugby, discus, hurdle-jumping, high-jumping and basket-ball as examples of sport activities in which projectile motion is applied.

The following unedited reasons for understanding of projectile motion in order to win matches in the sport activities are provided by the learners:

Incorrect belief about application of projectile motion in sport activities

Reason	Comment
1. "It teach you how much force is needed to the object to reach the point."	Almost all these reasons involve the concept 'force' as the main factor that can promote winning in sport activities in which projectile motion is involved. There is nothing said about the angle of projection, velocity etc. This may be an indication why some learners that are involved in sport are not good at their activities. They believe in having power and force as the only factors for them to win. The learners also, did not provide examples of sport activities in which projectile motion is involved. They may have not understood what was required of them.
"Due to the fact that they need a force so that you can win the match."	
2. "It's because you win by using the force you got to bat the ball."	
3. "Understanding this motion is best for swings in golf and best for throws in basketball."	
4. "Because both cricket and shot-put need power. There must be force applied."	
5. "It need force to land in long distance."	
6. "Its because you win using a force."	
7. "It is important because it teaches you how to focus and concentrate on how to aim the target."	

Grade: 12

Five learners did not respond to this question, some respondents included marathon running, skiing and skydiving as involving projectile motion. Others included vague examples such as athletics and skipping.

The most appropriate examples also mentioned in this grade include those for grade 11

Incorrect belief about application of projectile motion in sport activities

Reason	Comment
1. "By making some training exercises by running up and down."	These learners also did not provide examples of sport activities in which projectile motion is involved. They provided reasons which are just statements that do not show much understanding of what is required of them (as was the case with the grade 11 learners)
2. "The ball will be to quick for your oponante."	
3. "Because in this activities you must be as fast as you can."	
4. "Is important because when you win a match you had worked hard."	
5. "Where you heat the ball with a racket and the ball will move quickly, therefore is a force acting on the ball."	
6. "Because for every force there is an equal but opposite force."	
7. "Because when you use vertical projectile motion when the ball is projected vertically upwards and returns to the point of projection."	
8. "Because both the sport experience motion force when the ball go up."	
9. "In order to know the pulling force and know your velocity from starting point to end point."	
10. "Because this 2 activities involve projectile motion."	

4.2. Analysis of Physics I University Students.

There are four groups of these students, namely, the MBBCH, Physiotherapy, Pharmacy, and Biomedical students.

MBBCH students

15 scripts (out of 64) were randomly selected:

Correct responses	Incorrect responses
12 (80 %)	3 (20 %)

The following are comments based on the incorrect responses provided:

i) They only say that horizontal motion is linear, without further explanation in terms of velocity and acceleration.

ii) Vertically downwards motion is said to be "*acceleration*" or "*vertical motion*" without any explanation.

These students show lack of understanding of other concepts involved in projectile motion.

Physiotherapy students

There were eight scripts and all of them were analyzed and the following data recorded:

Correct responses	Incorrect responses
6 (75 %)	2 (25 %)

The two students who got incorrect answers are quoted below (unedited):

Student: 1

i) *"x-coordinate indicates the object's horizontal velocity from its point of projection."*

ii) *"The y-coordinate is the fixed velocity of the projected object."*

<u>Student 2</u>

i) *"Horizontal motion."*

ii) *"Vertical motion."*

These student do not have much understanding on the inertial and non-inertial motion.

Pharmacy students

15 scripts randomly selected (out of 36) were analyzed and the following data recorded:

Correct responses	Incorrect responses
8 (53.3 %)	7 (46.7 %)

The two students who got incorrect responses are quoted below (unedited):

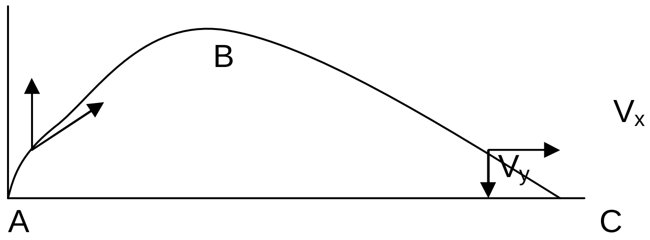
<u>Student: 1</u>

i) *"Horizontal motion is constant accelerated motion."*

ii) (No response for the vertical component)

<u>Student: 2</u>

Horizontal motion: "*x-coordinate shows uniform velocity, vertical motion, the y-coordinate shows uniform velocity from A to B then at B the velocity is equal to zero and from A to B the velocity is uniform again*."



<u>Student: 3</u>

i) *"Horizontal component indicate horizontal motion."*

ii) *"The vertical component indicates vertical motion"*

Student: 4

(same as for student: 3 above)

Student: 5

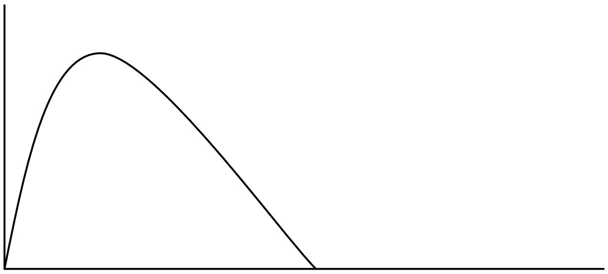
i) *"Horizontal component is the x-component of velocity, e.g., $V_{ox}= V_0\cos\Theta$."*

ii) *"Vertical component is the y-component of the velocity e.g., $V_{oy} = V_o\sin\Theta$"*

Student: 6

i) *"Horizontal component is horizontal motion."*

ii) *"Vertical component is circular motion."*



Student: 7

i) *"Horizontal component is horizontal linear motion, acceleration."*

ii) *"Vertical component is vertical gravitation motion, deceleration."*

All these student show lack of understanding on projectile motion.

Biomedical students

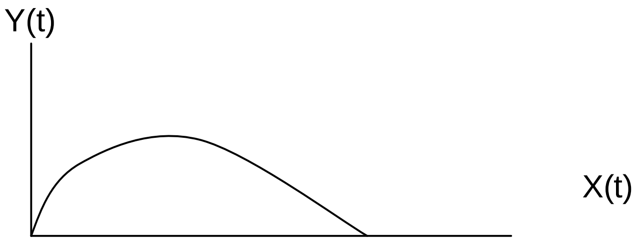
15 scripts randomly selected (out of 35)

Correct responses	Incorrect responses
8 (53.3%)	7 (46.7%)

The seven students who got incorrect responses are quoted below (unedited):

<u>Student: 1</u>

Drew the following diagram:



i) *"Horizontal component is decelerating kinetic motion;*

ii) *"Vertical component is accelerating kinetic motion."*

<u>Student: 2</u>

She/he wrote *vm* and scratched *hm* and vise versa for the second response.

<u>Student: 3</u>

Wrote only: i) "horizontal" and ii) *"projectile"*

<u>Student: 4</u>

i) *"The horizontal motion where acceleration due to gravity is equal to zero"*

ii) (Provided the correct response)

<u>Student: 5</u>

i) *"Along the x(t) coordinate linear motion is described."*

ii) *"Along the y(t) coordinate, parabolic motion is described."*

<u>Student: 6</u>

ii) *"Horizontal motion- movement along the plane."*

iii) *"Vertical motion- movement perpendicular to the plane."*

Student: 7

i) *"The x-coordinate is showing horizontal straight line movement of the projectile. It is positive motion, i.e., accelerating motion. Projectile going upwards."*

ii) *"Decelerating or negative motion. The motion of the projectile coming downwards."*

All these student show lack of understanding on projectile motion.

CHAPTER 5

DISCUSSION OF RESULTS

5.1. Interpretation

From the analysis of the results, it is clear that some learners do have alternative conceptions on projectile motion. There are several sources or origins of the alternative conceptions. Only a few important sources of alternative conceptions are discussed in this report.

5.1.1. Confusing the reference frames (inertial and non-inertial)

The first five questions in the diagnostic test are structured such that they assess which reference frame subjects were using to respond to the questions. For the responses to be correct, both the inertial and non-inertial reference frames should be viewed.

Very few subjects, particularly in grade 12, viewed both reference frames when predicting the motion of projectiles. Most of them used the non-inertial reference frames to respond to the questions. This resulted in most of them opting for incorrect responses. This seems to be a common problem.

Such problems originate from outside the classroom as the subjects play with toys throw objects around, *etc*. This fact is supported by McCloskey's (1983: 114) statement "*Experiences reported by some of our subjects soon led us to suspect that intuitive beliefs about motion play a role not only in people's thinking about hypothetical situations but also in their interactions with real objects*."

For example, when bouncing a tennis ball as you walk or run, it may seem that the tennis ball is falling straight down, that is, only the vertical motion will be observed in this case. The motion is therefore viewed from the non-inertial reference frame. The horizontal motion is not easy to observe in such a situation because both the person bouncing the tennis ball and the tennis ball itself have the same forward motion. Thus observing the motion of the tennis ball will only reveal the vertical component. This is one of the problems identified by Hynd *et al.* (listed in Chapter: 2 page 16 to 17). Such alternative conceptions may be permanently stored in the mind of the observer. This stored idea then adds to others, which then leads to alternative conceptions on projectile motion, which later have serious effects in the formal teaching of the topic.

McCloskey (1983: 121) also maintains that

> *"Studies in the perception of motion have shown that when an object is viewed against a moving frame of reference, a visual illusion can arise. The motion of the object relative to the moving frame of reference can be misperceived as absolute motion (that is, as motion relative to the stationary environment)."*

From the previous example, however, a second person who is observing the motion from the side may see the motion of the tennis ball differently from the first. To this observer the tennis ball will follow a parabolic path. This implies that this observer is seeing motion from both inertial and non-inertial reference frames.

Sometimes the media, particularly television, may add to the problem of alternative conceptions. Some science movies may perpetuate wrong ideas in some young learners, such that they believe in what they see. The star character, for example, jumping from one cliff to another which is very far may imply that there is only a horizontal motion, and the effects of gravity do not exist in such a case. Such perceptions may be instilled in the minds of the young for a long time.

These alternative ideas may also result in some learners being incapable of predicting correctly the motion of a projectile. This is the case with most of the high school learners who were involved in this study.

5.1.2. The effects of air-resistance and frictional force

Air-resistance and /or frictional force add to the misunderstanding of projectile motion. Most learners consider air-resistance as opposing the movement of a thrown object, such that they start to believe that the 'wind' (as some of them refer to air-resistance) will push the object backwards such that it tends to land some distance behind the release point.

In the case of frictional force, some learners in this study confuse the meaning of motion with that of force. To them, force and motion are synonymous. (Refer to definitions of projectile motion on the table, page 50) This is also a finding by Eryilmaz (2002: 1002):

> "*Some students share an idea that an applied force is necessary for the continuity of motion at a constant velocity although a frictionless medium is assumed (motion implies force misconception). It is found that such imagined forces are especially common in explanations of motions that continue in the case of obvious opposing forces*."

5.1.3. Language problems

Most learners that were involved in this research project are second-language English speakers. The language used to teach science (English) poses some problems in the understanding of science topics. This means that the learners not only struggle with the language of learning and teaching (the language in science), but also with the science concepts (the language of science). This language aspect has been studied in some details by Rollnick and Rutherford (1996) as well as by Rollnick and Manyatsi (1997).

Johnstone (1991) describe language as the vehicle of communication. Science concepts are not familiar to the learners in the classroom. When science concepts are discussed, confusion may set in, especially when that concept has a different meaning in a different context. For example, the concept "reduction" in electrochemistry is used to refer to a substance that gains electrons. However, to a layman outside the science context, this concept means making something small (in quantity). Such a concept becomes hard to understand when its teaching occurs.

In other instances, learners may tend to believe that a term which sounds the same in two different languages has the same meaning in those languages. Example, the Zulu word "*ugesi*" means electricity. Its pronunciation is the same as that for gas. It is for this reason that when an educator deals with gases, the learners, particularly in grade 9, tend to think of electricity, and vice versa.

Some educators have a tendency of using words that are not at the level of understanding of their learners. Technical terms, in most cases, will not transmit knowledge to the learners in the way it is intended to. Merzyn (1887: 483) mentions that "*most physicists and physics teachers are proud of their clear use of language*." This hinders the teaching-and-learning process in class. This problem of technical concepts is also found in textbooks. Some educators who use textbooks for teaching tend to use the difficult terms found in the book, without simplifying them. This is at the expense of the learners' understanding. Language in science is obviously important but educators are sometimes unable to make it accessible to their learners.

In the findings of this research project, some learners confuse such concepts as "*air-resistance*" with "*wind" or "air"*; "*curve*" with "*cave*" *etc*. This is made evident in the following unedited quotes from what the learners have written:

- *"I choose A because the car is open so there is much wind."*
- *"It is because the ball will be pushed backwards by air and that air comes from outside because the car is open on top."*
- *"Because when you throw something forward it will take a cave."*
- *"I choose C because air won't disturb the ball, because of the windscreen protection."*
- *"The bomb will be pushed backwards by the wind and it will be close to the target."*

- *“The bomb will go down; it will not be affected by the wind.”*
- *“Horizontal motion is constant accelerated motion.”*

This is in line with Johnstone’s (1991: 120) findings: “*’Audible’ is heavily confused with ‘edible’ and ‘efficient’ with ‘sufficient.*’”

5.1.4. Application of physics in sport activities

One question in the diagnostic test required learners to provide examples of sport activities in which knowledge on projectile motion is applied. This question was intended to check whether or not learners can integrate what they learn in class with what they do or observe in sport activities. Most of the respondents did provide adequate examples in the question. Does this mean that they will be able to apply knowledge on projectile motion correctly? This is a question worth researching.

Goff (2004: 280), who offered a Physics of Sport course at Oberlin College mentions that “*While preparing for the course, I faced a challenge that confronts many physics teachers: How can I make a general education physics course fun for nonscience students?*” This implies that alternative conceptions that are shown in class are also likely to be observed on the sports field and vice versa. It is therefore imperative to find a solution to this problem, both in classroom and on the sport fields.

5.2. Recommendations arising from the research investigation

1) It is important for educators to simplify their instructions, their explanation of science concepts, as much as possible, for learners to comprehend easily and to change their alternative conceptions into what is scientifically acceptable. For example, grade 11 educators need to take greater care to differentiate between inertial and non-inertial motions. This will help learners to find better ways of comprehending these concepts easily. Novak maintains that “*The fundamental challenge to ‘conceptual change teaching’ is therefore to help learners how they must choose to modify*

their concept and propositional hierarchies and to provide instruction that is conceptually transparent to learners" (Novak 2002: 562).

2) It is important to probe learners' beliefs for deeply-held views that are in conflict with modern scientific thought: encourage them to recognize these conflicts and work through their feelings about them. Concepts such as inertia, acceleration, force etc, are all abstract and not easy to comprehend. Their meanings must be clearly explained and presented to learners in simple forms. Novak (2002) regards this process as a negotiation of meanings between students and teachers, which is also a social as well as a personal reconstruction process.
3) Learners need to be challenged by the work given to them by the educator. Practical work that involves projectile motion may be prepared by the educator for the learners, in order to assist them understand the concepts involved in this kind of motion.
4) It is also important to prompt learners to think and not just answer. It is therefore important to keep asking the question: 'how do you know that' (Fisher and Lipson 1986).
5) It may be necessary to provide a demonstration in case learners find it hard to understand projectile motion. The use of a video camera to record the motion, and the viewing thereof might help. In this way you will be guiding learners in discovering a more acceptable explanation or describe the accepted scientific theory and show how it accounts for the observation.
6) The use concept mapping may be of help in the assimilation of scientific concepts. Taber (2002: 33) maintains that "*A concept map is a useful graphical representation, that can be used for any information that does not readily fit a linear pattern*". The logical link between concepts associated with projectile motion may be represented schematically to summarize what has been learnt in class.

5.3. Some other points worth trying in class or worth researching

The following are points of the work of Trowbridge and Bybee (1990: 91), applicable in the cognitive development to teaching science:

1. Attempt to determine which students in your class are concrete or formal in their thinking. You can ask students, individually, to hypothesize about some scientific problem which is not visible to them or to do reflective thinking, i.e., ask, “*If you were going to do an experiment again, how would you do it better*?” Present a problem with which a scientist was concerned and ask them how they would solve it. If students do not do well on these tasks, it is indicative that they are concrete operational or in a state of transition from one stage to another. Therefore, teaching should rely less on verbal instructions and more on actions using materials and concrete activities.
2. If the students are in the formal operational stage, require that they should analyze their procedures, data, *etc*., and suggest ways of improving the experimental design. The students in transition from concrete to formal reasoning may be able to do some of these activities and those who are formal in their thinking should experience little difficulty.
3. Ask students to design an investigation. Rather than first telling them how to perform an experiment, ask students how they would set up an experiment to find the answer to the problem under discussion.
4. Provide them with several things and let them establish a classification scheme.
5. Give students as much freedom as they can handle in creating, inquiring, and discovering. This freedom allows for more cognitive involvement, contributing to their thinking ability.
6. Involve students in group projects requiring the solving of problems. Try to constitute the groups so that there will be opposing views, requiring an interchange of ideas. Social interaction is one of the factors forcing cognitive growth. Certainly an intellectual argument requires logical thinking and analysis of positions, facts, and variables.

7. The adolescent mind becomes relatively capable of determining and synthesizing general properties. Adolescent, therefore, should have many opportunities to use reasoning to discover general laws and principles of science.
8. Formal students are able to make correlations and deal with proportionality. Science teachers should provide the necessary guidance to help students comprehend problems of this nature. Many students, however, may have considerable difficulty in accommodating these ideas until they have had several experiences with them.
9. Students should be encouraged to make hypotheses, think propositionally, evaluate data, and originate their own problems. Ask questions such as: "*What hypotheses would you make*?" "*If you were going to do an experiment to find out, what would you do?" "What other problems or experiments do you suggest*?"

Other points to consider in teaching science concepts are the following:

- Educators have spent and are rightly spending much time and effort on curriculum. That it, they do their best to work out what to teach and the sequence in which it should be taught. This is the case with science curriculum. As indicated earlier, projectile motion is taught in grade 11 and the Newton laws and inertia follow later in grade 12. This may contribute to the problems that learners face regarding the teaching of projectile motion. Hsu (2001: 206) states that "*Because of the traditional order of presentation, students do not yet have a precise concept of force as used in physics, and vague and imprecise language must be used while discussing projectile motion*." The topics in the physics syllabus may be rearranged such that the teaching of projectile is preceded by the teaching of inertia and Newton's laws of motion. This can be achieved by introducing inertia and Newton's laws in grade 11 while projectile motion is introduced in grade 12. This may allow learners to repeatedly use these concepts in grade 11 and 12, and thus develop a vocabulary related to projectile motion, as well as better understanding of the gravitational constant and its application.

- In the case of sport activities, the learners that participate must be introduced to a course on the Physics of sport (if possible). This may assist them to understand how to play the sport correctly and consequently, increase the chances of winning and reduce any possible injuries that may be sustained.

Goff (2004) in the course on Physics of Sport gave his students a task of bringing one sport video in which physics is applied. One of the videos was on projectile motion as a component of physics of sport. He mentions that

> "*Projectile motion was studied using the video clips of Bob Beaman's famous 1968 long jump and Doug Flutie's famous 'Hail Mary' pass in a 1984 college football game. In both cases, the students noted projectile distance and time of flight to calculate launch speed and launch angle. The results were obtained using constant-acceleration kinematics in a vacuum. After getting the results, we were able to then discuss how the numbers would qualitatively change if we would include air-resistance, a topic that was quantitatively beyond the scope of the course.*" (Goff 2004: 281)

Such strategies as applied by Goff may assist in the reduction or elimination of alternative conceptions regarding projectile motion and other topics in physics that applied in sport activities. However, it may be possible that alternative conceptions that learners have in class originate from practices on the sport fields, particularly if the course offered is not aimed at eliminating alternative conception.

The above recommendations may be a solution to the problems related to the understanding and correct application of projectile motion.

5.4. Conclusion

From this study it is clear that some students do have alternative conceptions about projectile motion. The performance of grade 11 learners is better than that of their counterparts in grade 12, though the same questionnaire was used for both groups. As mentioned earlier in this document, projectile motion is taught mainly in grade 11, and in grade 12 Newton's laws of motion are the introduced. It is for this reason that the performance of the grade 11 learners is better. They may therefore have better memory recall of the formal teaching of the topic. However, grade 12 learners might have resorted to a "re-understanding" of the various concepts as they have been acquired in their own world: these are what the literature refers to as, *inter alia*, alternative conceptions or naïve ideas.

Other learners were unable to predict the motion of a projectile and even provide explanations thereof (refer to Reason and Comments in TABLE 2, page 46). This is a challenge to all science educators whose learners have these problems, to find a way of assisting them to learn what is scientifically correct. Learners should also be taught in such a manner that what is scientifically correct is retained throughout life, and not to resort back to their naïve ideas about projectile motion.

The performance of university students was also better than that of the grade 12 learners. This may be due to a maturity factor, as well as the way in which projectile motion was dealt with in their lectures. Deliberative efforts were made to stress the most important concepts, and to deal thoroughly with the most common alternative conceptions. This group was therefore at an advantage.

The language used in the presentation of lessons to learners should be simple and understandable to all, without reducing the opportunities of transmitting all important facts on what is taught. Tables 1 to 5 indicate the misinterpretation, misunderstanding or incorrect definitions and concepts that are associated with projectile motion. This may be linked to poor understanding of the language of teaching and learning in class.

Coaches in various sport activities are, in the same manner as teachers in the classroom, faced with a challenge of teaching the correct physical principles required for a particular sport activity, even though they are not teaching physics in a formal sense. In this less formal way, learners will learn what is scientifically correct both in the classroom and on the sport field.

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APPENDICES

Appendix: A

PHYSICAL SCIENCE TEST: GRADE: 11 & 12

Name of learner: ______________________________

Date: ________________

Instructions:

1. Answer all questions in this paper.
2. Refer to the pictures to answer the questions 1 to 8.
3. Make a tick (√) on the box that corresponds to the correct answer, and to the reason where necessary.

e.g. If B is correct, the box must be ticked as shown below:

A	[✓ B]	C

and tick **i** if you think it is the correct reason for your choice above

[✓ i]	ii	iii

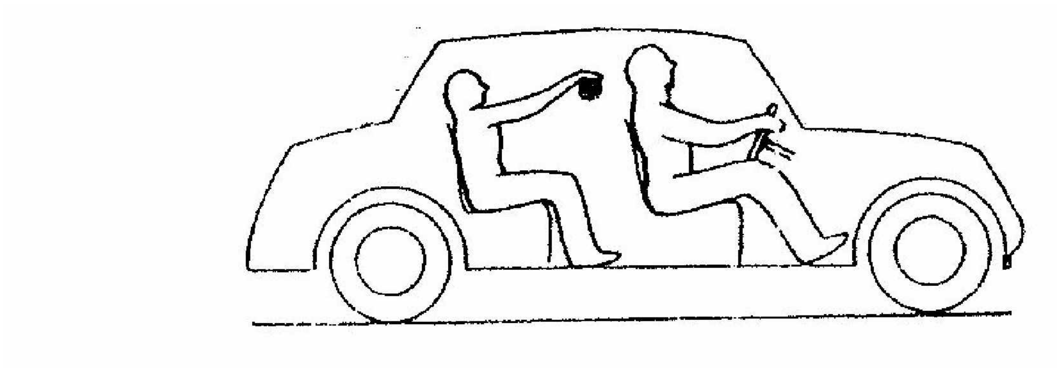
Use the spaces provided to write your own reason if necessary.

4. For question 9 and 10, you must provide your own answers.
5. In case you do not understand some questions, ask the teacher to explain.
6. Time allocated for this test is 45 minutes.

___

Question: 1

Study the following diagram carefully and answer the questions that follow:



A passenger seated in the back seat of the car is holding a ball. The car is moving forward at a **constant speed**. The passenger releases the ball. Where do you think it will land on the car when you observe from outside the car? Choose one answer from the following:

- The ball will land
  - A. immediately below the point of release.
  - B. a short distance behind the point of release.
  - C. a short distance in front of the point of release.

A	B	C

- The reason for my answer above is:

i) The ball is **not** part of the moving car and is therefore not moving with the car. It will land some distance behind the release point.

ii) The ball is part of the moving car and will therefore land some distance in front of the release point.

iii) The ball has inertia. It will not be affected by the forward motion of the car, and therefore land immediately below the release point.

Tick the letter in the box below that you think corresponds to your reason from those provided above:

i	ii	iii

- If there is no reason that corresponds to what you think, write your reason in the space provided (iv below):

iv)

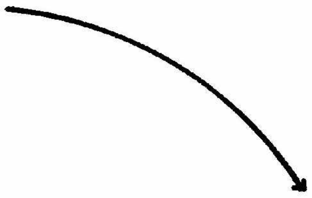
____

____

Question: 2

The path that the ball will follow **when observed from outside the car** is (choose from the following and tick in the box for your answer):

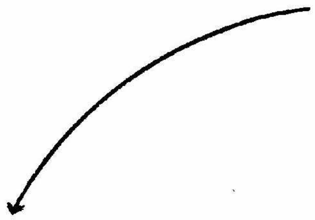
A.



B.

C.

D.

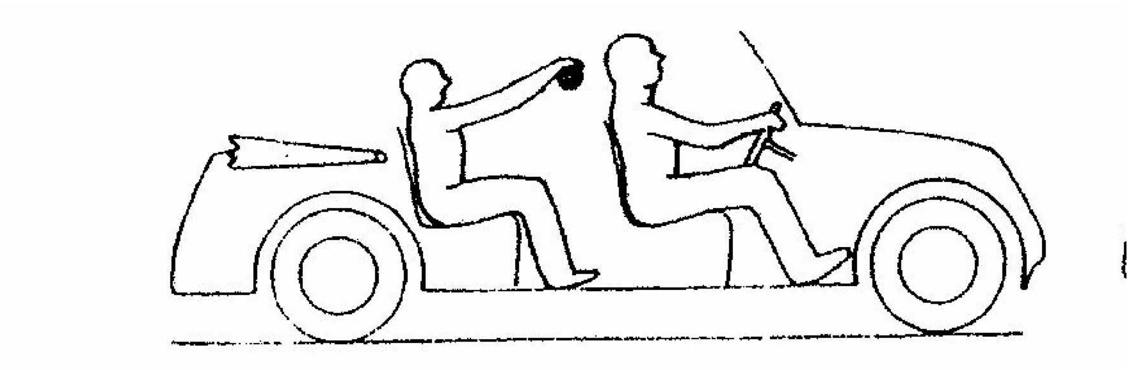


A	B	C	D

Give reason for your answer:

Question: 3

Study the following diagram carefully and answer the questions that follow:



The car is **open at the top** and is **moving at constant speed**. If the passenger releases the ball, where do you think it will land **on the car** when you observe from outside the car? Choose one answer from the following, and tick (√) the box with the chosen answer.

The ball will land

A. immediately below the point of release.

B. a short distance behind the point of release.

C. a short distance in front of the point of release.

A	B	C

The reason for my answer above is:

i). The ball is **not** part of the moving car and is therefore not moving with the car. It will land some distance behind the release point.

ii). The ball is part of the moving car and will therefore land some distance in front of the release point.

iii). The ball has inertia. It will not be affected by the forward motion of the car, and therefore land immediately below the release point.

Tick (√) the letter in the box below that you think corresponds to your reason from those provided above.

i	ii	iii

If there is no reason that corresponds to what you think, write your own reason in the space provided (iv below):

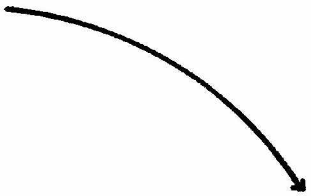
____

____

Question: 4

The path that the ball will follow when observed from outside the car is (choose form the following and tick in the box for your answer):

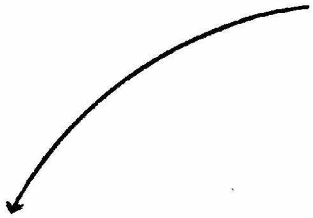
A.



B.

C.

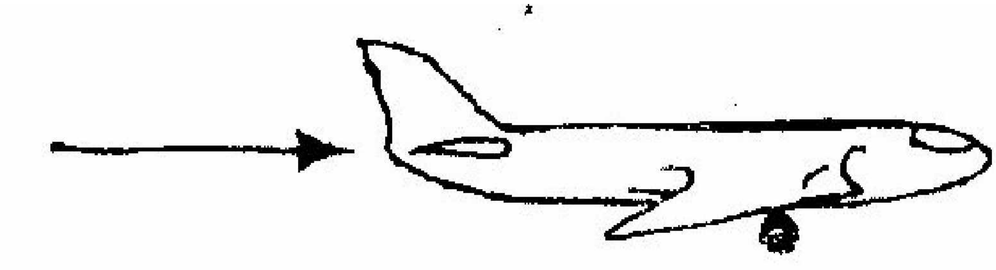
D.



A	B	C	D

Give reason for your answer:

Question: 5



- Imagine yourself piloting the aeroplane. If you were to release the bomb attached below the aeroplane, at which point will release the bomb in order to hit the target?

A. Immediately when the aeroplane is directly above the target.

B. Some distance before passing the target.

C. Some distance after passing the target.

A	B	C

- The reason for my answer is:

i). The bomb will still be moving forward as it falls. It will land some distance ahead of the release point, though affected by air resistance.

ii). The bomb will be pushed backwards by wind. It will land some distance behind the release point.

iii). The bomb has inertia. It will not be affected by the forward motion of the aeroplane, and therefore land directly below the release point.

Tick (√) the letter in the box that you think corresponds to your reason from those provided above.

i	ii	iii

- If there is no reason that corresponds to what you think, write your own reason in the space provided (iv below):

____

____

____

Question: 6

The inertia of an object can be used to explain the path it follows as it moves (refer to question: 4). Inertia is defined as:

A. The tendency of an object to remain at rest.

B. The tendency of an object to maintain its state of rest or of uniform motion in a straight line.

C. The tendency of a body to continue moving in a straight line.

A	B	C

If you have any alternative ideas or comments, please give these:

Question: 7

The explanation of inertia relates to the explanation of:

A. Newton’s First Law of Motion.

B. Newton’s Second Law of Motion.

C. Newton’s Third Law of Motion.

A	B	C

If you have any alternative ideas or comments, please give these:

Question: 8

Newton's First Law of motion is stated as follows:

A. Every object remains in its state of rest or of uniform motion in straight line unless it is compelled to change that state by force acting on it.

B. When a resultant force is applied to an object, it produces acceleration of that object in the direction of the force. The acceleration is directly proportional to the force applied and inversely proportional to the mass of the object.

C. For every force or action, there is an equal but opposite force or reaction.

D. None of these.

A	B	C	D

Please provide reasons for choosing D:

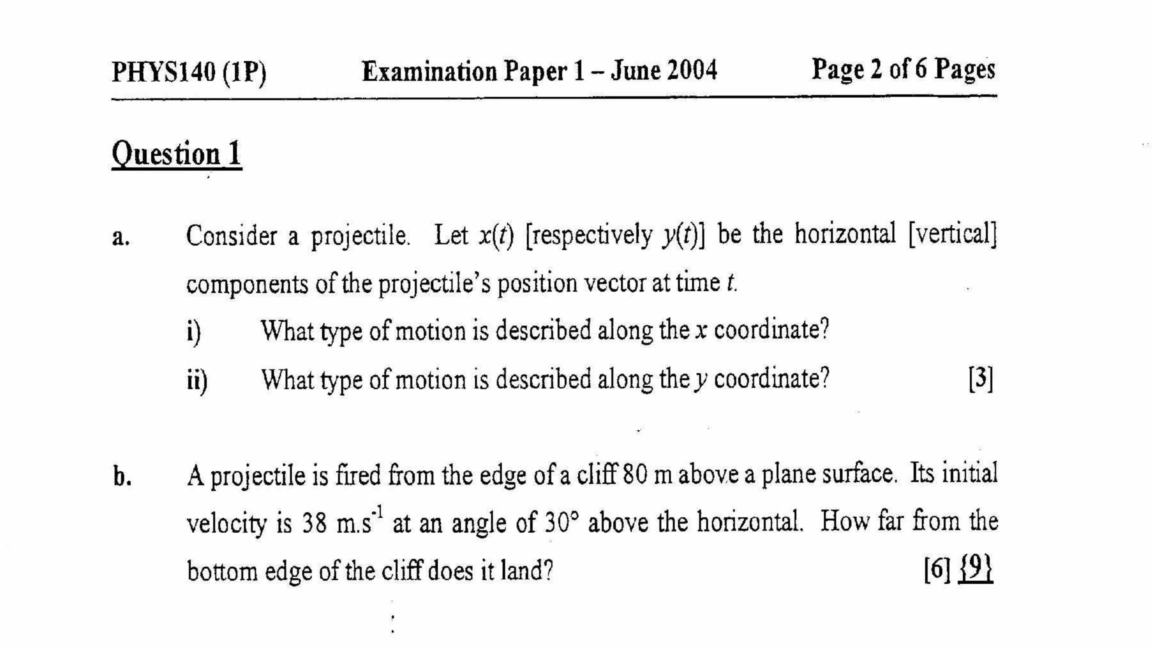
Question: 9

What is projectile motion?

Question: 10

Provide any two examples of sport activities in which understanding of projectile motion is important for winning matches. Why would this understanding be important?

Appendix: B



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Question 1

a. Consider a projectile. Let $x(t)$ [respectively $y(t)$] be the horizontal [vertical] components of the projectile's position vector at time t.

   i) What type of motion is described along the x coordinate?

   ii) What type of motion is described along the y coordinate? [3]

b. A projectile is fired from the edge of a cliff 80 m above a plane surface. Its initial velocity is 38 m.s^{-1} at an angle of 30° above the horizontal. How far from the bottom edge of the cliff does it land? [6] {9}

Appendix: C