Effects of an Integrative learning model on Grade 12 learners' conception of Vertical projectile motion

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A research project submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfillment of the requirements for the degree of Masters of Science in Science Education.

September 2017

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Declaration

I hereby declare that this research project report is my own work and that other than the parts indicated as quotations, no other part has been copied from another source. The paragraphs, sentences and phrases taken from other work have been cited and the reference recorded in the reference list. I further declare that this report has not been submitted before for any examinations or degree purposes in any other university, and that all sources of ideas that are not mine have been referenced.

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H. Chinorumba

04/09/2017

Date

Dedication

To my late mother, Anna Matandule Mugejo: I know you are looking and smiling at me from above. I remain comforted in the knowledge that you are in God's arms.

Acknowledgements

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Abstract

National diagnostic reports have shown that learners perform dismally in Physical sciences, with Vertical projectile motion as one of the most problematic topics (National Senior Certificate Diagnostic reports, 2012-2015). Yet, there is no clear-cut instructional strategy aimed at improving the conceptual understanding of the topic in South Africa, in spite of learners' misconceptions and alternative frameworks being well documented in the extant literature including yearly NSC diagnostic reports.

The study explored the impact of an Integrative learning model - an intervention study I designed, underpinned by Toulmin's argumentation pattern (TAP), Predict-Observe-Explanation (POE) and Contiguity argumentation theory (CAT) - designed to shift students' perceptions towards scientifically accepted ideas though dialogical argumentation. The benefits of dialogical argumentation in sense-making are well documented (Msimanga and Lelliot, 2012). The pinnacle of the ILM, itself embedded on dialogical argumentation, is eliciting for learners' pre-conceived ideas and crafting an instructional package based on these ideas.

Two Grade 12 classes from one school in Gauteng province, South Africa were involved in the study: one as an experimental group (n=38) and the other as a control group (n=36). Data were collected using a pre-post test approach in the main and focus group interviews on selected learners, making it a mixed method approach.

Data were analyzed using the cross tabs method, from which Chi square values and bar graphs were obtained. The level of significance for Chi square values was set at 0.05. By comparing the performance of the two groups in the pre-test using Chi square values, it was discovered that – save for only three items – learners shared common pre-instructional ideas on most items, confirming that the two groups shared common ideas possibly gained from similar experiences with falling objects. This was understandable given that participants came from similar backgrounds, hence potentially share similar or closely related experiences, making it possible to do inter-group performance in the pre-post test on items where the two groups performed comparably. Three items that showed huge significant differences were excluded from discussion involving inter-group comparison of performance to improve results validity.

Further, the findings confirm that learners have common misconceptions, lack of skills and alternative conceptions about vertical projectile motion, some of which are resistant to change in the wake of instruction. This confirms findings in NSC diagnostic reports.

In addition, these misconceptions were then characterized and further probed using focus group interviews with a view to gaining deeper insights in learners' thinking reflective of these misconceptions. The reasoning behind the misconceptions was probed using focus group interviews. The analysis was mixed-method approach since it combined quantitative and qualitative techniques, with the former being the predominant analysis method used in this study.

 The success of the Integrated learning method (LIM) – an instructional strategy proposed in this study - on the EG group was more significant on most items judging by the Chi-square values obtained from comparing the impact of the two teaching methods namely the ILM and the traditional methods in the post-test. Thus, the ILM produced more learning gains on the experimental group than the learning gains realized from the traditional methods on the control group. For instance, the ILM produced significant learning gains on item 4 (see Appendix A), while traditional methods failed to produce any shifts towards the science view on the same item, pointing to the effectiveness of the ILM in comparison to traditional methods.

However, it was difficult to use the TAP to assess and compare the quality of arguments of learners in the two groups on the topic. This was because most learners struggled to construct at least level 2 arguments, restricting themselves instead to lower level argumentations. This calls into question the need to develop teachers on how to use argumentation-based lessons in the teaching of science concepts. Teachers will in turn train learners to engage in debates in science lessons as they co-construct knowledge through what Msimanga and Lelliot (2012) refer to as sense-making.

Keywords: misconceptions, alternative conceptions, integrative learning model, dialogical argumentation.

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CHAPTER ONE   INTRODUCTION TO THE STUDY

1.1 Introduction

One of the topics examined in the National Senior Certificate (NSC) Physical Sciences examinations is Vertical projectile motion (VPM). Candidates' mistakes and errors, coupled with their deficiency of mathematical and manipulative skills in answering questions on VPM – notwithstanding instruction, are well documented in NSC Diagnostic Reports (Department of Basic Education(DBE), 2012 – 2015). In addition, children's misconceptions and alternative conceptions about this topic are distinctly exposed in the extant literature both locally and internationally (Mudau, 2014; Caramaza, McCloskey and Green, 1981; Clerk and Rutherford, 2000; Dilber, Karan and Duzgun, 2009). The combined effect of these factors potentially reflects in low marks on VPM depicted in aforementioned NSC diagnostic reports.

While children's pre-instructional ideas are well catalogued, little/no research has been done in South Africa aimed at improving learners' performance in VPM. Particularly worrying is the lack of sufficient research on dialogical argumentation as a teaching and learning method aimed at improving learners' conceptual understanding of VPM, a reason why the current study finds relevance. That the low marks on VPM persisted in recent years, unabated, became a matter of more concern to me, triggering an exigent need to conduct the study as I attempt to gain insight into learners' thought processes in knowledge construction of VPM concepts.

This study therefore attempts to assess how learners' prior knowledge impacts on their understanding of Vertical projectile motion, with a view to designing appropriate intervention strategies aimed at enhancing better comprehension of the topic. This was done by eliciting learners' pre-instructional ideas which were subsequently used in designing an instructional sequence - embedded in argumentation, aimed at aligning learners' ideas with scientifically accepted views.

1.2 Context

South Africa continues to be impacted by skills shortage in Engineering, Technical and Health professions; trades that, in the main; require good passes in Mathematics and Physical Sciences at matric (South African Government Gazette, 2014). This means that South Africa continues to rely on foreign skilled labour to ameliorate shortages in the aforementioned professionals. Yet, in most recent years, the percentage pass rate for Physical Sciences achieved at 50% and above has repeatedly declined from 25.6% in 2013 to 22.4% and 22.0% in subsequent years respectively; despite concerted efforts by stakeholders in education to improve pass rates. Quite worryingly, the same trend could also be noticed even at percentages achieved at 30% and 40% over the same period.

Table 1.1 NSC Physical sciences achievement rates (NSC Diagnostic reports: DBE, 2011-2015)

Year	Number wrote	Number achieved at 30% and above	Percentage achieved at 30% and above	Number achieved at 40% and above	Percentage achieved at 40% and above	Percentage achieved at 50% and above
2011	180 585	96 441	53,4	61 109	33,8	20,5
2012	179 194	109 918	61,3	70 076	39,1	24,2
2013	184 383	124 206	67,4	78 677	42,7	25,6
2014	167 997	103 348	61,5	62 032	36,9	22,4
2015	193 189	113 121	58,6	69 699	36,1	22,0

With the exception of 2013, it can be inferred from Table 1.1 that the National Senior Certificate (NCS) pass rate over the last five years shows slight improvements in learner performance in Physical sciences. Furthermore, Table 1.1 above indicates that out of a small proportion of learners who do Physical Sciences over the years under consideration, less than 25% on average pass the subject with an average mark of 50 % or more, leaving around 75% of Physical Science learners not qualifying to do Bachelors at University. That puts the number of learners passing Physical Sciences and who end up taking courses in scarce skills even lower.

This extremely low-slung number of learners taking up Physical sciences continues, unabated, in spite of the Government's National Development Plan's(NDP) drive to increase the actual number of learners who pass Physical Sciences (together with Mathematics) with grades that qualify them to do University Bachelors in aforementioned scarce skills (Education Minister's report on NSC Matric results, 2015).

The NDP is a long term initiative by the South African government to jettison poverty as well as reduce inequalities by the year 2030.The NDP, amongst other things, aims to:

"…*unleash the energies of its citizens, grow an inclusive economy, build capacities, and enhance the capacity of the state and leaders working together to solve complex problems*" (GZA, 2013).

The above narration calls for/warrants narrowing down the problem to the exploration of issues around the conception of VPM, itself a clearly problematic topic in Physical Sciences. For me, VPM provides a foundation to understanding other concepts in Newtonian mechanics, believing that all topics in this section radiate from VPM. Conversely, failure to grasp key concepts in VPM exacerbates the problem of low pass marks in VPM, discussed shortly.

A look at recent NSC diagnostic reports shows that learners grapple with some concepts in VPM, among other topics, warranting a closer inspection into effective ways of teaching and learning aimed at increasing conceptual understanding of VPM. Without doubt VPM is a fundamental topic integrating science with mathematics, requiring learners to be able to draw and interpret graphs and apply equations of motion (CAPS document: DBE,2011) - for me, indisputably, underscoring its integral position as a crucial topic in Physical Sciences.

1.3 Statement of the problem

An analysis of learners' performance on VPM from NSC Diagnostic Reports points to learners struggling in answering some, if not most, sections of the questions on VPM (NSC Diagnostic reports: DBE, 2013 - 2015).

Notwithstanding the fact that the trend may not be the same for all years, I now consider the analysis 2015 NSC Physical Sciences paper - for ease of illustration, to highlight the problematic nature of VPM, drawing the basis of my argument on data reflected in Table 1.2 and Figure 1.1.
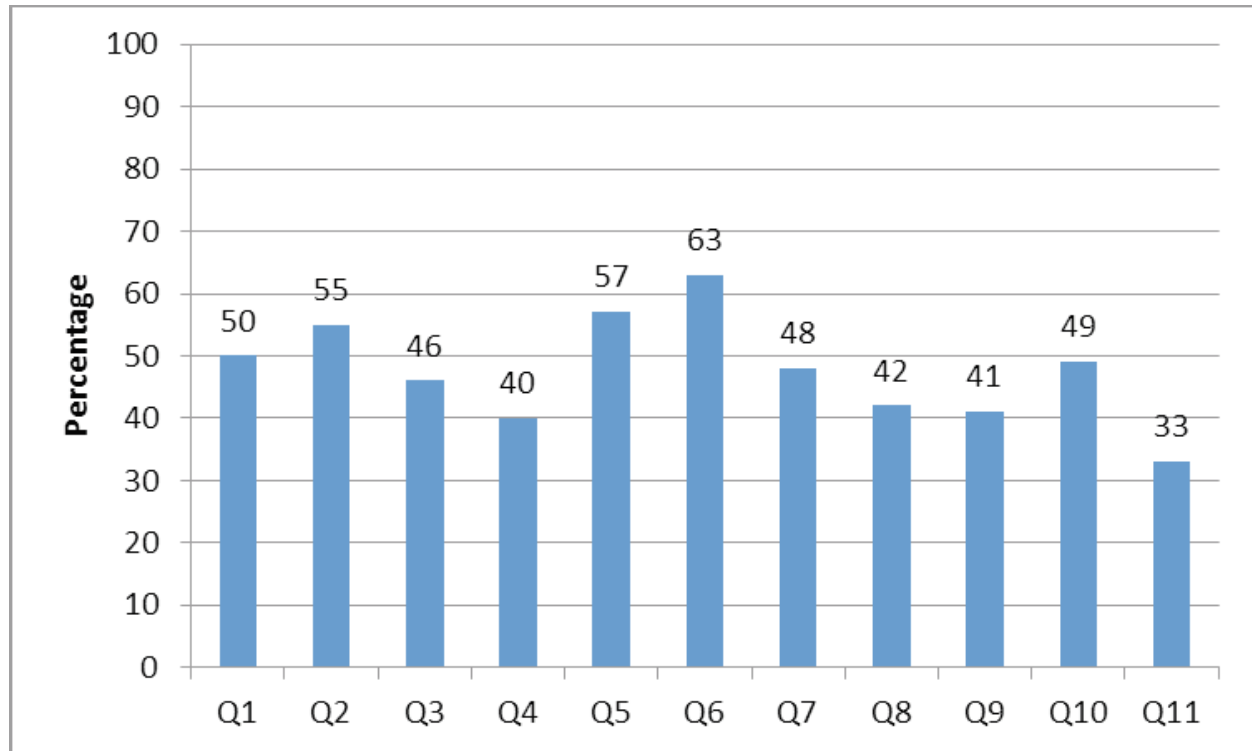
Figure 1.1 Average marks per question expressed as a percentage for Paper 1.

(Source: NSC Diagnostic reports, DBE,2015)

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Table 1.2 Average marks per question expressed as a percentage for Paper 1 (NSC Diagnostic reports: DBE, 2015).

Question number	Paper 1Topics	Average marks (%)
1	Multiple choice questions – all topics	50
2	Newton's laws of motion	55
3	Vertical projectile motion	46
4	Momentum	40
5	Work, Energy and Power	57
6	Doppler Effect	63
7	Electrostatics(Coulomb's Law)	48
8	Electrostatics(Electric fields)	42
9	Electric circuits	41
10	Motors, Generators and Alternating current	49
11	Photo-electric effect	33

Since mark allocation for each topic is not the same, expressing the average marks as a percentage probably gives a level platform, making it possible for us to compare the relative difficulty of topics.

Table 1.2, summarizing average marks obtained by candidates for each of the topics, shows an average mark obtained by the sampled candidates of 46% on Vertical projectile motion (VPM) - a percentage that is relatively low compared to other topics such as Doppler effect (63%), Work, Energy and Power (57%) and Newton's laws of motion (55%), probably pointing to the fact that most learners have more challenges in the conceptual understanding of VPM in comparison to other topics like the ones mentioned above. Even so, for me, an average mark less than 50% on a topic indicates that the topic or part of it was poorly answered by most candidates. In this respect, it can be said that VPM questions were poorly answered by most candidates in the 2015 National Senior Certificate (NSC) Physical sciences examinations.

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According to this line of argument, the average percentage mark obtained by sampled candidates in VPM of 46% is worrying since it is below 50%. It can be seen from Table 1.2 that topics that were difficult for candidates in the year under consideration are Photo-electric effects (33%), Momentum (40%), Electric circuits (41%) and Electric fields (42%), Vertical Projectile Motion (46%), Coulomb's law (48%), Motors, Generators and Alternating current (49%), considering that their average marks were less than 50% in each case. On the other hand, candidates, by comparison, did fairly well in answering Newton's laws of motion (55%), Work, Energy and Power (57%), Doppler effect (57%) as well as multiple choice questions (50%).

That the data used in Table 1.2 is from sampled candidates rather than from all the 2015 Physical Sciences candidates may raise questions to do with generalizability precisely because the sampling method used is not clearly explained. However, according to the same 2015 NSC diagnostic report, Table 1.2 above is nevertheless, a useful approximation of the relative degrees of challenge of each question as experienced by candidates.

While this dismal performance may not be for all the other previous years, it is, however, a good and convenient basis for illustrating the current research problem. Whereas other topics namely Momentum, Electric fields, Electric circuits and Photoelectric effect were poorly answered as compared to VPM in 2015, my choice of VPM for this study was based on my belief that it would be easier to illustrate misconceptions using VPM than using the aforementioned topics.

And even more perturbing is an assertion made by Mudau (2014) to the effect that teachers find VPM difficult to teach, a scenario worth taking a closer inspection and further investigation as it probably points to the poor results depicted in Table 1.2. Accordingly, this calls for a rethink into instructional strategies aimed at integrating a number of approaches to specifically address and modify learners' pre-conceived ideas so that they can align with scientifically accepted views.

Putting it succinctly: In my view, VPM might potentially fare as well as or even better than other topics like Doppler Effect that attained 63% in the year under consideration if instructional strategies are modeled along ILM- itself a teaching strategy anchored on learners' unique pre-conceived ideas expected to be aligned into scientifically accepted views using dialogical argumentation.

In summary; considering the above analysis of the results painting a gloomy picture on learners' performance on VPM, what remains problematic over the years is the failure by learners to score higher marks in VPM, in spite of them being taught or exposed to VPM. Even more problematic is the lack of clear-cut instructional strategies that take into consideration learners' unique pre-instructional ideas in South Africa. This study, therefore, intends to explore learners' ideas on VPM which are subsequently used in the design of a teaching strategy anchored on argumentation, thereby attempting to narrow the gap in this avenue of research.

1.4 Rationale and purpose of the study

This study has been necessitated by the poor performance of learners that I note each time I teach VPM. Yet, it can be argued that comprehending VPM concepts places a learner at an advantage in mastering a whole lot of other concepts in Science because of the treatment of formula, graphs and trigonometric ratios (Mudau, 2014).

As indicated above, VPM, in my view is one of the fundamental topics in Physics every Science learner must get a basic and concrete understanding of. But still, I believe that learners have alternative frameworks and misconceptions, all the while exhibiting a lack of mathematical and manipulative skills in answering VPM questions - a potential contributor to their low marks.

Consequently, I became curious to know the sources of learners' pre-instructional ideas in VPM with a view to crafting teaching and learning intervention strategies that take into account learners' pre-conceived ideas. Potentially, the study will, in some measure, help enhance better understanding of VPM concepts, in part, culminating in good results.

In consequence, the purpose of this study is two-fold. First, it seeks to inform Physical Sciences teachers about learners' pre-instructional ideas on VPM, with a view to tracing and linking these ideas back to their sources. Perhaps appropriate and specific intervention strategies could then be designed with a view to enabling learners to better restructure and align their viewpoints with scientific views.

Second, the study sought to investigate the effects of an Integrative learning model to teach some concepts on VPM. The Integrative learning model is an intervention strategy whose philosophy is anchored on argumentation, and is discussed in more detail in Chapter two.

While it is clear from recent research that learners perform poorly on VPM (National Diagnostic reports, 2013-2015), what is even more worrying is the idea that teachers see VPM as difficult to teach, perhaps another factor contributing to the overall poor results in Physical Sciences (Mudau, 2014). But, interestingly, many educational researchers, curriculum developers and educational practitioners are in agreement that children are indeed active learners, arguing that learners bring to class their pre-conceived ideas, a fundamental concept upon which constructivist ideology is built (Duit and Treagust, 2003).

Accordingly, any teaching on VPM should inevitably consider learners' kinematical intuitions and other pre-conceived ideas which they bring to the lesson.

In doing this research, therefore, I am guided by the following research questions:

1. How do learners' ideas on Vertical projectile motion compare with scientifically accepted views?
2. How effective is the Integrative learning model in bringing about better conception of Vertical projectile motion by learners?

1.5 Significance of the study

The study was done with a view that it would contribute to existing literature in science education by:

1. Reporting on learners' prevalent pre-instructional ideas on Vertical projectile motion in the sample under consideration, thereby adding an academic voice to the existing literature.
2. Comparing and characterizing learners' pre-instructional ideas with alternative ideas and misconceptions that learners have worldwide in Vertical projectile motion as reported in extant literature.

3. Assessing the effectiveness, or none, of an Integrative learning model in teaching Vertical projectile motion to Grade 12 learners. This will possibly inform teachers about teaching strategies that explicitly consider learners' ideas arising out of their interpretations of everyday phenomena, thereby calling for multi-perspective approaches grounded on dialogical argumentation in effecting conceptual change inherently based on learners' unique pre-instructional alternative frameworks.

1.6 Thesis outline

The thesis has five chapters. The introduction of the study is contained in chapter one. That is, Chapter one acts as a signpost - presenting the background and rationale of the study. It interrogates the problem being investigated in the study, further explaining the significance of the study including outlining research questions guiding the study. Chapter one then concludes with a chapter summary as well as a glossary of terms.

Chapter two serves as a review of literature relevant to the thesis including literature review on argumentation and conceptual change. The chapter starts by outlining the historical developments around VPM. Relevant theoretical and conceptual frameworks are then discussed, with a view to situating the study within these germane theoretical and conceptual frameworks.

Research design, processes, and methods of data collection and analysis are included in chapter three. This chapter provides the research path – the path the researcher follows in doing the study. It provides the thread interweaving all chapters.

Chapter four comprises of analysis of data and discussion of results. Here, an in-depth analysis of the data is done, making specific reference to research questions.

Chapter five makes provision for conclusion of the research paying special attention to implications of the study and recommendations thereof to stakeholders – teachers, learners, and curriculum developers. The chapter answers research questions, and attempts to make recommendations at the same time highlighting limitations. It concludes by exploring fertile areas for further research.

1.7 Summary

This chapter provided the context and background for exploring learners' ideas about vertical projectile motion with a view to designing instructional strategies aimed at increasing the overall understanding of the topic. This was achieved through a discussion of pass rates in Physical sciences over the years as well as comparing the average marks in each of the topics, in the process justifying why vertical projectile motion was chosen for current study.

 Lastly, I provided the purpose, rationale and research questions driving the study. This paves way for the next chapter which provides a review of literature relevant to this study.

1.8 Definitions of key terms

a. Alternative conceptions: views or ideas that people have that may not necessarily be accepted by scientists. These views represent the people's worldview about certain phenomena, sometimes referred to as 'common sense beliefs', itself a "codification of experience providing meaning to our natural language" (Halloun and Hestenes, 1985).

b. Misconceptions: are incorrect scientific concepts, usually based on casual observation and understanding of the world.

c. Dialogical argumentation: a sense-making process in which claims and counter-claims are put forward by at least two participants, supported by data, as well as warrants, backings and rebuttals. Dialogical argumentation is viewed in this study as a teaching and learning strategy aimed at making sense of concepts.

d. Projectile: Is an object that is thrown or shot through the air and the only force acting on it (after being launched or dropped) is the gravitational force.

e. Free fall: The unhindered movement of an object in the gravitational field of the earth, when only the gravitational field of the earth is acting on it.

f. Gravitational field: The space around an object of mass (e.g. the earth) in which another mass experiences a gravitational force.

g. Acceleration due to gravity (g): Acceleration due to gravity is the acceleration of a falling object as a result of the gravitational force of the earth, in the absence of other forces such as air resistance.

h. Curriculum and Assessment Policy Statement (CAPS): policy statement for learning and teaching covering all subjects in South African schools and comprising of syllabus, promotional requirements and reporting and recording standards for Grades R-12.

i. School science: Science that is taught at school predominantly based on the syllabus and textbooks.

j. Integrative learning model: The teaching model herein proposed in which dialogical argumentation is central in the teaching of scientific concepts.

CHAPTER TWO LITERATURE REVIEW

2.1 Introduction

Since time immemorial, our beliefs, myths and ideas have been shaped by our physical interactions with nature. Whereas some beliefs and ideas evolved - in part because the then held beliefs could not explain certain phenomena inevitably resulting in a new viewpoint - other beliefs stood the test of time despite being in contrast with scientifically accepted views.

Researchers, amongst them Caramaza, McCloskey and Green (1981) and Prescott (2004) argue that Vertical projectile motion (VPM) dates back to prehistoric times in that humans; through their interaction with the physical world, might have witnessed objects falling or being thrown in the air leading to intuitive and/or evidence-based interpretations of such observations. Such interpretations potentially constitute alternative frameworks if they do not agree with scientifically accepted views.

Consequently, I posit that in order for us to understand the alternative frameworks that learners have about VPM would require us to go back in history and trace the historical developments around the topic. I am of the belief that in this way, we will be in a better position to not only compare ideas that current learners have with scientifically accepted views but to also compare their ideas with pre-Newtonian ideas.

The chapter therefore begins with an outline and interrogation of the historical developments of VPM. This historical journey makes its departure from the world of Aristotelian Physics, proceeding into the Impetus Physics by Johannes Philoponus of Alexandria and ending with Newtonian Mechanics. Such progression will exude key features of the Nature of Science(NOS) which Matthews (1998) asserts as not only being tentative, messy and problematic but also as being socially created and arising out of consensus reached after observations and argumentations due to divergent assertions and explanations. In other words, what we now know as scientifically accepted views about VPM is a culmination, over time, of claims, counter-claims, warrants and rebuttals – key characteristics or features of dialogical argumentation upon which the intervention strategy proposed in this study is premised.

Put in other words, this historical journey is pivotal in that, first, it traces and categorizes the beliefs about VPM dating back to Aristotle, thereby providing us with insights into thoughts processes of learners as they present their alternative conceptions that are grounded in their physical experiences (Halloun and Hestenes, 1985).

After all, several researchers, amongst them Caramazza, McCloskey and Green (1981), Halloun and Hestenes (1985) and Prescott (2004) argue that learners' pre-instruction ideas about Vertical projectile motion exhibit part or most of pre-Newtonian theory of motion, reinforcing the belief that personal experiences are not only key in shaping one's worldview about a phenomenon but have also transcended centuries.

Second, the historical considerations potentially support the nature of science as progressing through argumentation and consensus and laying bare the dispute-laden, problematic and tentative nature of science (Mathews, 1998). More importantly our knowledge of such a history will potentially inform us, amongst other things, about holistic instructional designs that take into account these alternative beliefs fully aware of the nature, history and philosophy of Science, in the process giving learners reason to modify their viewpoints through a sense-making process embedded in common sense beliefs, themselves a springboard upon which all effective instruction should be launched from.

In addition, the chapter looks at theoretical and conceptual frameworks underpinning the study. Theoretical and conceptual frameworks discussed include the Toulmin's Argumentation pattern, the Contiguity argumentation theory, Dialogical argumentation, Vygotsky's Zone of proximal development as well as Conceptual change.

2.2 The history of Vertical Projectile Motion (VPM)
The history of VPM, as discussed by Caramaza, McCloskey and Green (1981) and Prescott (2004), is now summarized in chronological order, starting from Aristotelian physics, through Impetus physics and ending with Newtonian mechanics, believing that the narration will expose historical VPM ideas shared by present-day children.

2.2.1 Aristotelian Physics

Aristotle regarded motion as change of position within a frame of reference. His definition assumes that every motion has a cause, which cause or force can either be Inherent or Contact. An Inherent force places every object with the tendency/property to seek its 'natural place'.

A contact force, however, is regarded as a pull or push exerted by an external agent. Thus, an object's inertia (intrinsic resistance to motion - mass) can be overcome if a large enough force is applied, otherwise the object stays at or tends towards a state of rest. Unlike living things, non-livings were said not to be exerting forces. That is, only living things in direct contact with an object or via some connection (such as rope) can exert an external force on the object.

Accordingly, a person who throws an arrow using a bow is a living agent. In the Aristotelian model, the force that is exerted by the living agent is transmitted to the arrow by means of air 'collapsing in' behind the arrow. Long range forces were not considered by Aristotle.

Further, Aristotle treated the motion of heavy and light objects differently. Aristotle regarded gravity as being applied to heavy objects which he argued have a "centripetal tendency" to fall towards the centre of the universe while Levity, on the other hand, applies to light objects having a 'centrifugal' tendency to move towards the centre of the universe. Prescott (2004) presented Aristotle's qualitative theory of motion, summarized thus:

1. The average speed, v of a falling object is directly proportional to its weight, w. Thus, heavier objects fall faster than lighter objects of the same shape.

Thus: $V=D/T$ ………………………………. (1), where V is the average speed, D is the distance covered and T is the time taken to cover the distance.

2. The average speed, V of a falling object is inversely proportional to medium resistance assuming that size and shape of the falling object is the same in the same medium.

Thus: $V=W/R$ ………………………………. (2), where V is the average speed, W is weight and R is the resistance.

Thus as resistance increases, velocity decreases.

3. For two objects of same size and shape released from rest at the same instant, heavier objects move faster/further in proportion to their weight.

Thus: $V_1 / V_2 = D_1 / D_2 = W_1 / W_2$ ………………. (3), where V_1 and V_2 are respective speeds of objects with weights W_1 and W_2 respectively covering distances D_1 and D_2.

4. Increase in speed can be achieved by an increase in force and/or a decrease in resistance. A bigger force results in a greater speed. Speed also increases if resistance is minimal. Mathematically, $V = \dfrac{F}{R}$ …………………… ………. (4), where V is the average speed of the object, F is the applied force and R is the resistance of the medium.

2.2.2 Impetus Theory

Scripted by Johannes Philoponus of Alexandria, the impetus theory, according to Prescott (2004), assumes some "immaterial motive power" imparted by an active agent. This motive power 'sustains' the object's motion. Thus, the motive power was regarded as being transmittive. Ibn-Sina (11th century) saw impetus as self-expending.

2.2.3 Galileo Galilei

Galileo (17th century) introduced two dimensional trajectory motions which can be decomposed into horizontal and vertical components. The path taken for the motion under acceleration due to gravity is therefore parabolic.

2.2.4 Newtonian Physics

Expanding and building on Galileo Galilei's work, Newton (17th century) posited that an external force, as opposed to an internal one, is required to change motion. This external force, according to Newton, does not sustain constant motion. Thus, projectile motion can be modeled along Newton's three laws of motion and the four equations of motion. Further, objects fall with the same acceleration regardless of shape and/or size.

2.2.4 (a) Newton's laws of motion

Newton's laws as well as equations of motion find application and relevance in VPM, since they represent the scientifically accepted views – a benchmark against which children's pre-conceived ideas are compared.

In view of this assertion, a brief discussion of Newton's laws of motion, themselves an embodiment of science views, is presented thus:

Newton's first law: Every object stays in its state of rest or uniform motion in a straight line, unless it is acted upon by a non-zero external force. Mathematically, if $F_{net} = 0$, its state of rest or uniform motion remains unchanged.

Thus when the resultant force is zero, the forces are said to be in equilibrium, and the object maintains its state of rest or uniform motion. Consequently, the greater the mass of the object, the greater its inertia. Inertia the measure enabling the object to resist change in its state of motion.

The first law finds its application in the design and use of safety belts in vehicles where it was discovered that if the brakes of a moving vehicle car are applied to bring the vehicle to a stop, the occupants continue to move since there is no force exerted on the occupants protecting them from their inertia.

In the event of a collision or sudden stops, the occupants continue travelling at the same velocity due to their inertia. The safety belt therefore keeps occupants in their seats, preventing them from crashing through the windscreen and being thrown out of the vehicle.

Newton's second law: When a resultant force greater than zero is applied to an object, the object will accelerate in the direction of the net applied force with an acceleration that is directly proportional to the net force and inversely proportional to the mass of the object.

Mathematically, $F_{net} = ma$,

where F_{net} is the net Force (N),

m is mass (kg) and a is the acceleration (ms^{-2}).

Newton's third law: To every action, there is an equal and opposite reaction. Thus, when a body A exerts a force on another body B, body B in turn exerts an equal but oppositely directed force on body A.

2.2.4(b) Equations of motion:

(i) For motion at a constant velocity,

velocity (ms^{-1}) = displacement (m) / time(s).

(ii) For motion at a constant/uniform acceleration, the following equations of motion are used:

- $v_f = v_i + a\Delta t$
- $v_f^2 = v_i^2 + 2a\Delta x$
- $\Delta x = v_i \Delta t + \frac{1}{2} a\Delta t^2$
- $\Delta x = (\frac{Vi + Vf}{2}) \Delta t$,

  where v_i and v_f are initial and final velocities respectively (in ms^{-1}),

  a is constant acceleration (in ms^{-2}),

  Δt is time taken (in seconds), and

  Δx is displacement (m).

Having looked at both the Impetus and Newtonian theories, the following section highlights the differences between the two aforementioned theories, clearing the stage for easy comparison of learners' ideas on VPM, as gleaned from the current study, with scientifically accepted views.

2.3 Comparing Newtonian and Impetus theories

There are stark differences between Newtonian and Impetus theories and these are now summarized in Table 2.1 below.

Table 2.1 Newtonian versus Impetus theories (Source: Kozhevnikov and Hegarty, 2001: 445).

Principle	Descending motion	Ascending motion
Newtonian Physics(in the absence of air resistance)	All physical objects, regardless of mass and shape fall with the same acceleration.	All physical objects, regardless of mass rise with the same acceleration.
Newtonian Physics(in the presence of air resistance)	More massive objects are influenced by the force of air resistance and, as a consequence, descend faster than less massive objects of same shape.	More massive objects are influenced less by the force air resistance and, as a consequence, ascend faster than less massive objects of the same shape
Impetus theory(regardless of air resistance)	More massive objects accelerate faster. Gravity imparts an impetus to a descending object, which then moves it in combination with gravity. The more massive the object, the faster it falls.	More massive objects accelerate at a slower rate. An object's initial impetus continually dissipates because it is overcome by the effect of gravity. The more massive the ascending object, the more gravity counteracts its impetus.

2.4 Children's ideas about Vertical projectile motion

Before enumerating learner ideas on VPM as reported in the extant literature, a distinction between the terms *misconceptions* and *alternative conceptions* is made. Although both are based on observation, misconceptions denote *incorrect* ideas regarding scientific concepts, while alternative conceptions, on the other hand, are non-scientific but correct explanations of reality as interpreted from a different paradigm (Solomon, 1987).

Learners' prior overarching ideas constitute their worldview about phenomena, thereby creating a lens through which they view and subsequently interpret natural phenomena. For me - much in agreement with most constructivists, it is beyond question that children's ideas should not be treated hastily as misconceptions, but rather as ideas seen from a different worldview requiring serious consideration. Researchers like Driver and Oldham (1986) and Hamza and Wickman (2007) acknowledge that learners develop prior knowledge before the introduction of formal instruction, highlighting the importance of our knowledge of pre-instructional ideas.

It is worth noting that children's ideas have earned several terms in literature such as *non-scientific ideas,* alternative *conceptions/frameworks, mini-theories and intuitive theory (Driver* and Oldham, 1986; Hamza and Wickman, 2007). While '*alternative'* suggests a non-traditional framework in explaining scientific concepts; '*mini-theories'* places construction of knowledge squarely in the learner's head based on learner's own interpretation of observation of natural phenomena. On the other hand, '*intuitive'* points to explaining natural phenomena based on feelings as opposed to evidence.

As Driver and Oldham (1986) assert that learners - when faced with new or similar scenarios, will likely 'dig' into their past to look for explanations that closely resemble their current situations, potentially resulting in personal constructs which could be seen as 'correct' or 'wrong' interpretations (depending on the analytical lens used), with the latter forming alternative ideas – a part of this research.

Several researchers, working in different disciplines, have studied the role of children's ideas in the learning of new knowledge, suggesting that they potentially present cognitive illusions – acting as possible hindrances in the effective acquisition of school science knowledge (Hamza and Wickman, 2007, p.142). In fact, Driver and Oldham (1986) note, quite correctly, that oft-times, children' ideas are inconsistent with science views in spite of their ideas linking coherently within their own frameworks.

Yet, for all the potential cognitive barriers or illusions that children's ideas may present to the learning of school science, instead of discarding them, I am of the conviction that our understanding of children's pre-instructional ideas will equip teachers better in planning instruction - much in agreement with scholars like Nesher (1987) and Hamza and Wickman (2007).

Thus, our knowledge of pre-instructional ideas should be a starting point in instructional design. Instead of treating children's ideas as trivial mistakes, I am compelled to concur with the subscribed views that researchers like Halloun and Hestenes (1985) embrace in treating learners' ideas as "serious alternative hypothesis", requiring consideration in instructional designs.

Nesher (1987) asserts that the most significant contribution by the learner in the learning process is in making errors, further suggesting that the errors and misconceptions constitute what Nesher refer to as "learner's expertise" to the process of learning. As Nesher asserts, misconceptions are 'beacons' of the learning pathway to the teacher and represent the learners' contributions and progress to the teaching and learning process or pathway.

Furthermore, Nesher (1987) explains that the teacher's responsibilities would be to anticipate errors and misconceptions and 'purposely allow for them' to be made with a view to 'addressing' them accordingly. Thus, while the teacher uses misconceptions as beacons in navigating the learning and instructional pathways, the learner should present such errors as signposts guiding the learning process (Nesher, 1987). This aligns quite reasonably well with constructivists who assume that learners are not blank slates, instead believing that learners are actively involved in the construction of new knowledge building on their prior knowledge.

The argument many scholars like Nesher (1987) and Hamza and Wickman (2007) make in this regard is that our knowledge of the intersection of learners' pre-instructional knowledge as it interferes with new knowledge should mark the genesis of instructional strategies. Thus, according to Nesher (1987), the interplay between new knowledge and pre-conceived knowledge systems determines the success, or failure, of conceptual change, itself a variable dependent upon effective instructional strategy.

While some misconceptions - especially those deeply-rooted in pre-taught content- are difficult to detect, there is need for inclusion of discriminating items in the baseline assessment (Nesher, 1987). This is premised on the argument that some errors could be disguised or masked as correct answers like in cases where a learner gets the correct answer based on wrong reasoning or explanations (Nesher, 1987).

The following is a summary of misconceptions, errors and deficiencies in mathematical and manipulative skills which NSC Physical Sciences exhibited in answering VPM:

- Poor problem-solving skills.
- Failure to make a distinction between acceleration and velocity.
- Failure to make a distinction between displacement and distance.
- Failure to draw and/or interpret displacement versus time, velocity versus time and acceleration versus time graphs.
- Failure to understand the concept of a frame of reference of motion.
- Failure to use relevant equations of motion.
- Incorrect copying of formulae from the data sheet.
- Incorrect mathematical manipulation/substitution.
- Failure to use sign conventions.
- No or incorrect unit in the final answer.
  (Source: Department of Basic Education(DBE) NSC Diagnostic Reports, 2013 - 2015)

For me, the lack of clear-cut teaching strategies that take into account learners' pre-instructional ideas on Vertical Projectile Motion, thus making the topic easier to teach and perhaps easier for learners to understand, remains a matter of great concern especially in light of low marks in VPM.

Interestingly, most of the above misconceptions are similar to the ones reported in literature.

2.5 Beliefs about force and gravity from the literature

Prescott (2004) summarizes students' pre-conceived ideas regarding gravity and force as recorded by extant literature worldwide thus:

- If an object is on the ground then gravity is not acting on it, because it has already fallen to the ground.
- Gravity is the result of air pressure.
- Gravity is a property of the object itself.
- Those objects that fall have more gravity than stationary objects, or gravity is not exerted upon stationary objects.
- If an object is moving, then there can be no force acting on it.
- If an object is moving, then there must be a force in the direction of the motion.
- Force as a kind of fuel or energy that sustains the motion but at the same time is consumed by the motion itself (the impetus motion of Johannes Philoponus).
- An increase in force will produce an increase in speed.

At this stage conceptual change is now discussed, believing our understanding of knowledge construction will help us in addressing misconceptions.

2.6 Conceptual change

Driver and Oldham (1986) cite researchers like Rumelhart and Norman (1981) and Pope and Gilbert (1983) giving explanations regarding ways in which cognitive structures undergo change. Rumelhart and Norman (1981), as cited by Driver and Oldham (1983), posit that cognitive structures change through *accretion, tuning and restructuring*. While they argue that *accretion* is about adding of new information to existing schema, *tuning* and *restructuring* on the other hand involve making minor and major adjustments to existing knowledge respectively. Accretion and tuning/restructuring could be compared with Piaget's equilibration processes of assimilation and accommodation respectively. Assimilation involves the use of already developed knowledge to deal with a new situation while accommodation is about modification of existing knowledge to deal with peculiar situations (Piaget, 1963, 2004).

Over the years, conceptual change based instruction has been postulated in which student dissatisfaction with existing concepts is created by highlighting the inability of currently held concepts to solve problems. This is referred to as cognitive conflict. At this stage, a new conception that is *intelligible, plausible* and *fruitful* is introduced.

An intelligible concept is believable and understandable, while a plausible concept has the ability to solve problems. A fruitful conception opens up new areas of inquiry.

For conceptual change to be successful, the level of belief in learners must change, hence a need for persuasive power in instructional strategies employed by the teacher (Dilber, Karaman and Duzgun (2009)). Furthermore, Dilber, Karaman and Duzgun (2009) stress the need for active learning facilitated by constructivist methods, contrary to the traditional, transmissive methods blamed for apparently perpetuating passive, rote learning.

2.7 Theoretical framework

Research draws from and is informed by particular concepts anchored on theories affecting how empirical data are analyzed - the theoretical framework (Christiansen and Bertram, 2015). The theoretical framework thus acts as a road map in guiding research around design, data collection, analysis and interpretation as well as functioning as a lens through which the study is conducted and viewed.

Accordingly, the intervention strategy advanced in this study-the Integrative learning framework, draws from the Prediction-Observation-Explanation (POE), Toulmin's Argumentation pattern (TAP) and the Contiguity argumentation theory (CAT) – with the latter two constructs making up dialogical argumentation pattern. Thus, in the main, the framework draws from the Toulmin's Argumentation pattern and integrates the Predict-Observe-Explain model and the Contiguity argumentation theory; three constructs which I discuss shortly.

Since the study aims at assessing the impact of a teaching and learning instructional framework, it is important to discuss how learning is viewed according to different perspectives. This will give us a window through which learning is viewed using different and probably diverse lenses, allowing us to look at teaching from different but complimentary perspectives.

2.7.1 Learning according to Social constructivism

This study is underpinned by social constructivism in modelling learning of scientific concepts. According to social constructivists, learners' prior knowledge obtained from every day experiences is important in the construction of new knowledge. Hence teachers must ascertain learners' prior knowledge with a view to designing appropriate teaching strategies, a powerful assertion made by Ausubel (1968).

As a forerunner in constructivism, Ausubel (1968) argues that prior knowledge is important in the learning of new knowledge. Without doubt this assertion is quite relevant to the teaching and learning discourse inherently underpinned by constructivism since learners' prior knowledge is perceived to be what I call fundamental 'raw materials' in the construction of new knowledge. As opposed to being blank slates, learners are regarded as active processers of knowledge (Driver and Oldham, 1986).

The question that confronts us then is: How do learners, as active participants, make sense of natural events? In answering this question, social constructivists precisely argue that learners gain some of their 'knowledge' from their daily interactions at home and in their everyday discourse (Driver et al, 1994). Thus, learning viewed in this way is analogous to change of conceptions; presenting themselves in the child's mind as tentative models, which models are not only formed from experience but are also subjected to continuous and sometimes rigorous testing (Driver and Oldham, 1986). This assertion places individual knowledge as not being discrete but rather as a product of continuous modification of children's mini-theories.

How social constructivists look at reality, knowledge and learning is very important and is now a subject of the following discussion.

- Reality: Social constructivists posit that reality is constructed through human activity, regarding reality as a social invention.
- Knowledge: According to social constructivism, knowledge is a human product that is socially and culturally constructed. Thus, knowledge is gained through experience and is, in the main, embedded in individual interactions.

- Learning: Social constructivists regard learning as a social process, further arguing that meaningful learning occurs when individuals are engaged in social activities. To social constructivists, learning therefore occurs in a social set-up with the learner's experience shaping up his/her knowledge base.

2.7.2 Assumptions of Social constructivism in relation to learning

Stetsenko and Arievitch (1997) explicate three assumptions of social constructivism which I shall now discuss by highlighting its differences with cognitivism. First, social constructivists argue that an individual actively participates by constantly interacting with the world, in the process 'conceiving and shaping' the individual's development.

Thus, human development is regarded by social constructivists in this sense as a human process mirroring or reflecting social dynamics as opposed to it being viewed as a static structure (Stetsenko and Arievitch, 1997).

The second point made by Stetsenko and Arievitch (1997) is that social constructivists make an assumption of taking human development as a result of shared activities, as opposed to it being a passive maturation as inferred by Piaget. Thus under social constructivism, human development is anchored on and embedded in cultural and historical contexts, with social interaction playing a pivotal role in shaping mental capacities via mutuality, co-operation and communication, highlighting the 'social embeddedness of the self and of the individual's development'.

This can be summed up by what Stetsenko and Arievitch (1997) - borrowed from Vygotsky's work, refer to as the "*sociogenesis of mental processes*". Sociogenesis of mental processes is when "psychological processes emerge first in collective behavior, in co-operation with other people, and only subsequently become internalized as the individual's own 'possessions' "(p.161). Thus knowledge is socially negotiated and learning happens in these social settings mediated by the more knowledgeable other.

The third assumption is in the role of language as a cultural mediator of human development. Language, together with other cultural semiotic devices, they claim, is regarded as a 'cultural gene' containing accumulated knowledge gained and subsequently passed from generation to generation and is therefore acquired by an individual as a tool in individual behavior regulation and development (Vygotsky, 1978; Stetsenko and Arievitch, 1997).

The underlying differences between Social Constructivism and Cognitivism as espoused by Stetsenko and Arievitch (1997) are summarized in Table 2.2 below.

Table 2.2 Differences between social constructivism and cognitivism.

Social constructivism	Radical constructivism
1. Human development is characterized as a process (dynamics).	Human development is characterized as a structure (statics).
2. Human development is a result of social activity.	Human development is a passive maturation.
3. Human development is an ongoing, contextualized interaction, mediated by language and other semiotic devices in culturally and historically relativized contexts.	Human development is a solitary practicing of an 'internal machinery' of cognitive skills.

(Source: Stetsenko and Arievitch, 1997)

In summary; while social constructivists see human development as a dynamic yet social process mediated by language, cognitivists like Piaget, on the other hand, assume that human development is a result of physical maturation linked to age.

2.7.3 Vygotsky's zone of proximal development (ZPD)

Vygotsky (1978) posits the Zone of proximal development as the cognitively fertile ground in which learning pathways could be created as mediated by scaffolding and instruction. He further defines the zone of proximal development as the region between the *actual level of development* of the learner and the *potential level of development*, with the latter being able to be achieved in collaboration with a more capable peer or teacher – the knowledgeable other. What the child already knows is the *'actual level of development'* and what the child can only do with the assistance of a more knowledgeable other is what Vygotsky refer to as the '*potential level of development'*.

Thus, according to this Vygotskian theory, learning occurs in a social set-up and proceeds by way of both *scaffolding* and *instruction* (Msimanga and Lelliot, 2012). Accordingly, both scaffolding and instruction must happen within the learner's ZPD, which must be identified by the teacher. *Scaffolding* involves the knowledgeable other supporting and guiding the learner, and depending on the learner's progress the support or guidance in place is either removed or intensified, while *instruction*, on the other hand, is about the knowledgeable other giving information to the learner mostly regarding the use of tools for meaningful engagement (Msimanga and Lelliot, 2012).

In mastering the concept, what was the learner's *potential level of development* latter becomes the *actual level of development* and the **new** potential level of development is set, much like the scaffolds used in building multi-storey buildings. The idea is for the learner to realize his/her full potential by progressively moving from what Vygotsky (1978) refers to as the interpsychological to the intrapsychological planes. Such learner progression – occurring in a social set-up, is mediated by the knowledgeable other.

The ZPD is appropriately summed up in the following diagram or illustration.
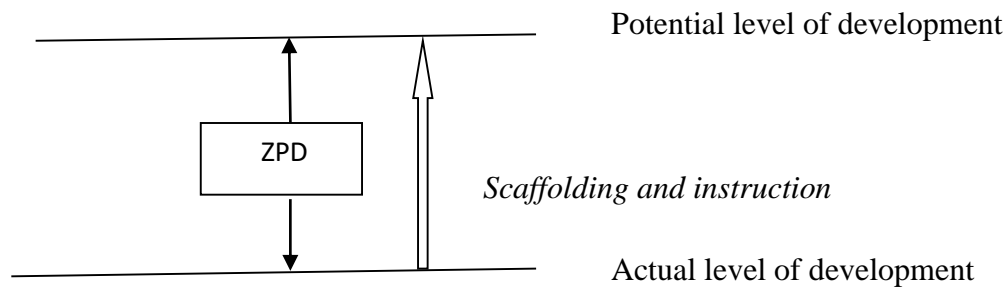
Figure 2.1 Zone of proximal development (ZPD).

The diagram above shows the fertile cognitive space - the ZPD, onto which scaffolding and instruction should occur during learning of concepts.

In this study, the learners' prior knowledge; equivalent to Vygotsky's '*Actual level of development*' in Fig.2.1, was measured by the pre-test while the '*Potential level of development*' was assessed using the post-test, much in line with research questions 1 and 2 of the current study respectively. The ZPD is therefore the equivalence of acceptance of scientifically accepted views, aided by the ILM, and which research question two attempts to address.

In conclusion, because science is a cultural practice illuminating how people think and talk (Leach and Scott, 2003); the comprehension of science occurs through social interaction and instruction (Vygotsky, 1978). Thus, as active learners, radical constructivists like Von Glaserfield (1991) posit that learners engage cognitively in the conceptual construction of knowledge in their minds.

2.7.4 Learning according to the situated perspective

Learning, according to the situated perspective, is regarded as a way of enculturation into a community of practice (Brown, Collins, and Duguid, 1989) involving a change of participation (Hanks, 1991). At the centre of learning is the contextualized and yet authentic activity (Lave, 1996).

From participating on the periphery (novice), learners will be in a position to participate at the centre of an activity (mastery) as a result of practically engaging on the task as cognitive apprentices in the classroom science discourse.

Thus, learning science according to this perspective happens over time and entails being able to solve real world problems, in a community of practice, using practical skills and tools used by scientists (Bowen, 2005). To assess the extent of comprehension of concepts by learners, learners are given practical, authentic tasks against which comprehension or mastery levels are measured or assessed (Lave, 1996; Bowen, 2005).

The teacher and the learner co-participate in the authentic task of science knowledge construction. Similarly, learners are said to have internalized scientific skills if they can use them as a community of science learners to solve real life problems, as alluded to earlier on. According to this perspective, science classrooms would resemble a community of practice of science learners, with the teacher acting as an expert privileged in knowing the scientific practice and content. Thus the teacher's role would involve allowing learners same access to the school science practice. The learning outcomes would require learners to be able to comprehend science concepts practically.

Social constructivists argue that learning happens in a social setting and involve a process of sense-making where a learner benefits from the knowledgeable other. It can be argued that argumentation provides a platform for this sense-making process, and without doubt Toulmin is the forerunner in this discipline.

2.8 Toulmin's Argumentation Pattern (TAP).

Toulmin (1958) advanced a structure of argumentation - predominantly used as an analytical framework by many researchers, whose components are summarized in the Figure 3 below.
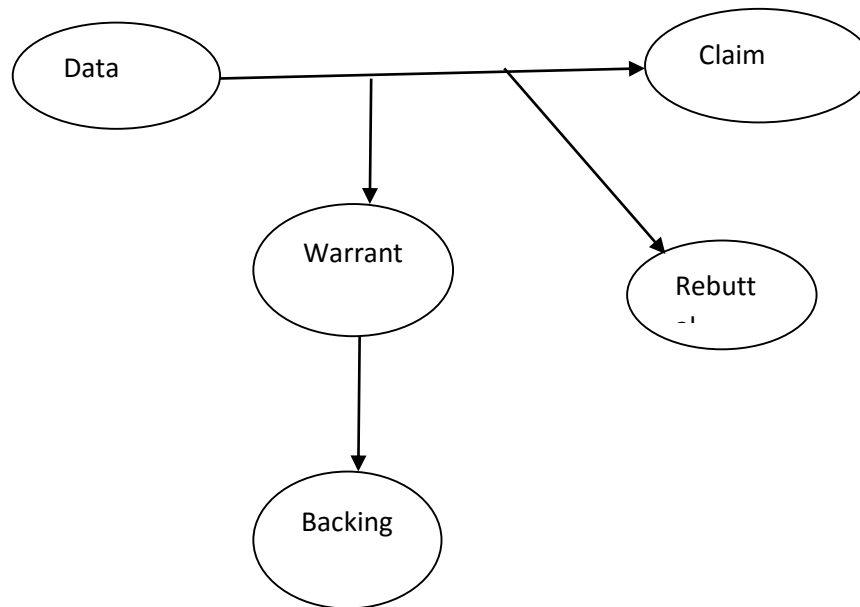
Figure 2.2: The structure of TAP (Erduran, Simon and Osborne, 2004).

According to Toulmin (1958), arguments consist of claims, data, warrants and rebuttals. Claims are assertions/conclusions advanced in argumentation. Counter-claims are therefore alternative assertions. Whereas some of the claims are baseless, other claims tend to be supported or backed by data. Data are facts in support of claims. Data therefore could be explicit evidence or views based on morals/ethics. Warrants, on the other hand, are reasons linking data to claims. Warrants make for a strong argument in justifying a claim. Backings, on the other hand are basic assumptions that are used to justify warrants. Backings make up scientific models, laws and explanations. A reasoned refutation/rejection of a claim, warrant or backing makes up a rebuttal. For me, argumentation thus happens in a social setting and works well alongside scaffolding and instruction.

Table 2.3 below shows the different levels of argumentation in a scientific discourse used as an analytical framework in characterizing arguments. Five levels of argumentation and their corresponding characteristics per level are hereby identified and summarized.

Table 2.3 Levels of argumentation (Source: Erduran et al., 2004)

Level	Characteristic of an argumentation discourse
1	Argumentation involves a simple claim versus a counter claim or a claim versus a claim, with no grounds or rebuttals.
2	Argument involves claims or counter claims, with grounds (data, warrants or backings) but no rebuttals
3	Arguments with a series of claims or counter claims with grounds but only a single weak rebuttal challenging the claim.
4	Arguments with a claim(s) and/or counterclaim(s) and a clearly identifiable rebuttal
5	Extended argument with multiple rebuttals challenging the claim.

The weakest argument is level 1, where a claim is made and no grounds or rebuttals are made, while the strongest argument is level 5 above involving an argument where a claim is followed by multiple rebuttals. For me, the presence of level 5 argumentation is evidence that sense-making - hence knowledge construction, is taking place, while on the extreme end, level 1 is an indication that little, if any, comprehension at all is happening.

2.8.1 Argumentation in science lessons.

It is important at this stage to define and discuss argumentation with a view to applying it as an instructional strategy in science lessons. Argumentation involves "the intentional explication of the reasoning of a solution during its development or after it" (Krummheuer, 1995:231; Newton, Driver and Osborne, 1999). Furthermore, argumentation can follow a single line of thought: monological or can be dialogical, in which case multiple contrasting lines of thought are pursued in the argument.

The emphasis placed by the CAPS document on creating critical and creative thinking in learners calls for a rethink in the use of argumentation in the effective teaching of science.

This objective aligns well with views held by many scholars, amongst them Erduran et al. (2004), Braund et al. (2007) and Msimanga and Lelliot (2012), who argue in support of the explicit training of learners in argumentation for them to use the skill effectively as a tool for sense-making.

Argumentation seen in this light, is not merely a process of arguing where claims or conclusions are verbally made (what scholars call weak argumentation) but it goes further in requiring learners to back or support their claims with evidence/data, in the process listening and assessing other learners' substantiated claims, key features of strong arguments (Erduran et al.,2004). Effective learning can thus be anchored in argumentation discourse as a basis for co-construction of knowledge.

Thus the components of TAP discussed in the preceding table are then key in such a discourse since these components enable learners to make meaning of science concepts by not only verbalizing their thoughts via unsubstantiated claims but rather by making claims that are appropriately backed by data while at the same time listening to and assessing claims, warrants and rebuttals advanced by others (Msimanga and Lelliot, 2012, Erduran et al., 2004).

Braund et al. (2007) identified key issues of argumentation in a science class, the characteristics of which I summarize as dependent upon number of participants, claim and nature of topic whether the argument is open ended or closed and type of data.

(i) Number of participants

Argumentation tasks in class can be in small groups (including pairs) and/or can involve whole class. The discussions can be between/among learners or between teachers and learners. Typically, as Braund et al. (2007) affirm, the task may start in small groups, subsequently culminating into whole class debates.

(ii) Topic specific

Argumentation is initiated by a claim/conclusion/assertion in the form of a statement. An example of a claim can be: Two objects of different masses falling simultaneously from the same height hit the ground at the same time could be a claim which can potentially act as an initiator to argumentation. Naturally, some learners can be in agreement while others oppose such a claim, leading to counter claims, backings, warrants and rebuttals.

(iii) Nature of topic

In a science argumentation task, claims can be on concepts/issues that are scientific, socio-scientific/cultural or existential in nature.

(iv) Open-ended or closed-ended

The argumentation task could be limited to a few concepts (closed) or could be open-ended. Alternatively, it can start as a multiple choice question (closed), leading to open-ended arguments that are not restricted to a few concepts.

(v) Type and source of data

Data could be numerical (as depicted in tables and graphs), text or pictorial. Thus an argumentation task in a science lesson can depend on the type and source of data given.

2.8.2 Teacher's role in argumentation

Osborne, Erduran and Simon (2004, 2006) developed, tested and reported on a typology of pedagogic strategies aimed at fostering argumentation in science lessons in which they highlighted the need for a teacher to scaffold argumentation tasks, in the process stimulating higher levels of argumentation in learners. Scaffolding as earlier defined is when the knowledgeable other intentionally and strategically supports and guides a learner (in the zone of proximal development) in making sense of concepts and then withdrawing or intensifying the support or guidance based on learner progress (Msimanga and Lelliot, 2012).

Equally, researchers like Erduran et al. (2012) argue that teachers, to a greater extent, can initiate and sustain argumentation while teaching children how to make arguments as a tool for making sense of science. Thus, argumentation is seen in this way as a tool that can be used by teachers and learners in the co-construction of scientific knowledge (Msimanga and Lelliot, 2012, Erduran et al., 2007). This lends credence to Vygotsky's assertion of learning occurring in a social setting in which mediation is provided by way of both scaffolding and instruction. Language is used as a semiotic tool for verbalizing thought.

Sense-making thus starts and occurs in a social setting, extending to the individual's mind– much akin to the Vygotskian inter to intra plane transformation.

Alternatively, socio-cultural scientists may view the sense-making process as a movement from the periphery and subsequent progression towards the centre of a shared/common activity in the community of practice as described by Lave (1996) and Wenger (2000).

2.8.3 Benefits of argumentation

The benefits of argumentation in the construction of knowledge are well documented in the extant literature (Erduran et al., 2004). First, in building models, explanations and theories to explain phenomena, scientists argue as they relate data to claims using warrants and rebuttals (Erduran et al., 2004). As Newton, Driver and Osborne (1999:555) put it so succinctly, *"It is on the apparent strength of arguments that scientists judge competing knowledge claims and work out whether to accept or reject them"* (own italics).

This quotation above brings into perspective the assertion that science evolves through argumentation as scientists argue on their claims, data, warrants and rebuttals as espoused by Toulmin' Argumentation Pattern. Thus, if learners can be explicitly taught how to argue in science lessons, they will possibly think, talk and act like scientists in creating theories, models and explanations (Erduran et al., 2004).

In addition, verbalization provides learners with checks on claims, data, warrants and rebuttals ensuring quality theories, models and explanations that explain natural phenomena; leading to an induction of learners into science that is akin to enculturation into a community of practice (Newton et al., 1999).

Second, the externalization of thought through verbalization allows children to express themselves publicly thereby promoting children's ability to think critically as they engage in knowledge construction (Erduran et al., 2004). Verbalization of thought requires one to critically look at claims, in the process seeing the relevant grounds in support of or against such claims (Msimanga and Lelliot, 2012).

Thirdly, according to socio-cultural perspectives, learners acquire shared community practices in using argumentation as a tool of enculturation into the scientific discourse, one of which is the ability to question claims. Arguments are anchored on questioning existing claims (Newton et al., 1999; Aguiar, Mortimer and Scott, 2009)). By questioning existing assertions or claims, learners are not only able to learn about the inquiry nature of science but also have an opportunity to enhance their problem solving skills, in the process improving themselves as active and autonomous learners capable of resolving conflicts and generating explanations through collaborative thinking (Aguiar et al.,2009).

Thus, in this regard, questioning is pivotal in sense-making, hence a key feature in the process of argumentation. Although asking questions can expose learners' thinking and reasoning; wonderment questions, nevertheless, reflect curiosity, puzzlement, skepticism and speculation – all great potential contributors to conceptual change (Aguiar et al., 2009). Wonderment questions are questions that are pitched at a conceptually higher level requiring an application or extension of ideas in resolving discrepancies (Aguiar et al., 2009).

For me, argumentation, therefore, assists learners in sense-making as they ask wonderment questions in attempting to relate new knowledge to existing knowledge much in agreement with the co-construction of scientific knowledge as highlighted by Msimanga and Lelliot (2012).

Quite relevantly, Msimanga and Lelliot (2012) noted that argumentation is important in sense-making, articulating and persuading. *Sense-making* is when learners attempt to make sense of task or content, *articulating* involves using scientific language in explaining and clarifying ideas while *persuading*, on the other hand, is a skill of presenting own claims and data in order to achieve common understanding or consensus (Msimanga and Lelliot, 2012).

2.9 Contiguity Argumentation Theory (CAT)

If learning of school science is considered as a means of enculturation (Brown et al,1989), then a closer look at dynamics surrounding 'border-crossing' into another culture require us to look at different worldviews playing out in South African schools as learners learn school science.

Learners' cognitive sites/schemata consist of three worldview systems namely: (1) the traditional, indigenous and cultural beliefs making up IKS, (2) commonsensical beliefs that are largely intuitive and (3) school science which, in the main, is non-intuitive, and thereby allowing for harmonious dualism (Ogunniyi, 2008).

Harmonious dualism, as defined by Ogunniyi (2008), is the ability of a learner to hold two 'diametrically' opposed views simultaneously without necessarily slipping into cognitive conflict. Based on this description, I present the diagram showing the three worldviews supposedly in dynamic equilibrium on a learner's cognitive site as espoused by Ogunniyi (2008).
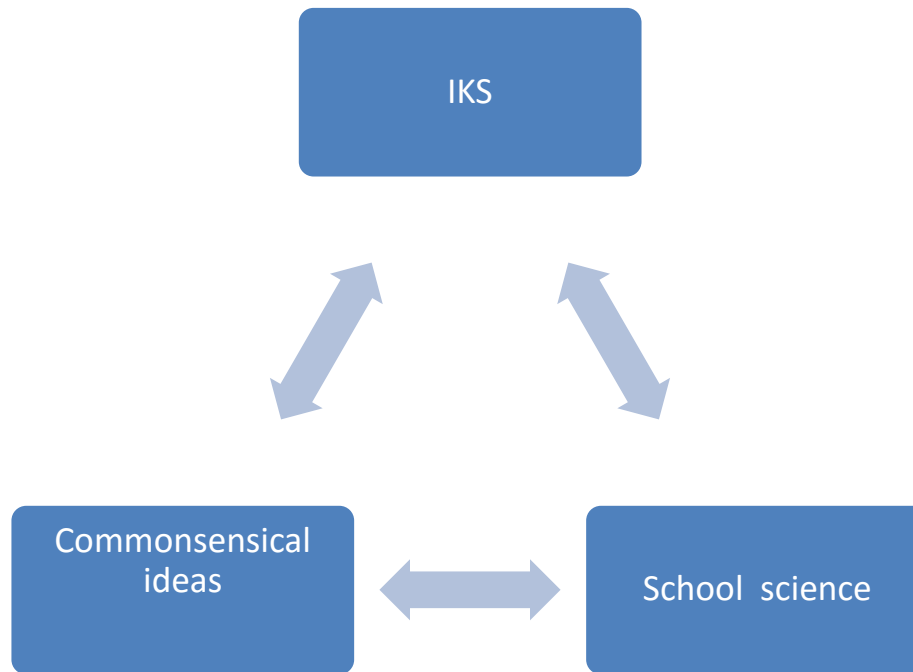
Figure 2.3 Distinct worldviews and their interaction.

Thus, IKS, commonsensical ideas and school science interact in dynamic equilibrium on cognitive sites of learners, with the dynamism between knowledge systems represented by two-way arrows in the diagram above. While commonsensical ideas are intuitive, IKS is the unique indigenous knowledge passed from generation to generation and school science is, according to Taber (2008), the scientific content presented to learners as formal education in classrooms and drawn from textbooks, syllabi, and so forth.

2.9.1 Co-existence of two thought systems: Abandonment, Replacement or Addition?

While learners inherit and acquire local knowledge and beliefs, constituting Indigenous Knowledge Systems (IKS), they are, nevertheless, taught science, itself a western culture, in a science classroom (Ogunniyi, 2008). Since school science is a selection, reduction and subsequent representation of the natural world - a model of reality (Carr, 1994), it is introduced in science classrooms as a new knowledge system that has to be learnt by the learner.

Figure 2.3 above requires students to integrate their existing knowledge systems (IKS and commonsensical ideas) with western beliefs (school science) and more often than not, conflicts arise between IKS and school science -representing western worldview (Govender, 2014; Ogunniyi, 2008).

Thus, cognitive conflict arises when a learner's IKS, commonsensical ideas and school science are not compatible. While school science is treated as the dominant knowledge system over both IKS and commonsensical ideas; students, nevertheless, interpret, create and defend knowledge positions based on their beliefs (Govender, 2008). For instance, an African child could have prior traditional and cultural beliefs about lightning as having destructive powers linked to witchcraft as well as some myths about lightning in their community. As such, the treatment of lightning in school science as electrostatics could potentially create conflicts in the child's mind requiring pedagogic interventional support systems that are sensitive to and recognize students' commonsensical ideas, cultural and indigenous backgrounds (Ogunniyi, 2008).

That learners are exposed to the school science against the backdrop of IKS means a balance must be struck wherein the knowledge to apply a certain system in a given context becomes paramount.

Does the learner have to sacrifice his/her pre-conceived ideas on lightning gained over time at the altar of electrostatics, itself a new worldview presented in the form of school science? Putting it simply: Should the learner abandon his beliefs about witchcraft in explaining lightning's destructive power, replacing it with electrostatics, or shall the learner allow his/her earlier beliefs and the new scientific concepts to co-exist? The shift from learners' prior knowledge towards the scientifically accepted views is best explicated by Ogunniyi in his CAT as the interaction of two thought systems.

According to CAT, where any two distinct worldview systems meet; the distinct ideas interact by overlapping, or conflicting with each other, resulting in these clashing ideas initiating internal dialogue or intra-argument (Ogunniyi, 2008).

For me, the interaction of the three worldviews as explicated by Ogunniyi (2008) should occur in the learner's Vygotsky's Zone of proximal development for it to ignite cognitive conflict and subsequent resolution process as opposed to merely effecting cognitive illusions that potentially cause barriers to science learning. This requires proper scaffolding and instruction.

The intellectual space of 'commonality' between two different ideas or worldview systems is what Ogunniyi refer to as *contiguity*. Assuming neither of the systems dominate the other (same/equal status), co-existence of distinct ideas occurs through conceptual appropriation, accommodation, integrative reconciliation and/or adaptability, resulting in the formation of dominant, suppressed, assimilated, emergent and equipollent ideas(Ogunniyi,2008).

The definitions of dominant, suppressed, assimilated, emergent and equipollent ideas are given by Ogunniyi (2008) as follows:

1. Dominant idea:

     A dominant idea is a stronger, more powerful idea that becomes influential hence favourable to the learner in effectively explaining and predicting facts and events in the face of overwhelming and convincing new evidence.

2. Suppressed idea:

    A suppressed idea is one that ceases dominance and becomes recessive in the face of new and yet more valid evidence.

3. Assimilated idea:

    An assimilated idea forms when a weaker idea is taken in by a more influential idea as a result of the relative persuasiveness power of the dominant idea, thereby modified by new ideas to create a more stable idea.

4. Emergent idea:

     An emergent idea is that idea just beginning to form for the first time with no prior knowledge similar to it, hence have no rival or competing ideas in the learner's existing schemata, yet new knowledge has to be acquired.

5. Equipollent ideas:

Equipollent ideas form in instances where two distinct ideas with fairly similar intellectual and emotional forces on the learner's cognitive sites co-exist harmoniously without necessarily resulting into cognitive conflict. Because of their equal force, they will, in a way, 'compliment' each other in explaining and interpreting phenomena in different contexts.

2.10 Predict-Observe-Explain model (POE).

The POE model, of Gunstone and White (1992), is a science teaching strategy embedded in constructivism and which has been used on science experiments or demonstrations. Recently, researchers like Karamustafaoglu and Mamlok-Naaman (2015) used the POE effectively in an electrochemistry lesson in which learners predicted the results of an experiment demonstration. The predictions were meant to elicit learners' prior knowledge and were then followed by demonstrations and explanations.

In this study, I combined the POE with argumentation to design an instructional package used in teaching projectile motion to the Experimental group. The reason why I chose to include POE is three fold. First, learners expose their prior knowledge on projectile motion by verbalizing their predictions, giving the teacher insights into learners' mini-theories. Furthermore, learners' predictions act as assertions or claims, setting into motion the argumentation process which is pivotal in sense-making.

Second, the process of observation creates cognitive conflict in that learners at this stage compare their earlier predictions with what they will be shown in demonstrations or experiments. Cognitive conflict is when a learner is at a cross road upon being presented with new information that may be incompatible with earlier held beliefs, making decisions difficult to make. Depending on the persuasive power of the observation, learners may accept or reject scientifically accepted views as presented by demonstration. This enhances learners' critical thinking skills.

Third, the last stage of POE involving explanation can be combined with dialogical argumentation in teaching scientific concepts. Earlier made assertions are at this stage backed or challenged with data from observations or experiments, and the result is the co-construction of potentially lasting scientific knowledge. This way, learners take ownership of the knowledge they co-construct during this process. The structure of the science lesson based on POE, as advanced by Gunstone and White (1992, 2000), progresses in three stages of experiment demonstration namely Prediction, Observation and Explanation. The following sequential diagram depicts the three stages involved in using POE as an instructional strategy.

Figure 2.4 Stages in POE.

2.10.1 Stages in POE

Prediction, Observation and Explanation are the three stages in the POE model:

Stage 1: Prediction

This is the first stage of the science lesson and is aimed at uncovering learners' predictions and reasoning exposing their prior knowledge.

Learners are presented with a scenario in which they are made to make predictions. This allows learners to verbalize and hence externalize their thoughts.

For me making predictions in POE is similar to what Toulmin (1958) refer to as making 'claims' in that at this stage of the lesson the prediction is not backed by data.

Further, the stage assumes the basic tenet underpinning constructivism in placing learners' prior knowledge as the foundation onto which new knowledge is constructed or modified.

Thus by making predictions, learners expose their prior knowledge on the topic, key to unlocking possible alternative frameworks on projectile motion inherent in learners. This stage is important in the current study because it aligns well with the first research question of the study aimed at eliciting for learners' prior knowledge on vertical projectile motion.

Stage 2: Observation

This stage starts with learners observing a demonstration or experiment, followed by writing down their observations based on what they see in a demonstration or experiment. This is aimed at creating cognitive conflict with earlier made predictions leading to reconstruction and revision of prior knowledge. This signals the genesis of internal argumentation where a learner tries to reconcile his/her earlier predictions with new information as observed in the demonstration. Thus this observation process sets into motion a sense-making process triggering the construction of knowledge via internal argumentation.

Stage 3: Explanation

Students discuss and explain their predictions and observation with a view to resolving conflicts, if any, so created in the first two stages, while at the same time consolidating a position. This allows for learners and teachers to reach a consensus as they support while revising their claims based on available data/evidence. Learners and teachers at this stage co-construct knowledge presumed to have a long-lasting impression through dialogic argumentation.

2.10.2 Limitations of POE.

Like many instructional strategies, Gunstone and White (2000) assert that POE is not without its share of limitations. The first limitation cited by Gunstone and White (2000) is that POE "does not work when students do pure guessing". The authors argue that it requires learners to be actively engaged in tasks as opposed to guessing which may result in rote learning. Secondly, for POE to work learners must express themselves freely in making predictions, writing down observations and in explaining their observations (Gunstone and White, 2000).

2.10.3 Benefits of POE.

Gunstone and White (2000) propound that while POE has limitations; its benefits as an instructional strategy are many and in theory outweigh its limitations. I discuss the four benefits of POE thus:

First, POE exposes learners' prior knowledge and attempts to connect it to new content/knowledge. This is similar to the teaching that progresses from the known to the unknown.

Second, POE makes it possible for learners to apply their learning to practical or real life context. This way, learners link their science theories to practice as they sharpen their practical skills. This way they will see and treat science as a practical subject which I strongly believe arouses interest in science learning.

Third, POE gives learners opportunities to explore the appropriateness of prior ideas, thereby giving them a chance to revise their old ideas or beliefs. Thus prediction and observation create cognitive conflict which is subsequently resolved in whole class discussions.

In my view, this increases learners' argumentation skills in critically examining scientific claims and data, key in co-construction of scientific knowledge.

Fourth, POE can be used in small or big sized groups. This flexibility in its use allows the teachers to structure their lessons according to the number of learners in a class since it even accommodates large classes. Lastly, POE can be used as a tool for teaching and assessing.

Besides using POE as a teaching and learning strategy, the teacher can also present an assessment task in the form of POE.

2.11 Conceptual framework.

This study is underpinned by an Integrative learning model which draws largely from three theoretical constructs namely the Toulmin's (1958) Argumentation pattern (TAP), Gunstone and White's (1992) Predict-Observe-Explain Model and Ogunniyi's (2002) Contiguity argumentation theory. The constructs were chosen since they have roots in constructivism.

Toulmin's (1958) argument pattern (TAP) has been adopted for use in science classes based on dialogical argumentation involving claims, data, warrants, backings and rebuttals as earlier on discussed. Where classroom discourse is characterized by whole class as well as small group discussions, such classroom discussions presents fertile ground for the initiation of argumentation discourse in science lessons (Erduran et al., 2004). In such instances, TAP could be used as an analytic framework: a lens through which the quantity as well as the quality of argumentation in science discourses is viewed.

TAP thus acts as both a quantitative as well as a qualitative indicator of teaching and learning, useful as a tool that quantitatively and qualitatively analyzes verbal data arising out of classroom-based interactions in spite of difficulties researchers may find in classifying claims, data, warrants and rebuttals (Erduran et al.,2004, Braund et al.,2007, Msimanga and Lelliot,2012)

2.11.1 The Integrative Learning Model (ILM)

In essence, the ILM aims at tying up children's ideas with a view to aligning them with scientifically accepted views by way of offering platforms for making claims, counter claims and refutations backed by data and warrants; key tenets of argumentation.

This is premised on the assertion that learners' alternative ideas, misconceptions and mini-theories on this topic are well documented; making it easier for the researcher to compare and assess a shift in learners' ideas after teacher intervention.

Researchers like Dilber, Karaman and Duzgun (2000) assert that learners have alternative conceptions; most of which are quite stable in that they are not easy to replace with scientific conceptions. To this end I propose an Integrative Learning Model embedded in constructivism and aimed at holistically bringing about better acceptance of scientific views by learners.

This model is premised on the notion that indeed learning is an active process requiring assimilation and accommodation of concepts (Piagetian model), while at the same time happening in social setting requiring mediation (Vygotskian model).

Assimilation, as earlier explained, is about using already developed cognitive structures in dealing with new situations while accommodation deals with modifying existing cognitive structures because of its failure to explain a new challenge, hence the need to be altered altogether (Piaget,1964, 2003). That is, students are indeed not passive learners since they make sense of their experiences (Duit, 2003; Msimanga and Lelliot, 2012). Argumentation is the foundation upon which the Integrative learning model is built, drawing from Gunstone and White's (1992) Predict-Observe-Explain, Toulmin's (1958) Argumentation pattern and Ogunniyi's (2008) Contiguity argumentation theory.

The Integrative learning model acknowledges the nature of science as progressing through dispute, conflict and argumentation. That is, scientific theories are open to scrutiny, challenge and refutation, a key feature of the argumentation process (Driver, Newton and Osborne, 1998). Consequently, this places argumentation in science classes as pivotal in providing teachers with the chance to 'empower' students with the skills of critically examining scientific claims from their own perspectives.

 Thus the Integrative learning model acknowledges the interplay between individual cognition and the potentially mediatory socio-cultural parameters playing out in a science class. The following diagram shows the stages in the ILM:
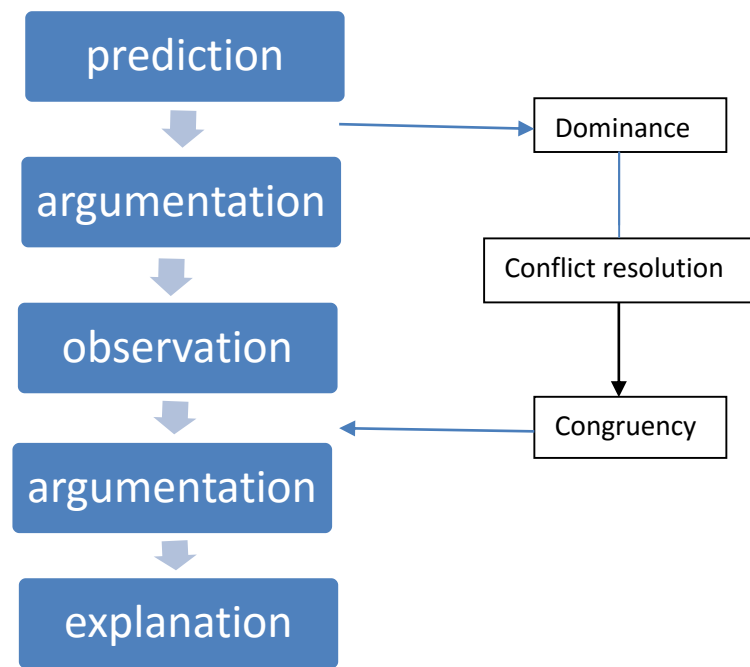
Figure 2.5 The Integrative learning model (ILM).

The intervention strategy proposed herein is modeled along the Integrative learning model
above, progressing in five stages. The five stages are now outlined.

Stage 1: Prediction

The first stage is prediction and is adapted from POE. Here, learners are presented with a phenomenon in
which they are asked to predict an outcome. Prediction is aimed at eliciting learners'pre-instructional ideas
about Vertical projectile motion much in line with the first research question of the current study.

For instance, learners were asked to predict the path taken by an object as it falls from a
jetfighter that is moving parallel to the ground at constant speed. This was an open-ended
question requiring learners to use their own prior knowledge to make predictions of the path of a
falling object.

Figure 2.6 Picture of jetfighter

For illustrative purposes, I use the following question that was given to learners in the pre-post test.

Question:

A jetfighter travelling due west drops a bomb. In the picture below, draw a line that best describes the path of the bomb as it drops to the ground?

Thus, in the picture above, learners were expected to predict and hence draw pathways of the object as it falls from a moving jetfighter based on their prior-conceived ideas. These predictions would then be used   in later stages.

Stage 2: Argumentation

The second stage is argumentation, in which the class engages in an argumentation discourse about their prediction in the first stage. This is aimed at challenging learners' dominant ideas they have about projectile motion, a situation described by some researchers as creating cognitive conflict or dissonance. I will call it *Initiative* argumentation for its cognitive dissonance 'spark'. Thus it marks the genesis/beginning of cognitive conflict resolution. During this stage, learners are expected to make and verbalize their claims, backed by data, warrants and rebuttals – characteristics of higher levels of argumentation.

Newton, Driver and Osborne (1999) assert that by talking learners are presented with a platform to make conjectures, articulate and justify standpoints or views, while putting forward reasons in support of argument and challenge as they attempt to make sense of experiments, explanations and events.

Such arguments offer opportunities for learners to express doubts allowing for the emergence of alternatives to be made that allow for clearer conceptual understanding, culminating into the co-construction of knowledge (Newton et al., 1999).

In the aforementioned test question, for instance, learners are expected to then support their claims, marking the process of argumentation. Reasons why the learners chose particular pathway as the bomb drops from the jetfighter are debated.

Stage 3: Observation

The third stage is observation. Learners are presented with an observation schedule of the same phenomenon aimed at challenging their dominant ideas. This potentially serves as a signpost requiring learners to rethink their original claims in light of opposing claims, data, warrants and rebuttals. It is indeed a second chance for learners to review their initial claims. A simulation of the bomb as it falls to the ground can be shown to learners so as to challenge their existing ideas.

Stage 4: Argumentation

The observation schedule is then followed by yet another round of argumentation discourse in which learners engage in argumentation, this time with a view to resolving cognitive dissonance so created in the second stage cited above together with the observation schedule in stage 3 above. At this stage of cognitive conflict resolution, it is expected that learners' ideas will shift from dominance to congruency in view of the new data, warrants and rebuttals.

Stage 5: Explanation

The final stage is Explanation. Based on all the other stages described above, learners are expected at this stage to then draw conclusions that are plausible, intelligible and fruitful.

This is aimed at causing more permanent shifts in learners' conceptual understanding of projectile motion.

Overall, it is expected that the Integrative Learning Model will help learners recognize conflicts and/or inconsistencies as they attempt to make sense of science phenomena in general, resulting in more stable shifts in their ideas.

Advantages of ILM

The ILM is a teaching and learning model accentuating active engagement made possible by dialogical argumentation. It is a hands-on approach promoting critical thinking, a reason why it was later administered to the control group.

Challenges of ILM

Although the ILM is beneficial as an effective teaching and learning method, it has its fair of shortcomings. First, it requires more time to implement. The total time allocated for VPM in the syllabus is five hours, but it turned out that more time was required. Second, the ILM works with around twenty learners in a class, in contrast with the large classes that characterize township schools.

2.12 Summary

The literature reviewed in this chapter affirms that science is a social construct, presented to learners as models of reality in the form of school science; itself a western knowledge system distinct from both IKS and commonsensical beliefs, with the latter shaping learners' prior knowledge. Accordingly, teaching and learning should thus consider learners' prior knowledge in planning, delivery of content and assessment.

The interaction of distinct knowledge systems as espoused in CAT should cause cognitive conflict in a way that sets the sense-making process in motion, consequently enhancing effective science learning. This gives birth to Integrative learning model underpinned by POE, argumentation and CAT and aimed at enhancing the comprehension of VPM.

Earlier in the chapter, the historical conception of VPM was traced with a view that earlier frameworks on vertical projectile motion could be compared with current learners' alternative frameworks and school science.

The next chapter outlines research design and methodology.

CHAPTER 3   RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Vertical projectile motion (VPM) was portrayed as a problematic topic requiring an exploration into factors affecting its comprehension by learners. This was against a backdrop of low marks attained by candidates in the topic on NSC examinations in recent years, requiring a paradigm shift in the way we teach VPM to Grade 12 Physical Sciences learners.

This current chapter outlines how the study will be carried out in assessing the effectiveness of the Integrative learning model in the teaching of VPM.

First, research setting and sample is described. This provides context as regards methodology used in the study. Second, the procedure used in collecting data as well as research instruments used in the study is explored with special emphasis on their validity and reliability. Third, data collection and analysis techniques used in the research are discussed. And finally, the chapter addresses pertinent ethical issues concerning the study, followed by the chapter summary.

3.2 Research Setting

The research is a case study carried out at a Secondary School in Tokoza, a township south-east of Johannesburg. This school was conveniently chosen because this researcher was working there as a Physical Sciences teacher, saving on time and resources while ensuring a potentially high level of participation and cooperation from the learners, fellow teachers and the School Governing Board.

The school draws its learners largely from the townships and informal settlements nearby; pointing to a demographic of learners whose parents could be said to be very poor in relation to suburban families, a point that could be highlighted by the non-fee paying status of the school. That the school draws its learners, in the main, from predominantly lower and middle income families stands in sharp contrast to its single laboratory that is modestly resourced.

In addition, the school accommodates close to 1 400 grades 8 to 12 learners with a staff compliment of around 45 teachers including the Principal and two deputy Principals. An average class at the school has 40 learners although some larger classes, especially in the lower grades, accommodate close to fifty learners. As a school practice, learners are given textbooks and exercise books for free at the beginning of each year, made possible through state funding.

The learners at the school either do IsiZulu, IsiXhosa or Sesotho as their Home Language, with IsiZulu done by the majority. These learners are therefore from diverse social and cultural backgrounds, presenting a rich arena to elicit learners' alternative ideas about Vertical Projectile Motion. In addition, all the learners at the school do English as their First Additional Language, which happens to be the language of teaching and learning.

There were two Grade 12 Physical Sciences classes at the school at the time of doing the research. Starting from grade10 up to 12, all learners do either Mathematics or Mathematical Literacy. As a school practice, all learners doing Physical Sciences also do Mathematics. The pass rate for Physical Sciences over the past few years has been below 60%, a cause for concern.

3.3 The Research Sample

Both Physical Sciences classes at the school were involved in the study, one as an experimental group (Grade 12D) and the other as a control group (Grade 12C). The two classes were taught by different teachers (including this researcher) with comparable University qualifications and experience. Grade 12D class was taught by Mr. N (not real name) while Grade 12C belonged to this researcher.

Mr. N had a four-year Bachelor of Education degree in Physical Sciences plus more than fifteen years in teaching experience. At the time of the research, the researcher had a Bachelor of Science Education degree, Bachelor of Science Honours degree in Physics and sixteen years' experience in teaching Physical Sciences and Mathematics. Thus the teachers could be said to be competent and experienced.

Student allocation in the two classes was done randomly at the end of their Grade 9. I chose the class I was teaching to be the experimental group, leaving Grade 12D class as a control group, anticipating the easy with which we would implement the teaching strategy on my class. However, the teaching strategy designed in this study was administered to the experimental group by another Physical Sciences teacher at the school, giving the researcher time to take a back seat in the teaching process while concentrating more on classroom observations. The teacher, Mr. S, not real name, also held the same experience with the researcher and was at the time of the study doing an Honours degree in Physical Sciences at the University of Witwatersrand, where the researcher was also studying towards the Master of Science degree in Science Education.

It was anticipated that this would make it easier for Mr. S and this researcher to design and implement the teaching strategy used on the experimental group considering both of us were doing further studies and research in science education. This later on proved to be very effective since the contribution and input from Mr. S was complimentary to that of the researcher.

While an Integrative learning model was administered to the experimental group, the traditional lecture methods were administered on the control group by Mr. N. However, both groups of participants wrote the same pre-post tests. In the aftermath of the research, the ILM was also administered on the control group, believing that this group of learners could as well draw similar benefits as the experimental group.

The modal age of all the participants at the time of the study was eighteen years, with ages ranging from eighteen to twenty-one. The following table summarizes the number of learners who participated in the pre-post tests in the experimental group (EG) and control group (CG).

Table 3.1 Number of participants per group.

	Number who wrote the Pre-test	Number who wrote Post-test
Experimental Group	38	48
Control Group	36	36
Total	74	84

The sample was from grade twelve Physical Sciences learners at the school in 2016, consisting of a total of 74 and 84 learners in the pre-test and post-test respectively as is shown by Table 3.1 above. Altogether ten learners from both groups wrote the post-test without having written the pre-test because they were absent on the day others wrote the pre-test. For the experimental group (EG), 38 learners wrote the pre-test while 48 learners wrote the post-test, implying ten more learners in the EG wrote the post-test without having written the pre-test because of absenteeism. As for the control group (CG), 36 learners wrote both the pre-test and the post-test.

For both quantitative and qualitative analysis, the researcher decided to use data from participants who wrote both the pre and post-tests believing that it would give a fair comparison of the shifts involved in both the experimental and control groups.

3.4 Research methods

In the main, the study is a quantitative one, informed by a post positivist research paradigm. Bertram and Christiansen (2014) define a research paradigm as representing "a particular worldview that defines, for the researchers who hold this view, what is acceptable to research and how this should be done" (p.22). In addition, Bertram and Christiansen (2014) assert that a particular research paradigm ultimately dictates the type of research questions, the topic under investigation, how data are collected and how findings are interpreted.

Thus, according to Bertram and Christiansen (2014), post positivists believe in one truth about natural and social events, though they concede we can never to come to know it completely.

In addition, post positivists argue that the aim is to get closer and closer to the truth by employing quantitative, objective methods like tests and questionnaires that ask questions (Bertram and Christiansen, 2014). Quite relevantly, the instrument used in the study was pre-post testing, believing that the pre-post tests will yield measurable outcomes from test data.

Thus, depending on some responses, the researcher made follow ups with some participants of interest and did structured group interviews, attributes of a mixed approach study.

While the researcher was aware of the difficulties involved with the qualitative approach
especially in the transcription of large verbal data, perhaps it was one way of getting an in-depth
insight into the participants' views around what some researchers call 'children science'. The
researcher employed an interpretive view, itself embedded in the notion that assumes that
different people have different perceptions, needs and experiences. According to this perspective,
the only way to know the many truths and realities would involve recognizing the value and
depth of the unique individual content.

3.5 Methodology

A pre-post-test approach was administered on all participants. In addition, focus group
interviews were used on selected participants. The selection methods are explained in detail in
section 3.5.6.

Bertram and Christiansen (2014:95) argue that tests for research should be carefully designed,
making them different from tests teachers often use. It reasonably followed that the selection of
the test items largely drew from alternative ideas and errors reported in diagnostic reports, whose
concepts were covered in the syllabus. In addition, the test items were standardized in
accordance with Bloom's taxonomy levels as summarized in Table 3.2 below.

Table 3.2 Bloom's taxonomy levels (Source: CAPS document DBE).

Cognitive level	Description	Percentage
1	Recall	15%
2	Comprehension	35%
3	Analysis, application	40%
4	Evaluation, synthesis	10%

Thus, the pre-post test consisted of items with the relative level of difficulty as shown in Table
3.2 above. In addition, the content in the pre-post test was limited to VPM in one dimension
since vertical projectile motion in two dimensions is not part of the Physical Sciences CAPS
syllabus, notwithstanding the fact that there are potentially many alternative conceptions that
learners might have regarding VPM in two dimensions.

3.5.1 Instrument design: Development of the pre-post test

The questions in the pre-post test were structured in three ways, hoping that the diverse three-pronged approach in questioning would elicit as much pre-conceived ideas from the participants as is practically possible. In the first set of questions, participants were required to match four projectile motion terms to their corresponding definitions, while the second set of questions were multiple choice questions (MCQs) combined with a space for justifying the choice made. The last set of questions was open-ended questions requiring free responses. In all, the pre-post test consisted of MCQs as well as open ended questions.

The MCQs are considered closed because respondents are offered a limited choice from which to choose one option participants thought to be the correct answer. Consequently, MCQs are easy for participant to answer as well as for the researcher to mark and quantify (Opie, 2004). Nevertheless, MCQs allow for guessing (Bertram and Christiansen, 2014), and the limited choice offered by MCQs could mean some views were not catered for, a possible source of frustration to some participants (Opie, 2004).

This was the reason why participants were required to justify their choices of answers in the multiple choice section. For the same reason open-ended questions was included. On the other hand, open questions, though difficult for participants to answer, allow for free responses that come with no preconceived responses (Opie, 2004). Opie (2004) makes an assertion that, to the researcher, the open questions are easy to ask but difficult to analyze and quantify. Thus, the researcher was cognizant of the fact that learners might not answer some of the questions since more time was required to answer them, worse still in a second language.

3.5.1.1 Structure of multiple choice questions (MCQs).

Question numbers 2 to 10 of the pre-post test consist of multiple choice questions. Although each of questions 2 to 10 had their first part as multiple choice, their second parts required the participants to justify the option chosen from the first part of the question, making them double-barreled questions or what I call *hybrid* questions seeing that they contain both the closed and open-ended questions.

Analysis of this set of questions is therefore in two parts: the first part is the analysis involving only the multiple choice part, while the second part is an analysis attempting to link the multiple choice answers to justifications given by participants.

For each of the MCQs (Questions 2 to 10), four options were given. Some participants chose not to give their responses despite having responded to other questions in the pre-post test. I did not, therefore, discard them from the sample space, seeing that these participants answered the majority of the other questions.

3.5.2 Administering of the pre-post test

(i) Pre-post test experimental design.

Table 3.3 The Experimental design of the test

Group	Pre-test	Teaching strategy	Post-test
Experimental group	Multiple choice and open-ended questions.	Integrated Learning Approach.	Multiple choice and open-ended questions.
Control group	Multiple choice and open-ended questions.	Traditional methods.	Multiple choice and open-ended questions.

Table 3.3 above provides a summary for the experimental design of the test. Thus, whereas both the experimental and control groups were given the same pre-post tests, the difference was in the intervention teaching strategy administered.

While the Integrated Learning Model was administered to the experimental group, the traditional chalk and talk teacher-centered methods inclined towards lecture methods were used on the control group by a different teacher. The ILM is explained in section 2.11.1 while the traditional method does not provide a platform for argumentation.

(ii) Methodology

Figure 3.1 depicts sequences in the methodology flow chart. As earlier mentioned, two classes of learners were involved; one as a control group (CG) and another as an experimental group (EG). But for the pilot study, ten learners from the CG were selected so that they represented the different ability groups in that class. The pilot study was undertaken on the CG as opposed to the EG believing, like researcher Opie (2004:105), that piloting should not be done on participants in the main study since in Opie's words they shall have been "sensitised to the question so that any answers they give in the main study will be influenced in a different way from those who have not". Ideally, piloting should have been done at a different school involving different learners. However, in this study it was done on the CG from the same school, citing time constraints. However, to prevent contamination of the control group participants, the all material used was retrieved.
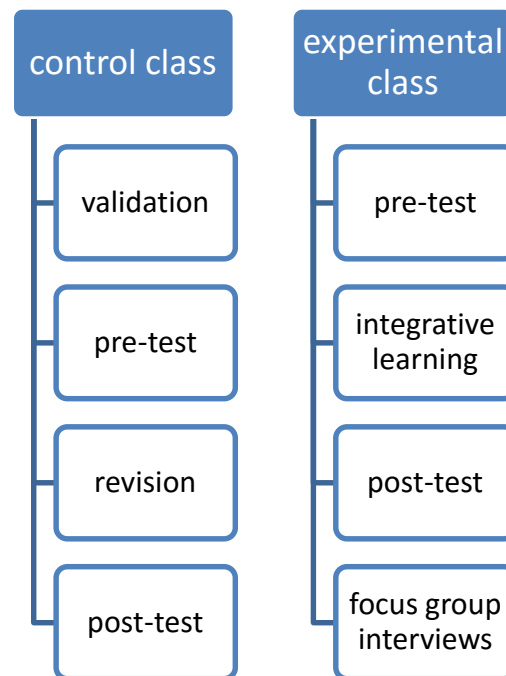

Figure 3.1 Methodology flow chart.

The test was piloted by administering it to ten learners from the CG of mixed abilities with a view to validating the test items as propounded by Opie (2004).

Opie (2004) argues that a pilot test gives an indication of the duration and level of difficulty of the test, in the process checking the clarity of instructions to avoid ambiguity across all intellectual abilities of learners.

The ten learners consisted of four moderately performing and three from each of above and below average categories, as supplied by the teacher based on the marks on his mark sheet. Marking and analysis of the scripts was carried out with the help of two other Physical Sciences teachers at the same school and a Wits University lecturer. Based on the feedback, the test items were adapted, moderated and conceptually pitched to the appropriate level of participants. For instance, I made three major changes to my initial test.

First, for all MCQs, spaces where participants were expected to give reasons for choosing a particular option were added, making them a set of double-barreled questions encompassing closed-ended and open-ended questions. This was aimed at potentially gaining deeper insights into the participants' thought processes in much the same way an interview would do.

Second, each concept was tested in at least two, slightly different ways so as to eliminate, as much as possible, avenues for guessing. Lastly, vocabulary was adjusted, making sentences and instructions clearer to participants.

The test was then administered to the rest of the control group as well as the experimental group, using a pre-post test approach. The same question paper was used in the pre- post tests in order to measure the shift or otherwise of learners' views noting that literature reports that some of the ideas withstand or are resistant to change. While the pre-test attempted to identify learners' preconceived ideas on vertical projectile motion, the post-test attempted to gauge or assess the shift, if any, in learners' ideas on vertical projectile motion, thereby giving an idea of the enduring nature of misconceptions and/or alternative conceptions.

For the experimental group only, an intervention strategy in the form of Integrative learning model, already explained in chapter 2, was administered in between the pre- and post-tests, while traditional revision was done to the control group, although the ILM was later administered to the CG after the study, citing potential benefits of ILM.

The pretest addressed my first research question of attempting to elicit and characterize learners' ideas about vertical projectile motion arising out of intuition and other sources, while the post-test addressed the effectiveness or otherwise of an Integrative learning model as an instructional strategy, thereby seeking to address the second research question outlined in chapter one.

3.5.3 Phases of methodology

The following flow chart summarizes the different phases in my methodology. Phase one involved the validity and reliability of the test administered to a control group and whose time frame was about a month. This was followed by the second phase wherein a pre-test was given to both control and experimental groups, lasting a week. Teacher intervention in phase three was done in two weeks. Phases four and five involved the administration of post-test and focus group interviews respectively, lasting for one week apiece.

Table 3.4 Stages of methodology

Phase 1(1 month)	Phase 2(1 week)	Phase 3(2 weeks)	Phase 4(1 week)	Phase 5(1 week)
Test development - Validity test - Reliability test: Pilot test on Control group	- Pre-test on (Both groups) - Marking and analysis of responses.	Intervention: IFL on the experimental group and revision on control group.	- Post-test (Both classes). - Marking and analysis.	- Focus group interviews (Experimental group). - Follow-up interviews

3.5.4 Teacher intervention

During intervention, teachers were introduced to an Integrative learning model combining argumentation and process oriented instruction. Teacher discussion on this intervention strategy led to the designing of teaching materials aimed at addressing the alternative conceptions, misconceptions and errors identified in the pre-test.

While one teacher used the Integrative learning model for the experimental group (EG), the other teacher used traditional revision methods on the control group (CG). At that stage, it was intended that after intervention, if the Integrative learning model was found to be beneficial to the EG, then this teaching and learning method would be extended to the CG as a post project follow-up. Indeed, after the analysis, the control group was taught using the ILM as a post-research follow-up.

3.5.5 Structure of questions in the pre-post test and standardization.

As mentioned above, the test was based on common alternative conceptions as exposed by researchers worldwide and consisted of multiple choice questions (closed questions) as well as longer, structured questions (open questions), itself an approach exuding a positivistic paradigm (Opie, 2004).

With the help of two other Physical Sciences at the school, the test items were selected from past NSC examination question papers and textbooks. The questions included closed-ended and open-ended questions all the while encompassing Bloom's taxonomy levels as a way of standardizing the test (see Table 3.2).

Above all, the questions in the pre-post test were based on the following key concepts derived from the following extract of the CAPS document detailing the concepts covered in VPM in one dimension:

Table 3.5 Vertical Projectile Motion syllabus (Source: CAPS document, DBE)

Topics	Content, concepts and skills
Vertical projectile motion represented in words, diagrams, equations and graphs. Near the surface of Earth and in the absence of friction. Time: 5 hours.	• Explain that projectiles fall freely with gravitational acceleration, g, which always acts downwards and is constant irrespective of whether the projectile is moving upward or downward or is at maximum height. • Know that projectiles take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. This is known as time symmetry. • Know that projectiles can have their motion described by a single set of equations for the upward and downward motion. • Use equations of motion to determine position, velocity and displacement of a projectile at any given time. • Draw position vs. time, velocity vs. time and acceleration vs. time graphs for 1-D projectile motion. • Give equations for position vs. time and velocity vs. time for the graphs of 1-D projectile motion • Given x vs. t, v vs. t, or a vs. t graphs determine position, displacement, velocity or acceleration at any time t. • Given x vs. t, v vs. t, or a vs. t graphs, describe the motion of the object e.g. graphs showing a ball bouncing, thrown vertically upwards, thrown vertically downward, and so on. • Investigate the motion of a falling body. • Draw a graph of position vs. time and velocity vs. time for a free falling object. Use the data to determine the acceleration due to gravity.

Thus, the content was limited to the concepts in Table 3.5 above. Whereas, MCQs are 'closed' in that respondents are given a limited choice of alternative replies, they are relatively easy to administer and easy for participants to answer (Opie, 2004).

Further, Opie (2004) asserts that the test responses are relatively easier to analyze as opposed to qualitative data from interviews. I attribute this to the fact that participants are given the same test, thus ensuring that the test questions are the same for all participants and therefore easy to analyze (Bertram and Christiansen, 2014). In addition, unlike interviews, there are no large volumes of verbal data to be transcribed.

Of course, MCQs have their limitations. First, multiple choice responses consist of the most appropriate answer and some distracters. Clerk and Rutherford (2000) argue that such distracters are not necessarily indicators of learner errors.

Second, MCQs allow for guessing (Bertram and Christiansen, 2014). A participant who does not know the correct answer may guess and still get the correct answer. Thus, it is difficult to see if a participant has guessed or not since there is a twenty-five percent chance of getting the correct answer from a choice of four.

Third, the limited choice of responses may mean that some of the participants' views may not be catered for, a possible source of frustration on the part of concerned participants (Opie, 2004). To ameliorate this frustration and attempt to reduce guessing, I did include justification for the choice of an answer in MCQs. Thus all MCQs had a space for participants to make their justification for having made their choice of the answer they perceive to be correct, making them two-tier MCQs.

An example of such a question is like the one below, taken from the test, in which participants were not only expected to choose the correct answer (A, B, C or D), but were also expected to justify choice made. This way a 'correct' answer could be treated as guessed if accompanied by a 'wrong' or no explanation.

Example of Multiple Choice Questions with space for justification.

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

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

Explain your answer: _____

In the previous question, the correct answer was option C. However, to avoid guessing, it was expected that a learner who chose option C must as well give justification for the choice made by mentioning that objects, regardless of their mass or shape, fall at the same g, the acceleration due to gravity. This is true if air friction is assumed to be negligible. Thus a person who chose option C and failed to justify or explain the answer was regarded in the study as someone who could be disguising misconceptions, although responses alone without justifications were analyzed.

In addition, I included Open questions, which Opie (2004) asserts as allowing for free responses from participants and no pre-conceived or guided replies or answers. However, despite being easy for the researcher to ask, they are, nevertheless, difficult for participants to answer and even more difficult for the researcher to quantify participants' responses (Opie, 2004). Worse still, learners may not answer some or part of these open questions since lots of time is needed to answer them, more so in a second language (Opie, 2004).

I included diagrams in most questions cognizant of the fact that the test's purpose in the identification of learners' alternative ideas may end up being engulfed in language difficulties as learners grapple with the interpretation of the test questions. Researchers like Clerk and Rutherford (2000) argue that test questions ought to be illustrated by diagrams and pictures further arguing that the language used must be simple. To this end, diagrams were included on most items believing that it would help learners better understand the test questions.

3.5.6 Focus group interviews

Based on marked responses from the pre- and post-tests, focus group interviews were used to further probe enduring alternative conceptions which are not in line with scientific concepts taught during intervention.

The focus group interview schedule was based on learners' responses in the pre-post tests and therefore were only determined after the post-test. Only group leaders were interviewed believing they represented the views of their peers. In addition, only learners in the experimental group participated in the focus group interviews believing their responses could be then considered in designing instructional strategy used for the EG.

Although focus group interviews are less flexible and guided by the researcher, they are, however, short, direct, capable of soliciting specific information and therefore easy to analyze since questions are pre-arranged (Opie, 2004). The focus group interviews were audio-taped.

Table 3.6 below summarizes the advantages and disadvantages of tape recording.

Table 3.6 Advantages and disadvantages of Tape-recording (Opie, 2014:121)

Advantages	Disadvantages
1.Preserves natural language	Too much data
2.Objective record	Time consuming to transcribe
3.Interviewer's contribution also recorded	Presence of recorder off-putting
4. Data can be re-analyzed latter.	Irrelevancies collected

3.6 Validity, Objectivity and reliability

Objectivity is defined as the avoidance of bias by the researcher in collecting; interpreting and generalizing findings while validity is how close to the truth the research is (Bertram and Christiansen, 2104). By giving a similar test to all learners, I assumed bias was greatly reduced.

Construct validity, on the other hand refers to the data collection methods and instruments' extent in measuring the construct for which they are intended (Bertram and Christiansen, 2014).

That is, the researcher was informed by literature on learners' pre-conceived ideas on VPM in attempting to elicit for learners' pre-conceived ideas by using a pre-post test.

Reliability is the degree to which a test can be repeated with similar respondents and still produce similar results (Bertram and Christiansen, 2014). Wellington (2000) and Bell (1999) as cited from Opie (2004) define reliability in a more or less way by emphasizing that for an instrument to be reliable, it must give consistent results on all similar occasions even if carried out by different researchers. This assertion addresses the issue of 'quality in research' (Opie, 2004). In my study, the subjects were given a pre-test and a post-test as a way of improving reliability of the instrument in making a comparison of learner conception.

Wellington (2000) as cited from Opie (2004) defines validity as the extent to which a research instrument actually measures what it is intended to measure and not something else. In this study, I attempt to elicit for learners' ideas that they have from their past experiences and not arising out of linguistic impediments in interpreting the questions. As mentioned already, diagrams were therefore used in most test items so that the questions would be better understood by participants.

To summarize, the test was given to the following people for validation:

1. An expert in Physical Sciences. I made use of the Physical Sciences District Facilitator.
2. An academic. I asked for comments from a Physical Sciences lecturer at Wits University.
3. Physical science teachers. Comments were also sought from two practicing Physical Sciences teachers.

3.7 Data collection and analysis

Data in the study was collected using pre- and post-tests as well as focus group interviews. Considering the nature of the study and the instruments I used, I used quantitative analysis on the data collected from the pre and post-tests while data was classified into themes for analyzing the qualitative analysis from open-ended and focus group interviews. Focus group interviews were done to gain an in-depth understanding of learners' conceptions which could not be captured using the pre-post tests.

Thus this research allows for a mixed methods approach. Focus group interviews were used only on the experimental group since this researcher was interested in getting to see their argumentation skills taught in the ILM. The participants were chosen based on their responses in their pre-post tests that were found to be of interest. As mentioned earlier on, the group leaders who participated in presentations were involved in the focus group interviews, believing that they represented opinions of their fellow learners during their group deliberations. Data from MCQs were analyzed to give quantitative variables using the Software Package for Social Scientists (SPSS). The analysis was done according to Table 3.7 below.

Table 3.7 Methods used to analyze data.

	Pre-test		Post-test	
Control group	1		2	4
Experimental group			3	

Arrow 1 represents a comparison of the performance of the control and experimental groups in the pre-test aimed at establishing the commonality of misconceptions in the groups before formal teaching.

Arrows 2 and 3 represent effects of learning due to respective teaching strategies employed on the control and experimental groups respectively by looking at the shift in the pre-post tests.

On the other hand, arrow 4 represents a comparison of the post-test performance of the two groups, bringing out the effectiveness of each of the teaching strategies in addressing misconceptions.

In each of the above cases, the SPSS gave significance levels derived from Chi-square values, making it possible to make quantitative analysis. Thus, the cross tabs method, giving Chi square values with level of significance set at 0.05, were used to make these comparisons.

3.8 Structure of lessons

3.8.1 Lesson outline

Five lesson plans of one hour each are given in the appendices (see Appendix C). The lessons are drawn from the extract of the syllabus in Table 10. These lessons guided the lessons on Vertical projectile motion in both groups, with the difference being the emphasis placed on argumentation in the experimental group as outlined in section 2.11.1.

3.8.2 Classroom activities

Activities done in class were based on the ILM and, in the main, involved group work. The activities attempt to address key concepts being tested in the pre-post test and encouraged learners to make arguments.

3.9 Ethical issues

Bertram and Christiansen (2014) define ethics as having "to do with behavior that is considered right or wrong" (p.65). From this definition, it reasonably follows that a practice is wrong if one would not want that practice to be done on him/her as the researcher.

While the definition of right or wrong might be subjective hence problematic, this research did not seek intentionally or otherwise to put participants at a disadvantage or risk at the sole expense of the study, whether during or after the research.

Since the study was carried out on learners, the researcher therefore got signed consent from learners and their parents. Consent is defined by Bertram and Christiansen (2014) as an agreement by participants to voluntarily be part of the study, with a freedom to withdraw at any stage of the research.

In the consent forms the researcher explained to the participants why he was carrying out the study, at the same time emphasizing confidentiality of their responses including their right to withdraw at any time or stage of the research. Other than the respect of the autonomy of participants, the researcher remained conscious of the fact that the research must not do physical, emotional or social harm to the participants in any way or form.

This act of not doing harm to participants is what Bertram and Christiansen (2014) refer to as 'non-maleficence' (p.66) and calls for an assurance that the participant's personal information will remain confidential especially in publishing results, and that every care would be taken to ensure appropriate storage.

Lastly, this researcher was aware that my research in one way or the other should potentially benefit participants either directly or indirectly, including other researchers.

In application forms, the researcher outlined how he intended on upholding the autonomy, non-maleficence and beneficence regarding the study. Ethics clearance was obtained from Wits Ethics committee as well as the Department of Basic Education.

3.10 Summary

In this chapter, the research sample as well as the underlying methodology used in this study was described. In particular, the use of research tools used in collecting and analysing data was discussed. In addition, processes around standardization of the pre-post test, which is the main research instrument, were discussed.

In the main, the research followed a quantitative research paradigm in explaining ways of eliciting and analyzing participants' ideas on Vertical projectile motion, based on data collected in the pre-post tests. Qualitative analysis was used to support the quantitative analysis.

The chapter ends with a discussion of issues to do with ethics.

In the next chapter, the researcher presents and discusses results.

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents an analysis of data as well as a discussion of results. Data summarized in tables in this chapter were gathered from the pre-post tests. Two classes of Grade 12 Physical sciences at a school, south-east of Johannesburg, were involved in the study: one as an experimental group (EG) and the other as a control group (CG). The study sought to identify and characterize learners' enduring misconceptions about Vertical projective motion with a view to enhancing better conceptual understanding of the topic in learners through an Integrated learning model; a teaching model I designed and whose impact I tested in this study.

The research questions are the beacons of this study, used in this current chapter to guide analysis of results as follows:

4.2 Research Question 1: How do learners' ideas on VPM compare with scientifically accepted views?

In the main, this research question attempts to elicit learners' pre-instructional ideas on Vertical projectile motion (VPM) from both the experimental and control groups using a pre-test, with a view to comparing these pre-conceived ideas with scientifically accepted views. To answer this question, first, I make an inter-group comparison of learners' ideas on VPM (see Table 3.7 path 1) - gleaned from the pre-test, to establish the commonality, if any, of learners' pre-conceived ideas between the two groups. Secondly, these common ideas are later compared with scientifically accepted views to establish misconceptions.

The analysis made in this study is a mixed method approach. That is, it is double-barreled in that both quantitative and qualitative techniques were used to analyze the data.

The next section now looks at comparing the performance of experimental group against the control group in the pre-test. Thus, data in Table 4.1 below which were gleaned from the pre-test is used to compare pre-conceived ideas held by the control and experimental groups, leading to the identification and characterization of common misconceptions learners have about VPM.

Table 4.1: Comparing the performance of the experimental group (EG) and control group (CG) in the pre-test.

Item	Pre-test: CG (n=36)		Pre-test: EG (n=38)		Chi-square
	Right	Wrong	Right	Wrong	
2	26	10	33	5	0.101
3	15	21	23	15	0.08
4	21	15	29	9	0.08
5	20	16	23	15	0.42
6	17	19	28	10	0.018*
7	14	22	8	30	0.077
8	19	17	21	17	0.507
9	11	25	29	9	0.00*
10	9	27	22	16	0.004*

*Level of significance set at 0.05 threshold.

From the Chi-square values in Table 4.1 above that were generated from the cross tabs, it can be inferred that - save for items 6, 9 and 10, there was no significant difference between the performance of the control and experimental groups in the pre-test. The experimental group, nevertheless, answered items 6, 9 and 10 significantly better than the control group. That the experimental group outperformed the control group in these three items may, however, suggest that the selection model was slightly skewed towards the experimental group. The difference in group performance in these few items could be attributed to the fact that the two groups were taught by different teachers, who might have placed different emphasis on some earlier concepts related to vertical projectile motion.

Consequently, the researcher excluded items 6, 9 and 10 from discussions regarding the effectiveness of the different teaching methods believing these items will present an unfair comparison.

Thus, the rest of the items in Table 4.1 - showing insignificant differences, hence similar performances - were considered in making comparisons about the effectiveness of the ILM versus the traditional methods, believing this would increase the validity of results.

Still, both groups performed comparably in about two thirds of the items before formal teaching of the topic, pointing to similar or common pre-conceived ideas about VPM amongst participating learners in the two groups.

For me, this was understandable given that learners in the two groups came from similar social, cultural and geographical backgrounds and hence potentially shared similar ideas and experiences relating to Vertical projectile motion.

This probably suggests that the two groups were having the same misconceptions too, making it possible to make both quantitative and qualitative comparisons of the two groups in terms of the misconceptions that they have prior as well as after the respective intervention strategies employed on each class.

In summary therefore, the cross tabs method was used to establish the fact that the students in the two groups shared common misconceptions about most of the items in the Vertical projectile motion (VPM) test. This means that the two groups can be compared to find out the effectiveness of the Integrative learning method (ILM) on VPM relative to the traditional methods.

Now, having established the commonality of misconceptions about VPM between the two groups in this study, I now turn my attention to characterizing these misconceptions with a view to getting deeper insights into learners' thinking as shaped by their common sense, IKS and intuitive ideas. To do this, I identify common misconceptions from the pre-test whose explanations I followed up in the focus group interviews, with the latter only applying to the EG. While some of learners' pre-conceived ideas were found to be in phase with science views, others were, nevertheless, found to be misconceptions. The following section looks at the common misconceptions between the two groups.

4.2.1 Common misconceptions

The first common misconception discussed relates to Item 7. As can be seen from Table 13, Item 7 was poorly answered by learners from both groups, suggesting that most learners found it very difficult to accept that the acceleration of an object that is thrown vertically upwards is constant during the entire trajectory (see Appendix A).

While 30% of all participants agreed with this scientific view, 28% of all learners thought that the magnitude of acceleration of an object is lowest on its way down, while 24% believe that the magnitude of acceleration is lowest just after leaving the thrower's hand.

On the hand, 18% of all learners believed that the magnitude of acceleration is lowest at the top of the object's trajectory, a possible sign of confusing acceleration with velocity - what I call the 'acceleration-velocity' controversy. I think this misconception arises because learners do not consider deceleration as negative acceleration, believing instead that a slowing down object has no acceleration.

This is further confirmed by responses obtained from focus group interviews as well as open-ended questions, summarized in Table 4.2 below, which are now discussed in the next section.

Table 4.2 Sample explanations from learners for Item 7.

Learner	Choice	Reasons
C48	Acceleration = 0	It has reached its highest point.
C46	Acceleration decreases as object moves up	This means that it moves up the acceleration decrease due to gravity pulling the object down (sic).
C53	Acceleration = 0	Maximum point that why the acceleration is zero
C7	Acceleration decreases as object moves up	It's because of frictional force.
D21	Acceleration decreases as object moves up	The object accelerates as it launches from the ground but decrease when it on air.
D19	Acceleration is constantly $9.8ms^{-2}$ upwards	Because when the object is thrown up it zero then when it gets back down is still constant.
D16	Acceleration is $9.8ms^{-2}$ upwards	Because it goes in an opposite direction to the gravity.

In responding to why they thought acceleration of an object that is thrown vertically upwards is zero at the highest point, some interviewed learners argued that acceleration is zero (claim) because the object has reached its highest point (warrant). This response suggests a misconception in confusing acceleration with velocity, with the latter regarded by the scientific view to be zero at the highest point.

On the other hand, some learners who believed that acceleration decreases as a projectile is thrown vertically upwards went on to argue, in the focus group interviews, that the decrease in acceleration is due to gravity pulling the object down or that the decrease in acceleration is because of frictional force.

Even so, others thought that the object accelerates as it is launched, later decreasing when it goes up. Again, all these explanations point to learners confusing acceleration with velocity as well as their failure to consider that air resistance is assumed to be negligible, all exposing learners' mini-theories on VPM correctly reported in diagnostic reports.

Meanwhile, those who believed that acceleration is constantly $9.8ms^{-2}$ upwards argued that the object goes in the opposite direction to gravity, further pointing to the treatment of the velocity as being synonymous to acceleration. For me, learners do not treat a projectile whose velocity is decreasing as it moves vertically upwards as being under constant acceleration. Instead they end up confusing these two technical terms and use them interchangeably.

That learners had different views and explanations amongst themselves and the scientific view regarding the magnitude and direction of both the acceleration and the velocity of an object thrown vertically upwards is clear evidence of the many alternative ideas or mini-theories learners have regarding these two technical terms, probably explaining the poor marks highlighted in diagnostic reports.

In summary, the focus group interviews confirmed that learners have misconceptions around velocity and acceleration in the same way it is reported in the extant literature, including NSC diagnostic reports. The misconceptions are similar to those reported by Prescott (2004), as summarized in section 2.5 of this study.

Without doubt this explains the poor show that the quantitative analysis exposed on this item in the above analysis, making it difficult for some learners to accept the scientific view that regards acceleration of a projectile to be having a constant magnitude and a downward direction.

That acceleration is a constant, and always acting downwards even at the highest point of object's motion, was not be accepted by most participants. I posit that this concept was inconceivable to understand to participants who ignored the assumption that takes air resistance was assumed to be negligible for the concept of constant acceleration to hold water.

It is quite evident that some participants held the view that since the object's motion is **upwards** then its acceleration is also **upwards** and/or the magnitude of the object's acceleration progressively reduces until it is zero at the highest point of its motion, a clear sign of mistaking velocity with acceleration that is widely reported in NSC Diagnostic Reports.

The second misconception common amongst learners, closely related to the first one discussed above, relates to the scientific view that regards velocity (and not acceleration) of an object thrown vertically upwards to be zero at the highest point of its upward journey. This item was tested in Item 8 (see Appendix A). That learners confuse acceleration with velocity, two technical terms in vertical projectile motion, is clearly illustrated by participants who took acceleration to be zero at the highest point of a projectile that is thrown upwards.

On the other hand, while Option A correctly considers the **magnitude** of acceleration of an object that is thrown upwards to be 9.8ms^{-2}, it nevertheless, takes the direction of the acceleration to be **upwards,** instead of the scientifically accepted **downward** direction. This confusion in the directions of velocity and acceleration could be the reason accounting for 2 learners and 8 learners of the EG and CG respectively choosing Option A (see Appendix A).

This further exposes learners' belief in interchangeably using velocity and acceleration of projectiles, already reported in literature including diagnostic reports.

Meanwhile, Option D, assuming that acceleration decreases as the object moves upwards, was chosen by 1 and 7 participants of the EG and CG participants respectively. This clearly indicates that some learners believed that acceleration, just like velocity, decreases as the object is projected upwards, much in contrast with the scientifically held view that takes acceleration to be constant.

Overall, from the results summarized in Table 13 above, 40 learners agreed with the scientific view while 34 learners disagreed with the scientific view that takes velocity at the highest point to be zero. Even so, some of the explanations given by interviewed learners point to inconsistencies in learners' reasoning in much the same way to the first misconception already discussed above. The same analysis resembles the one done for the first misconception above.

To conclude: according to the scientific view, velocity is zero at the highest point and this might have been confused with Option B that wrongly regarded acceleration to be zero at the highest point of an object's trajectory, or Option C that takes acceleration as a minimum on its way down.

The third misconception that I found to be common between the two groups relates to Item 4 of the pre-test in which a distinction between vector and scalar quantities was being tested. While 50 learners were able to choose correctly '*time of flight*' as a scalar quantity, with the rest (24 learners) choosing either of acceleration, velocity or displacement, subsequent analysis from the explanations found gaps around the reasoning behind their correct choices.

Quite correctly, 50 learners chose '*time of flight*' as a scalar quantity. Thus the majority from both groups held the scientifically accepted view. However, 8 learners from both groups regarded velocity as a scalar (Option A), while 12 learners regarded displacement as a scalar (Option B). Lastly, the choice of acceleration (Option D) as a scalar quantity was made by 4 learners.

Overall, the majority of the participants from the two groups chose *time* as a scalar quantity, with the rest of the responses being distributed amongst acceleration, velocity and displacement as quantities that they regarded – quite wrongly (according to the scientists' view), to be scalar quantities.

In spite of the majority doing well in correctly choosing the science views, a further analysis shows that 7 out of the 50 learners who initially picked time of flight correctly as a scalar quantity could not, however, define a scalar as a quantity having magnitude only - the science view- probably exposing their lack of understanding of the term as reported in literature. On the other extreme end are the learners who chose velocity, displacement and acceleration as scalar quantities respectively, clear testimony of their ignorance of what scalar and vector quantities are. Knowledge of scalar and vector quantities is required in understanding VPM.

In summary, the majority of the participants from both groups were able to choose *time of flight* as a scalar quantity with only 24 out of 74 unable to do so. In addition, 43 of the 50 who correctly identified time as a *scalar quantity* went further to give correct scientific definitions of a scalar quantity. This item showed common ideas shared by the two groups which agreed with the science, at least for the majority of the participants. Even though, 31 learners that includes 24 who failed to pick time as a scalar and 7 who initially chose time of flight as a scalar but failed to explain their choice by defining a scalar potentially hid misconceptions.

The fourth misconception relates to choice of an object that is a not a projectile and was tested in Item 2. Item 2 required learners to pick an object that they regarded to be a non- projectile (see Appendix A). The scientifically accepted answer was Option C: a flying bird, since it aligns well with the scientifically accepted view that takes a projectile as an object that is thrown or shot through the air and the **only** force acting on it is gravitational force.

The reasoning is that, since the flying bird is powering its motion, there are therefore several forces acting on it, making it a non-projectile. In the pre-test, 33 participants from the experimental group (EG) chose Option C - a bird in flight, as an object that they considered to be a non-projectile. Equally, 27 participants from the control group (CG) held the same view expressed by the EG by choosing Option C.

On the other hand, 5 participants from each of the EG and CG chose the bullet fired from the gun (Option D) as a non-projectile probably believing that since it is fired from the bullet it is not a projectile. Perhaps the high speed of the bullet made these participants believe it was not a projectile. This line of reasoning probably takes the Impetus theory outlined in Chapter two.

A rock thrown upwards (Option A) as well as a ball kicked into the air (Option B) were very unpopular choices for non-projectiles amongst both the EG and the CG, an indication that participants had no problems in accepting them as projectiles. To be exact, neither Option A nor Option B was chosen by any of the EG participants, while only a single participant and 2 participants from the CG chose Options A and B respectively. This probably points to participants in both groups having the view that takes a rock that is thrown upwards or a ball that is kicked into the air as projectiles, rather than as non-projectiles. However, when it came to justifications, only 10 learners from each of the groups were able to choose with justifications what they regarded to be a non-projectile, suggesting that both groups held same conceptions regarding what is not a projectile.

The following provides a summary of justifications given by learners from open-ended questions and focus group interviews:

Table 4.3 Sample answers from learners for item 2.

Learner	Choice	Reasons
D42	A bullet from a gun	We know that the bullet will bounce back
D16	A Flying bird	The bird can still fly and gravitation will not pull the bird down.
D41	A Flying bird	A bird is not thrown or fired upward or downward
D9	A bullet from a gun	The gun doesn't experience gravitational force
C21	A flying bird	Because there's (sic) no force acting on it or towards it, when it flies it goes up freely and comes back freely with its force.
C42	A flying bird	Bird is controlled by kinetic energy is not machine
C18	A bullet from a gun	Because when you point a gun to a certain point it won't come back

Quite interesting is the response from learner D9 regarding a bullet fired from the gun as an object that cannot be regarded as a projectile, believing it does not experience gravitational force (see Table 4.3 above).

The other response of interest was made by learner C21 who regarded a flying bird as a non-projectile, further arguing - like learner D9 - that there is no force acting on it when it is in flight, further confirming misconceptions around the definition of a projectile.

 Thus, overall, the majority of participants from the two groups held the scientifically accepted view accepting a projectile as an object that is either thrown shot or dropped through the air and whose ONLY force acting on it is gravitational force. However, only 10 participants were able to further explain their choice of why a flying bird was not a projectile, possible indicator of misconceptions these learners could be harboring.

I now turn my attention to the first item of the pre-test aimed at testing learners' knowledge of definitions of terms used in vertical projectile motion (see Appendix A).

This was structured in the form of a table where learners were asked to match four terms namely: *projectile, free fall, gravitational field and acceleration due to gravity* with corresponding definitions, making it a closed ended question.

The following table shows a summary of correct responses from the participants.

Table 4.4 Correct response for VPM terms in the pre-test.

Term	EG (n=38)	CG (n=36)
Projectile	13	25
Free fall	9	10
Gravitational field	31	27
Acceleration due to gravity	26	15

From Table 4.4 above, most learners clearly showed a poor understanding of the term *free fall* with only 9 and 10 learners choosing the scientifically accepted definitions from the EG and CG respectively.

Further the term *projectile* was poorly understood by the EG (13 learners) while 25 learners from the CG showed a fairly better understanding of the term. On the other hand, only 15 learners from CG correctly defined *g, the acceleration due to gravity,* with 26 learners from the EG understanding the term. Gravitational field was fairly understood by 31 and 27 learners from the EG and CG respectively.

To summarize: Data in Table 4.4 above show that a number of participants from both classes had common misconceptions regarding definitions of key terms in VPM. Free fall was least understood by most learners from both classes while most learners from both classes understood gravitational field. However, since the questions were closed-ended, it was difficult to establish whether the correct definitions were as a result of guessing or not.

Having established the common misconceptions in the two groups, I now summarize the correct responses from the multiple choice items plus the corresponding correct explanations.

I am of the opinion that a correct answer must be followed by a correct explanation, lest (correct choices alone) that would be regarded as guess work.

Table 4.5 is a summary of correct responses from questions combining multiple choices with reasons for making the choices, making them a combination of closed and open-ended questions.

Table 4.5 Summary of correct responses for Science concepts in the pre-test.

Scientifically accepted concept	EG: correct(ca+ce) (n = 38)	CG: correct(ca+ce) (n = 36)
Choice of a non-projectile	33(18)	27(16)
For an object thrown upwards, its acceleration is constantly 9.8ms^{-2} downwards.	23(18)	14(7)
Time of flight, as opposed to vectors: velocity, displacement and acceleration, is a vector.	29(25)	22(20)
At the highest point of motion of an object thrown upwards, its velocity is zero and its acceleration is 9.8ms^{-2} downwards.	23(9)	16(7)
Time symmetry.	28(13)	17(11)
Magnitude of acceleration is constant.	8(2)	14(6)
Velocity is zero at the highest point of projectile.	21(7)	19(6)
Net displacement is zero for an object thrown upwards and returning to thrower's hands.	29(12)	11(4)
Acceleration is independent of mass of objects.	16(6)	9(3)
Trajectory of object falling from moving plane.	0(0)	0(0)
Free-body diagram.	12	19
Application: Newton's first law and trajectory of falling object.	4(2)	1(0)

Note: Numbers in brackets represent correct answers coupled with correct explanations.

From Table 4.5 above, it can be seen that the number of correct answers coupled with correct explanations was always less than correct choices only. In all the multiple choice items above, participants fared much better in selecting the scientifically accepted choices from the four given options in comparison to correct choices of answers coupled with correct justifications (see Table 4.5). Thus, it was clear that when it came to explaining the choices made, lower percentages in all cases were recorded suggesting a potential lack of understanding, perhaps signaling possible alternative ideas that could be hidden behind mere guessing of correct choices.

Furthermore, difficulties in language could not be ruled out, wherein participants failed to understand the question. Even worse is the failure by learners to express themselves sensibly and properly in English. The impact of language in participants' answering of the pre-post test is, nevertheless, beyond the scope of current research study. Perhaps, this could be a recommendation for future research to assess the impact of language in learners' conception of VPM.

The next item for analysis relates to free-body diagrams. Physical Sciences learners are introduced to free-body diagrams in Grade 11 in other contexts. In the pre-post test administered for the current study, one item asked participants to draw a free body diagram of a projectile in free-fall.
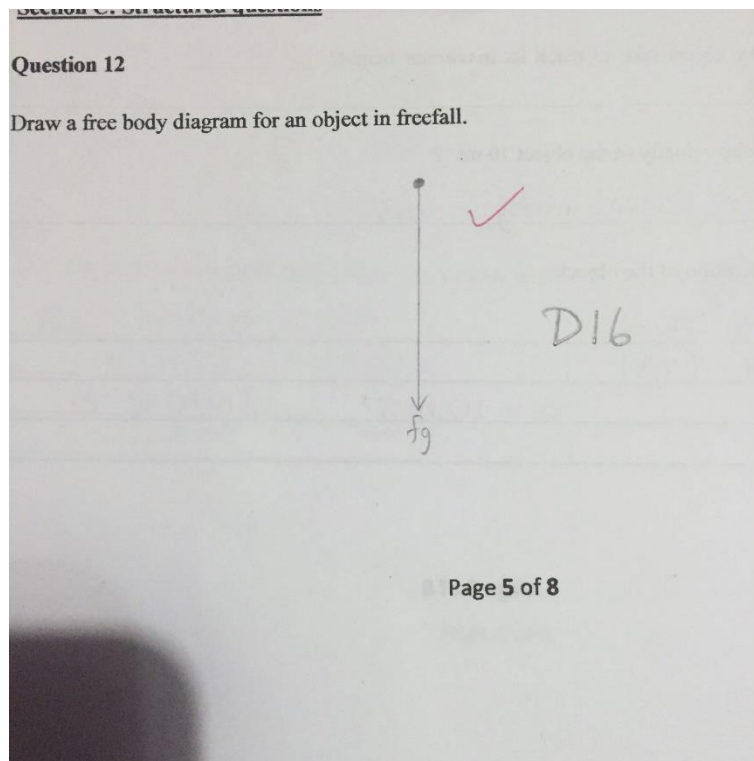
Diagram D16: Free-body diagram of an object in free-fall.

The above diagram (D16), drawn by one of the participants, was the scientifically accepted free-body diagram. This free-body diagram of an object in freefall follows the definition of a projectile in item 1 (see Appendix A). A projectile is defined in item 1 as the object thrown or shot through the air and the only force acting on it thereafter is the gravitational force. The diagram should therefore show only one force, the gravitational force, and whose direction is downwards as shown in Diagram D16 above.

As expected, the large percentage of the CG participants (69%) who defined a projectile in question1 according to the definition given above, has a bearing on the participants who were able to draw the scientifically accepted free-body diagram, which stood at 53%. For me, there appears to be a correlation between the scientifically accepted definition of a projectile in item 1 and the scientifically accepted free-body diagram in item 12.

The same pattern can also be observed amongst the EG participants, where 34% of them were able to define a projectile in question 1 and 32% drew the free-body diagram in question 12 according to the scientists' views, showing strong correlation between the scientifically accepted definition and free-body diagram of a projectile.

C: Structured questions

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ce body diagram for an object in freefall.
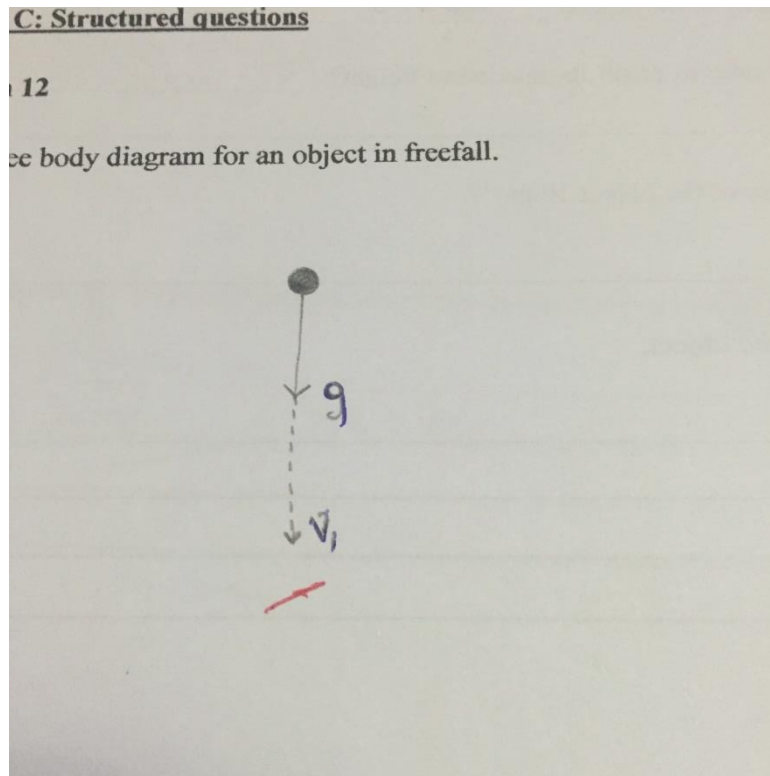
Diagram 17: Free body diagram drawn by a participant.

However, some participants disagreed with the science view shown in diagram 16. An example is the response shown by two downward arrows (see Diagram 17 above), suggesting that there could be two forces acting on an object, in contrast to the scientifically accepted view that assumes that the only force acting on a projectile is the gravitational force.
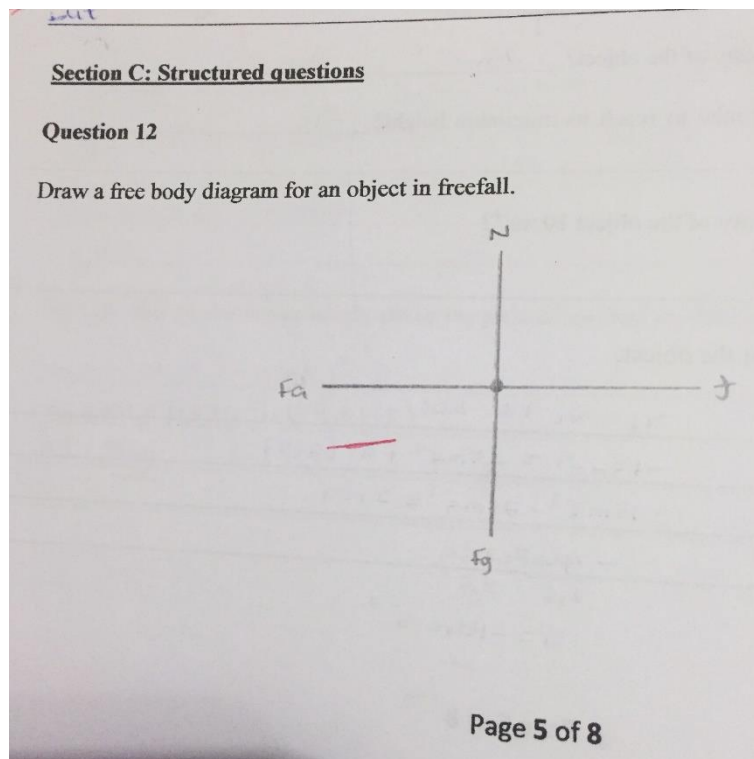
Diagram 18: Free body diagram drawn by a participant.

The above diagram assumes that there are four forces acting on a projectile, which does not align with the scientifically accepted definition of a projectile that regards only one force, the gravitational force, and acting on the projectile. This clearly shows a poor understanding of both the definition and the free-body diagram of an object.

I now discuss the responses obtained from graph-based questions, hoping to assess learners' misconceptions on graphs. Table 4.5 below is a summary of correct responses for questions requiring learners' appreciation of graphs of motion. All the questions in this section were open ended in that no choices were given. As a matter of fact, participants were expected to write their own answers - without restraint - thereby presenting them with an opportunity to expose their own thinking.

Table 4.6 Summary of correct responses from graphs for experimental group (EG) and control group (CG).

Acceptable Concept	EG(correct) n = 38	CG(correct) n = 36
Reading off initial velocity, V_i	32	28
Identify time to reach max. height	26	24
Reading off time given velocity	12	7
Calculating gradient (equal to acceleration)	13	15
Use equations	7	3
Plotting graph of displacement versus time	0	0
Use equations to calculate velocity	4	20
Use equations to calculate maximum height	0	1
Use equations to calculate time	0	0
Use equations to calculate time when displacement between two objects in motion are given.	0	0

Reading off the initial velocity from a velocity-time graph was well answered by both groups receiving 84% and 78% of correct responses from EG and CG respectively. Learners also do graphical work in other subjects like Mathematics, Life Sciences and Geography, a potential reason why they showed mastery of basics on graphs.

Similarly, another question that was fairly answered was where participants were asked to identify the time taken by an object that is thrown upwards to reach the highest point from the velocity-time graph. This is identified on the velocity-time graph as the time corresponding to the velocity of an object that is zero on the velocity-time graph. 68% and 67% of the EG and CG participants correctly identified the answer from the velocity-time graph. This is not surprising given that 55% and 54% from the EG and CG participants as noted earlier on were able to state that velocity is zero at the highest point of a vertically projected object, an essential concept to be applied on the velocity-time graph to determine the time corresponding to zero velocity.

The question requiring participants to determine the time(s) when the object's velocity is given was poorly answered by most participants with only 32% and 19% of participants from the EG and CG respectively giving the scientifically accepted answers.

Equally problematic to participants was the next question requiring participants to calculate gradient of a velocity-time graph which they were expected to equate to acceleration. This question had 34% and 42% of participants from the EG and CG respectively getting correct values of gradient, suggesting that most participants did not know how to calculate gradient of a straight line let alone realizing that the gradient of a velocity-time graph represents acceleration of the object whose motion is depicted in the graph. The lack of mastery of mathematical skills by learners was evident in this question. Calculation of gradient requires substitution into the following gradient formula:

$$\text{Gradient, m} = \frac{(y_2 - y_1)}{(x_2 - x_1)},$$

where $y_2 - y_1$ is change in y, and $x_2 - x_1$ is change in x.

Even worse was the performance of participants in choosing and correctly using equations of motion to determine the position of an object after certain time intervals. In this question only 18% and 8% of participants chose the correct equation of motion which they subsequently used correctly to determine the displacement of an object after a given time. This is understandable noting that it was a higher order question requiring application.

In summary, higher order question requiring participants to plot corresponding graphs of displacement-time graph from the velocity-time graph was poorly answered with none of the participants from both the EG and the CG plotting the correct graphs. This is Grade 12 work which learners are expected to know after instruction. That the pre-test was given to participants before the concept was formally taught is clearly evident in the poor performance displayed by participants on this concept. Save for the first part of the question, the rest of the parts were poorly answered by almost all participants, a sign that none had prior understanding of the concepts covered.

Furthermore, choosing and using correct equations of motions as well as graphs of motion were poorly answered, suggesting learners have difficulties in answering questions requiring applications. Further, these questions required the application of mathematical skills like substitution into formulae as well as change of subject of formulae, skills that seriously lack amongst learners – beyond doubt confirming NSC diagnostic reports.

To conclude: from the analysis of the cross tabs, learners from the two groups under investigation were found to have performed more or less the same on most items in the pre-test, bringing out common misconceptions they had regarding vertical projectile motion. The level of significance was set at 0.05 on the Chi values. Items where the performance was significantly different were excluded from discussions, enabling comparisons of inter-group performances to be made only on comparable items. This culminated into the subsequent characterization of learners' pre-conceived ideas on vertical projectile motion. Open-ended questions as well as focus group interviews gave deeper insights into these misconceptions. It was found out that learners bring to class diverse mini-theories about phenomena, much in line with social constructivists. While some pre-instructional ideas were found to be misconceptions, other ideas were, however, found to be compatible with the science views, even forming the majority of responses on some items. The misconceptions were identified, discussed and found to resemble pre-Newtonian mechanics which I outlined in Chapter two.

4.3 Research question 2: How effective is the Integrative Learning Model in bringing about better conception of vertical projectile motion by learners?

To answer this research question, I first compare the performance of the control group (CG) in the pre-test with their performance in the post-test (see Table 3.7 path 2). The same analysis is subsequently extended to the experimental group (EG) (refer to Table 3.7 path 3). This is done to establish whether or not each of the teaching method employed on each group produced learning gains on individual items in the test.

Lastly, the two groups' performances in the post-test are compared to see the relative effectiveness of ILM on the EG as compared with the traditional methods on the CG (see Table 3.7 path 4).

This is aimed at establishing which of these two teaching methods is more effective than the other in producing better quantitative and qualitative learning gains on physics concepts tested in the pre-post test.

4.3.1 Pre-test vs. post-test comparison for the control group (CG) using traditional methods.

Data in Table 4.7 were used to assess the effects of the traditional method on the control group by making a comparison of the CG performance alone in the pre-test and post-test. This is done in order to assess the impact of the traditional method in causing a shift on learners' perception of the items.

Table 4.7 Pre-test vs. post-test for the CG.

Item	Pre-test: Control (n=36)		Post-test: Control(n=38)		Chi-square
	Correct	Wrong	Correct	Wrong	
2	26	10	30	6	0.198
3	15	21	23	13	0.04*
4	21	15	26	10	0.161
5	20	16	20	16	0.594
6	17	19	23	13	0.118
7	14	22	18	18	0.239
8	19	17	22	14	0.317
9	11	25	19	17	0.047*
10	9	27	24	12	0.000*

Level of significance set at 0.05 threshold.

The traditional method produced some significant learning gains on the control group. Thus from Table 4.7 above, it can be seen that items 3, 9 and 10 produced significant shifts judging by the significant levels (see values with the asterisk). However, since Items 9 and 10 (together with item 6) have been excluded for discussion as explained earlier on, I now illustrate the learning gains derived by the CG from the traditional methods on Item 3 by means of a bar chart below, seeing that items 9 and 10 are excluded for discussion.
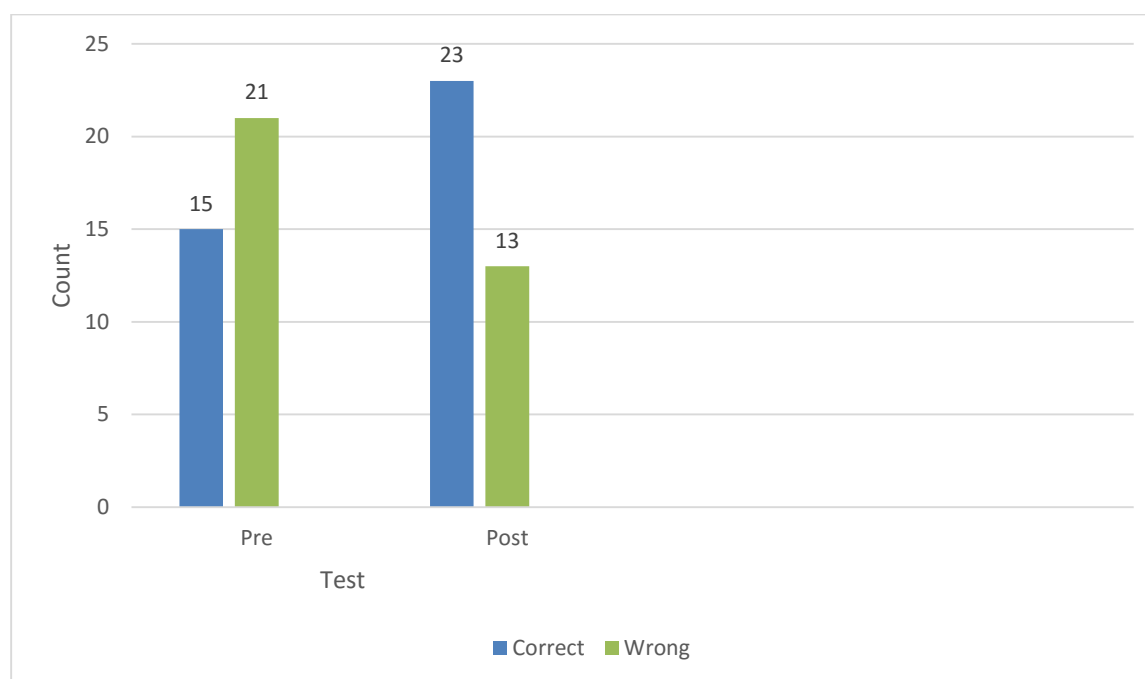
Figure 4.1 Bar chart for Item 3: pre-test vs. post-test for the control group.

Item 3, whose results are depicted in Figure 4.1 above, was about testing learners' views regarding the acceleration of an object that is thrown vertically upwards. For this item, the science view is that the acceleration of a projectile has a constant magnitude of 9.8ms^{-2} plus a downward direction irrespective of whether the projectile is moving upwards or downwards. While 15 learners from the CG held the scientifically accepted view in Item 3 in the pre-test, this number significantly increased to 23 learners in the post-test (see Figure 4.1 above) - without doubt pointing to the success of the traditional method on the CG on this item. This shows the effectiveness of traditional methods in teaching some concepts especially the ones presented as 'principles' typically associated with rote learning.

I would now like to shift my attention to those items that showed no significant improvement, in the process highlighting the possible shortcomings of the traditional method on these items. While Items 2,4,7 and 8 showed an increase in the number of learners accepting the science views, the shift was, nevertheless, of no significance (see Table 4.6) – requiring a rethink into the use of non-traditional methods in the effective teaching of physics concepts. Thus, the traditional method was not as effective for these items as it was for item 3.

Accordingly, in the next section, I examine the misconceptions associated with items 2, 4, 7 and 8 while attempting to configure why the traditional method was not as effective in bringing significant shifts on these items as it did on item 3. But first, I present bar graphs highlighting the slight shifts in some items, followed by a discussion of misconceptions associated with these items.
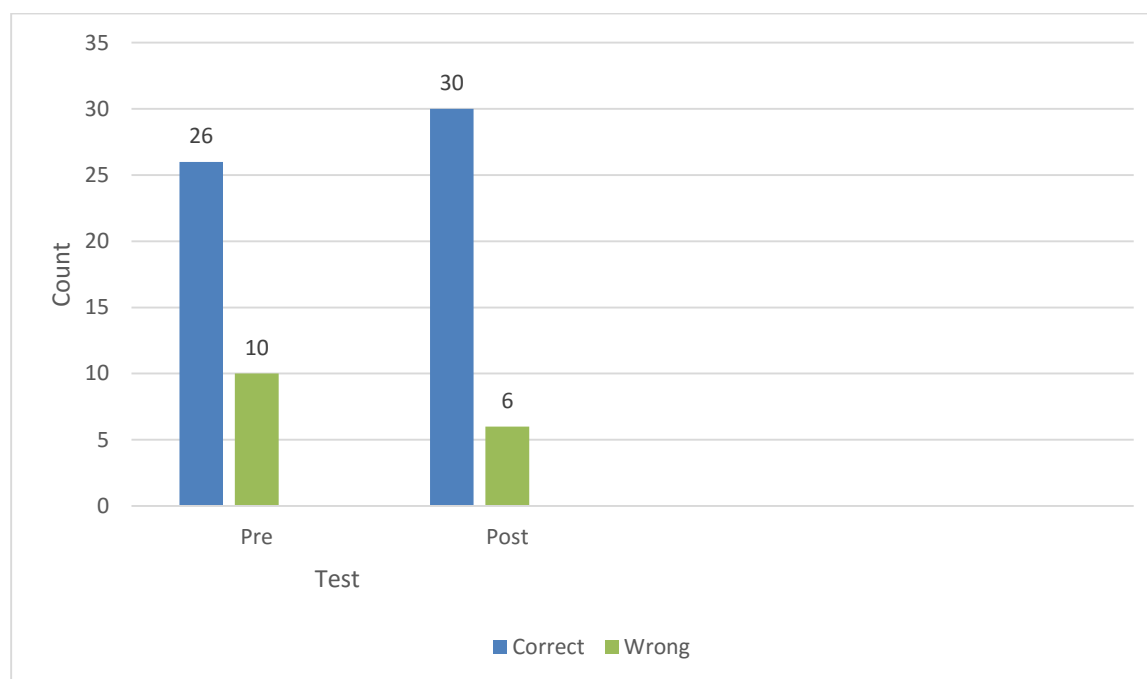
Figure 4.2 Bar chart for Item 2: pre-test vs. post-test for the control group.

In the pre-test, 26 learners from the CG got the scientifically accepted view in item 2, with the number increasing slightly to 30 in the post-test, proof that the traditional method produced slight significant learning gains on this item, perhaps pointing to its limitations in producing huge shifts (see Figure 4.2 above). Item 2 is about identifying an object that is not a projectile amongst the list given. This was premised on the scientific definition of a projectile as "an object that is thrown or shot through the air and the only force acting on it is the gravitational force". Accordingly, it was expected that learners would choose a flying bird as a non-projectile considering it is powering its motion, hence a several forces are at play. The associated misconceptions were discussed in research question one.

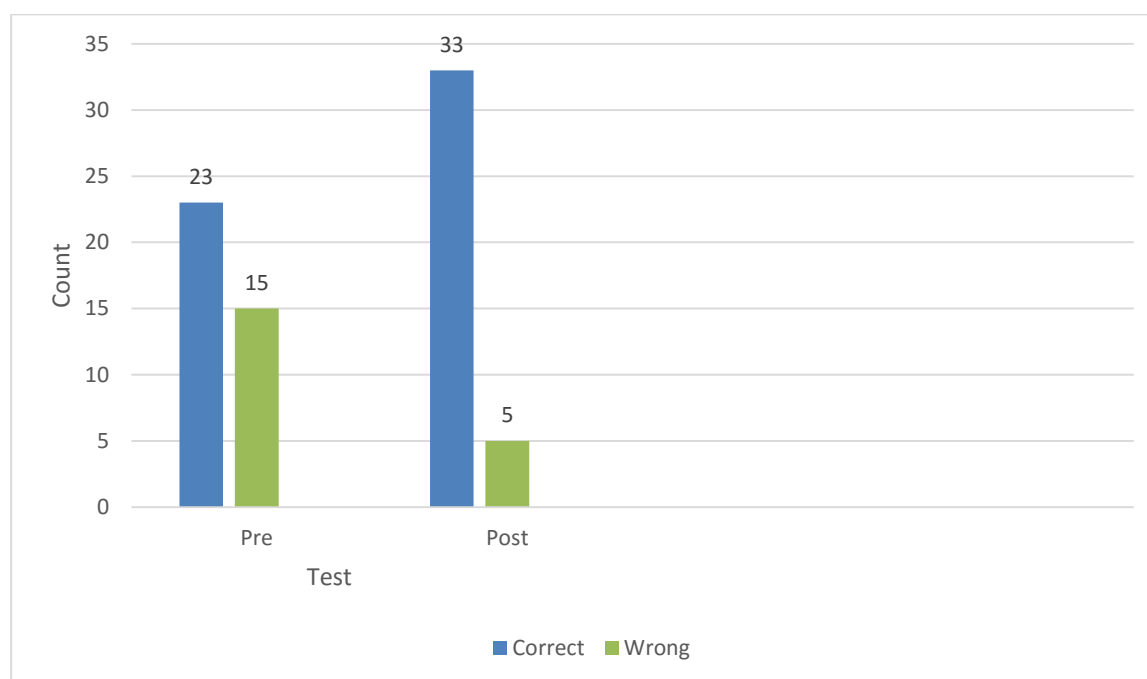# Effects of an Integrative Learning Model on Grade 12 learners' conception of vertical projectile motion.
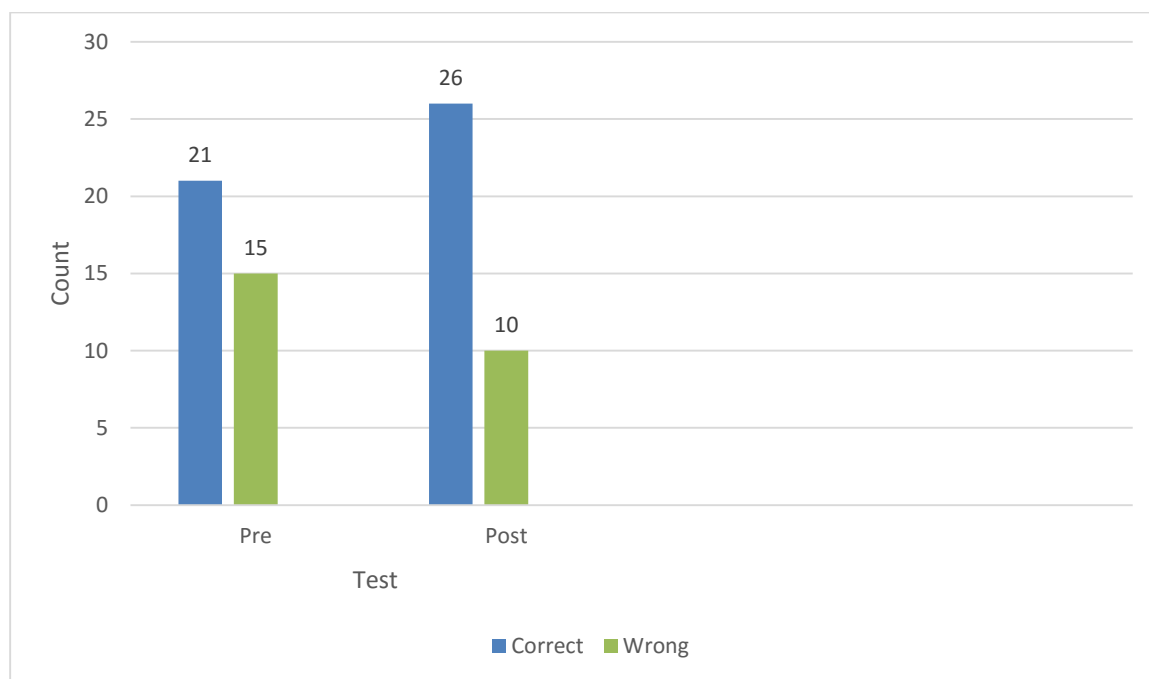
Figure 4.3 Bar chart for Item 4: pre-test vs. post-test for control group.

Equally, figure 4.3 above illustrates a slight increase from 21 to 26 learners agreeing with the scientifically accepted views in the pre-test and post-test respectively for the CG for item 4 - again clear evidence of the moderate effectiveness of traditional methods in bringing about comprehension of some scientific views.
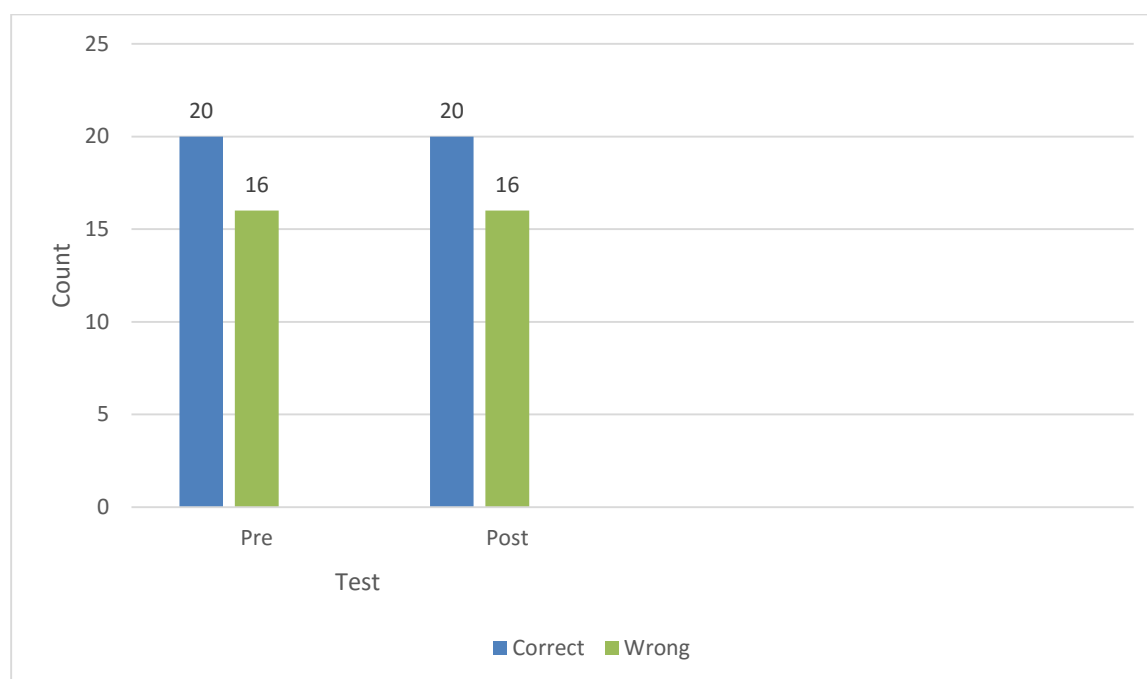
Figure 4.4 Bar chart for Item 5: pre-test vs. post-test for control group.

Nevertheless, some items resisted change in spite of teaching using traditional methods. A clear example is Item 5 which did not show a shift as illustrated by the bar graphs in Figure 4.4 above. Same number (16) of learners agreed with the science views in both the pre-test and the post-test. Equally, 20 learners who disagreed with the science views in the pre-test went on to further disagree with the same science view in the post-test, evidence of the resistant nature of some misconceptions learners have on VPM.

 That the velocity is zero and acceleration is downwards at the highest point of a projectile that is thrown vertically upwards was the most problematic concept in terms of shift towards the scientific views. It registered no shift on the control group showing clearly that the traditional methods failed to influence a shift in learners on this item, notwithstanding the fact that the same traditional method produced some learning gains in other items earlier on discussed.

In summary, the traditional method produced limited learning gains in most items. Worse still, Item 5 produced no shift or conceptual change at all, a reflection of the likely inadequacies of the traditional method in effecting conceptual change on some concepts.

4.3.2 Effects of the ILM on the experimental group (EG).

Data in Table 4.8 were used to assess the impact of the Integrative learning method on the experimental group by comparing the performance of this group in the pre- and post-tests.

Table 4.8 Comparison of pre-test vs. post-test for the EG

Item	Pre-test:Exp (n=38)		Post-test:Exp(n=38)		Chi-square
	Wrong	Correct	Wrong	Correct	
2	5	33	0	38	0.027*
3	15	23	6	32	0.019*
4	9	29	7	31	0.390
5	15	23	5	33	0.009*
6	10	28	1	37	0.003*
7	30	8	9	29	0.000*
8	17	21	4	34	0.001*
9	9	29	6	32	0.283
10	16	22	2	36	0.000*

Level of significance set at 0.05 threshold.

From significance values in Table 4.8 above, Item 4 - together with the discarded Item 9 - did not produce significant learning gains. While 29 EG learners held the science views regarding item 4 in the pre-test, this number increased by only two to 31 in the post-test. Conversely, 9 learners disagreed with the science view on this item in the pre-test, dropping by only two to seven in the post-test.

Item 4 wanted to test learners' view regarding scalar and vector quantities. Precisely, the question required learners to identify the '*time of flight*' as a scalar quantity from a list also including *velocity*, *displacement* and *acceleration* – all vector quantities.

From the Chi-values marked by an asterisk in Table 4.8 above, it can be noted that the Integrative Learning method (ILM) produced significant learning gains in all the other items. Thus major shifts were recorded in most items – a clear sign that ILM was effective in enhancing better comprehension of physics concepts. The exceptions to this, as noted above, are Items 4 and 9 which, even though, registered moderate gains. Overall the ILM was found to be effective in teaching VPM on the EG. The bar graph, presented in the next section - for Items 2, 5, 7 and 8, are further confirmation to this assertion.
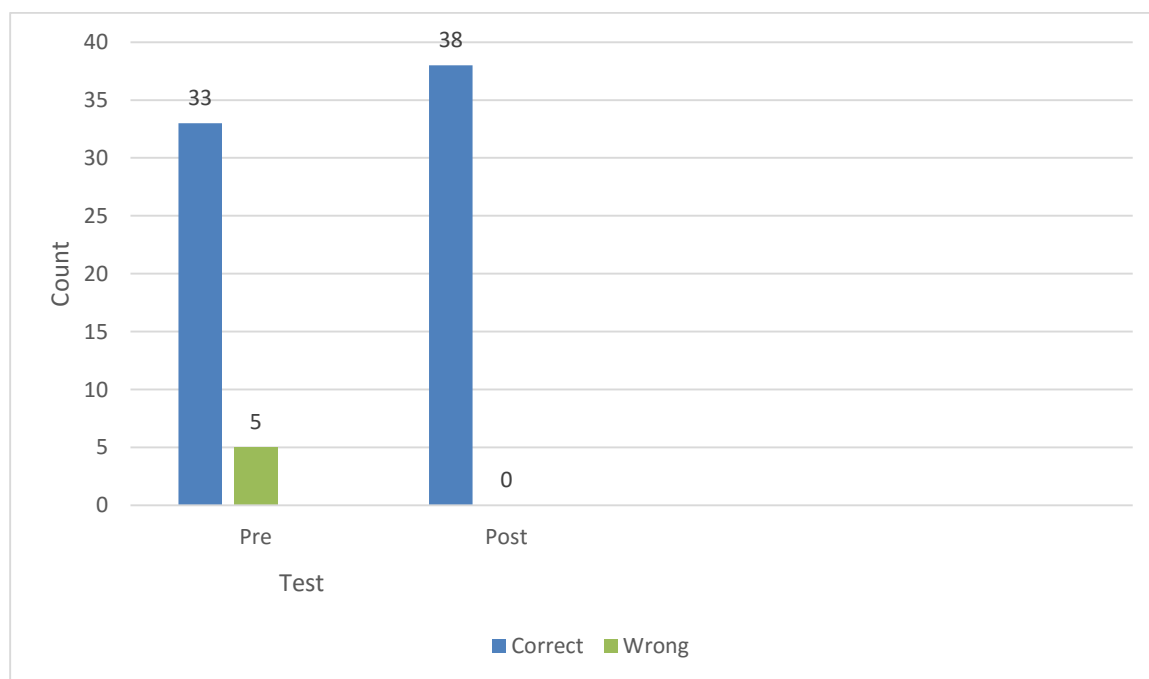
Figure 4.5 Bar chart for Item 2: pre-test vs. post-test for EG.

While 33 correct answers were registered in the pre-test for item 2, this number increased to 38 in the post-test; a sign that all the EG learners accepted the scientific view after being taught using the ILM (see Figure 4.5 above). This probably is testimony to the high impact that ILM has on the teaching of VPM concepts.

Figure 4.6 Bar chart for Item 5: pre-test vs. post-test for experimental group (EG).

Equally, for item 5, there was a significant shift in number of learners accepting the science views, jumping from 23 to 33 in the pre-test to post-test respectively (see Figure 4.6 above). This is quite interesting given that this is the same item that produced no shift at all when traditional methods were used on the CG (see Figure 4.4). This probably goes to show the effectiveness of the ILM in teaching some concepts of VPM where traditional methods were found to be ineffective. Conversely, this highlights some limitations of the traditional method in teaching some concepts.

Effects of an Integrative Learning Model on Grade 12 learners' conception of vertical projectile motion.
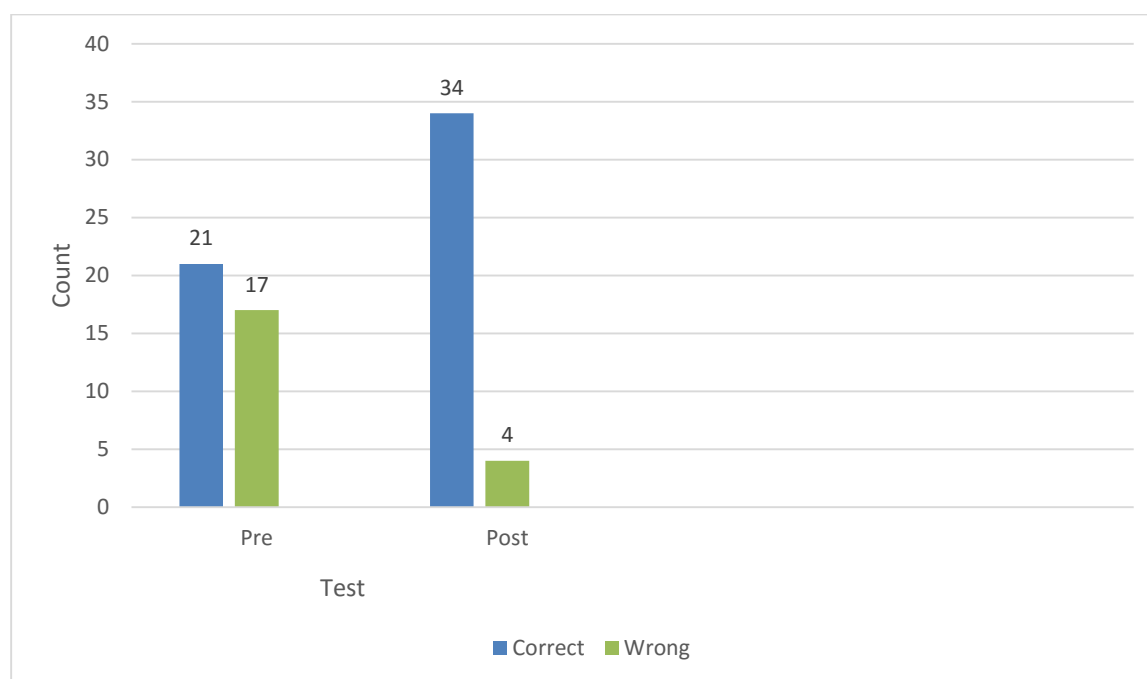
Figure 4.7 Bar chart for Item 8: pre-test vs. post-test for the experimental group (EG).

Figure 4.7 above shows 21 learners from the EG agreeing with the science view in item 8 in the pre-test, with the number increasing to 34 in the post-test. Conversely, while 17 learners disagreed with the scientific views in the pre-test, those who opposed it significantly dropped to only 4 in the post-test, evidence that ILM was effective in producing learning gains on this item (see Figure 4.7).
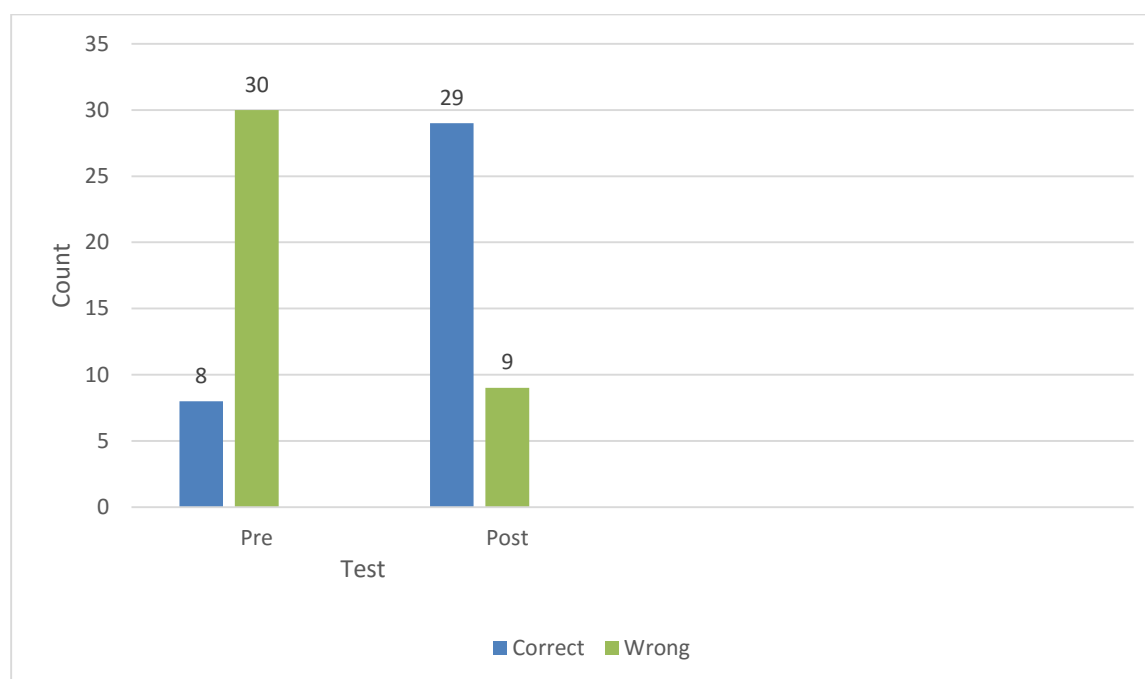
Figure 4.8 Bar chart for Item 7: pre-test vs. post-test for experimental group (EG).

Above all and quite interestingly, is item 7 whose results are represented in Figure 4.8 above, showing a huge shift – further confirmation of the effectiveness of the ILM within this experimental group in bringing about better understanding of Vertical projectile motion concepts in learners. Quite clearly, it can be seen that in the aftermath of the ILM intervention, most learners in the experimental group indeed appreciated that the magnitude of acceleration of a projectile is constant. Before administering the ILM on the experimental group, only 8 learners accepted the science views, with this number latter increasing to 29 after the intervention (see Figure 4.8 above). This large number in the post-test compared to the low number in the pre-test is attributable to the positive sway that ILM had in producing learning gains. This goes to show a major shift associated with huge learning gains brought about by the ILM on this item.

In summary; the ILM produced moderate to hugely significant learning gains in almost all items, evidence that the ILM was effective as a teaching strategy on the experimental group in the teaching of physics concepts. The exception to this was item 4, which nevertheless realized slight shifts.

4.3.3 Traditional methods vs. the ILM.

Data in Table 4.9 were used to make a comparison of the effects of the Integrative learning model against the traditional teaching method by comparing the two groups' performance in the post-test.

Table 4.9 Comparison of CG vs. EG in the post-test.

Item	Post-test: CG (n=36)		Post-test: EG (n=38)		Chi-square
	Wrong	Correct	Wrong	Correct	
2	6	30	0	38	0.011*
3	13	23	6	32	0.041*
4	10	26	7	31	0.248
5	16	20	5	33	0.003*
6	13	23	1	37	0.000*
7	18	18	9	29	0.017*
8	14	22	4	34	0.005*
9	17	19	6	32	0.004*
10	12	24	2	36	0.002*

Level of significance set at 0.05 threshold.

Item 4 produced the least level of significance as can be seen from Table 4.9. This is further confirmed by bar chart for the same item in figure 4.9 below.
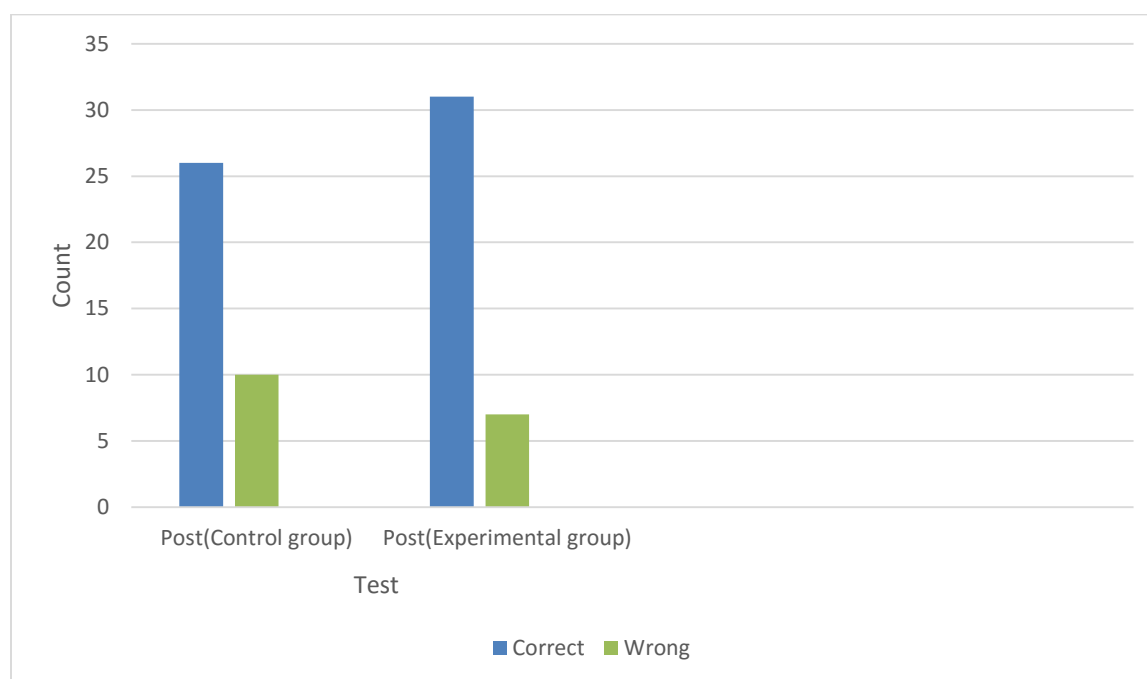
Figure 4.9 Bar chart for Item 4: Control group (CG) vs. experimental group (EG) in the post-test.

This shows that both the traditional method and the ILM produced almost similar learning gains on this item, implying neither of the two teaching methods was superior to the other by significant margins in causing conceptual change on this item (see Figure 4.9). Thus, similar proportions of learners from the two groups held the science view on item 4 in the post-test.

Item 4 was about identifying *time of flight* as a scalar quantity, a concept covered in grade 11. It was therefore not surprising that both groups were able to identify a scalar quantity in both the pre-test and post-test, in the process showing no major inter-group shifts in the two tests. Thus, both the traditional method and the ILM produced almost similar learning gains on item 4, illustrated using the bar chart in figure 4.9 above.

However, from the same Table 4.9 above, it can be seen from the Chi-square values that there were significant differences between the control and experimental groups' performances in the rest of the items in the post-test, showing differences in learning gains by the two groups as a result of different teaching strategies employed on the two groups. The ILM proved to be superior to the traditional methods. This was noticeable for all items except item 4 discussed above.

This further confirms that the ILM was more effective as a method of intervention than the traditional method in helping learners understand physics concepts save for Item 4 which showed little, if any, significant differences between the two groups.

I now use the following three bar charts to show significant differences between the two groups.
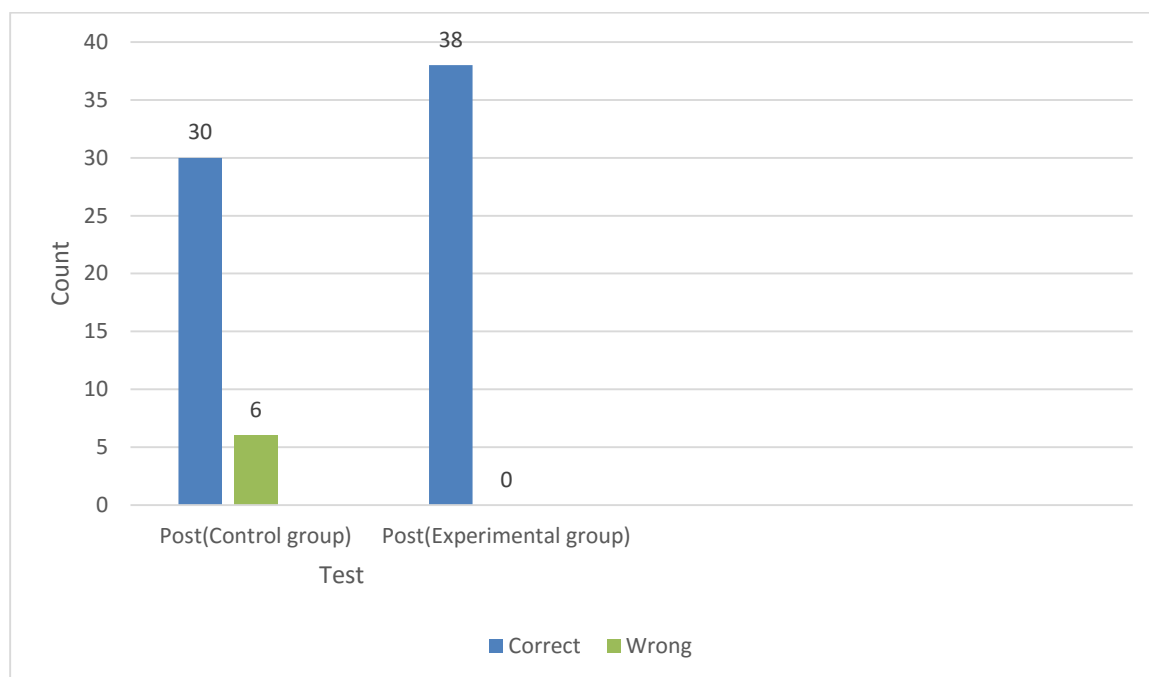
Figure 4.10 Bar chart for Item 2: CG vs. EG in the post-test.

From figure 4.10 above, it can be seen that all the 38 learners in the EG in the post-test agreed with the scientifically accepted view for item 2. On the other hand, 30 learners in the CG accepted the scientific view in item 2 in the post-test, which is a significant difference.
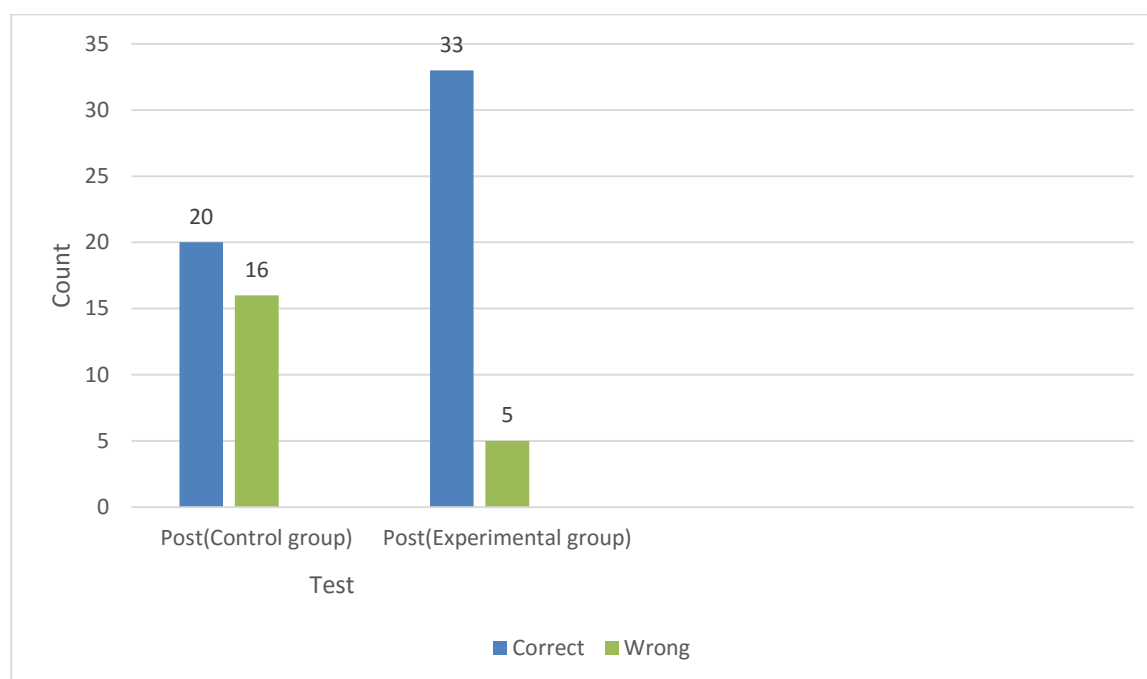
Figure 4.11 Bar chart for Item 5: Control group (CG) vs. experimental group (EG) in the post-test.

Equally, for Item 5 there was a significant difference between the two groups in terms of the number of learners accepting the science view in the post-test, with the EG having 33 while the CG has 20 learners agreeing with the science view (see Figure 4.11 above). Again, the ILM shows that it is more effective than the traditional method as a teaching method, judging by the significance levels pointing to more learners in the EG accepting the scientific views than in the CG which is clearly shown in Figure 4.11 above.
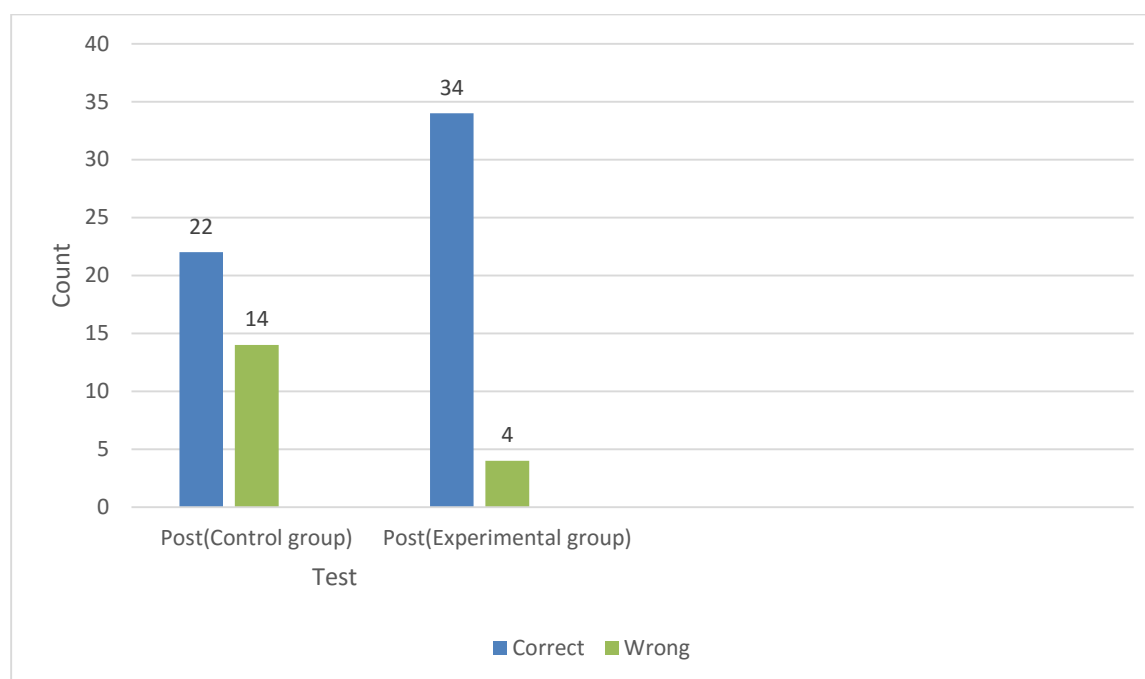
Figure 4.12 Bar chart for Item 8: CG vs. EG in the post-test.

From Figure 4.12 above, it can be seen that 22 learners from the CG agreed with the scientific views in item 8 in the post-test compared with 37 from the EG, clearly confirming that the ILM produced more learning gains compared with the traditional method on this item.

In summary, the ILM was more effective as a teaching intervention strategy in bringing about better understanding of physics concepts than the traditional method, assuming as we did, that before instruction the two groups were comparable in so far as their views were considered. The assumption is even tighter considering those items that gave large discrepancies in the pre-test were excluded from further discussion.

4.3.4 Chapter summary

In this chapter, data were presented, discussed and analyzed as guided by the two research questions. In research question one, common pre-conceived ideas between the two groups in the study on Vertical projectile motion including misconceptions were identified. These were found to be similar to the Impetus theory and other pre-Newtonian mechanics ideas outlined in chapter two, further sanctioning the role of physical experiences in shaping learners' beliefs.

As for research question two requiring a comparing the effectiveness of teaching methods, the ILM was found to be more effective in the teaching of most concepts on the experimental group than the traditional method that was used on the control group. The Chi-square values as well as bar graphs were used to confirm the conclusions arrived at. The level of significance for the Chi-values was set at 0.05 using the cross tabs methods.

The quantitative analysis was further supported with qualitative data gleaned from focus group interviews as well as open-ended questions. These further confirm the effectiveness of the ILM in the teaching and learning of physics concepts.

The next chapter provides a summary of the main findings. It ends with an outline of the conclusions, implications and recommendations.

Effects of an Integrative Learning Model on Grade 12 learners'
conception of vertical projectile motion.

CHAPTER 5 CONCLUSION

5.1 Introduction

The primary purpose of this study was to assess the effectiveness, or otherwise, of an inquiry-based method; the Integrative learning method (ILM), anchored on learners' alternative frameworks and misconceptions, in the teaching and learning of Vertical projectile motion with a view that if found to be effective, the method could be extended to other topics in Physical Sciences.

Put in other words, the anticipation was, if the instructional method was found to be effective, it would potentially arouse learners' interest, leading to improvements in learner performance in Physical Sciences. Perhaps more and more learners will pursue careers in Engineering, Technical, Health and other science related professions that are currently marred by shortages in personnel - a motivation for carrying out current study.

Following the detailed results presented in Chapter four, in this Chapter, a summary of the main findings of the study is given with a view to drawing conclusions as well as outlining implications and recommendations to teachers, curriculum advisers, policymakers and other relevant stakeholders.

5.2 Main findings

True to assertions explicated by social constructivists; the findings confirm that learners do not come to science classes empty-handed. Rather, learners bring to class prior-conceived knowledge about VPM, confirming that they indeed have multiple worldviews about phenomena in science classes. As was the expectation, some of learners' prior knowledge was not compatible with scientifically accepted views as portrayed from responses in the pre-post test, possibly making it difficult for learners' headway towards congruency and subsequent acceptance of school science, if not properly handled. In fact, most of the misconceptions identified in this study resembled pre-Newtonian mechanics ideas as discussed in chapter two.

Furthermore, from the quantitative analysis using cross tabs, the ILM was found to be more effective in the teaching of some physics concepts when compared with the traditional method, and was therefore extended to the control group as a post-research follow-up.

The effectiveness of the ILM was further confirmed by qualitative analysis of data gathered from focus group interviews as well as open-ended questions.

I now summarize the findings outlined and discussed in chapter four, guided by the two research questions.

5.2.1 Research question one: How do learners' ideas on VPM compare with scientifically accepted views?

Learners from the two groups were found, largely, to be in possession of common pre-conceived ideas on VPM, some of which were in line with scientific views. While some learners' pre-conceived ideas agreed with the scientifically accepted views, the study confirms that most of their ideas are in fact common misconceptions.

 The following is a summary of common misconceptions and alternative conceptions as well as errors and lack of skills learners exhibited in the study (see section 4.2.1):

- Failure to show understanding of VPM terms: projectile, free-fall, gravitational field and acceleration due to gravity.
- Failure to accept that acceleration due to gravity is a constant value, always acting downwards, assuming air resistance is negligible.
- Mistaking acceleration due to gravity with velocity of a projectile.
- Failure to accept that velocity is zero at the highest point of a projectile thrown vertically upwards.
- Failure to make a distinction between vector and scalar quantities, for instance displacement versus distance.
- Lack of mathematical skills like substitution, change of subject of formula and calculating gradient of a straight line.
- Failure to plot and interpret graphs depicting motion.

The above summary mirrors misconceptions, errors and deficiencies that are extensively reported in NSC diagnostic reports and these also resemble pre-Newtonian mechanics ideas.

That some misconceptions are resistant to change is evident in the post-test in much the same way it is reported in the extant literature as outlined in chapters one and two. For instance, learners continued to confuse acceleration with velocity in the post-test, believing that an object that is slowing down (decelerating) is not accelerating. This probably made it difficult for learners to accept that acceleration of an object thrown upwards is constant.

This probably calls for a well-thought out intervention strategy to align these mini-theories with scientifically accepted views, much in line with the objectives of this study as outlined in Chapter one. Teachers' knowledge of the different worldviews at play: IKS, common sense, intuitive ideas and school science in interpreting physics concepts is therefore paramount in designing and delivering lessons as well as in assessing learners' work.

5.2.2 Research question two: How effective is the Integrated Learning Model in bringing about better conception of projectile motion by learners?

The ILM was found to be effective in the teaching of most concepts on VPM on the EG. Thus, all items produced moderate to huge shifts as judged by the performance of learners in the EG in the pre-post tests. On the other hand, the traditional method also produced some gains on CG although these were not as significant as the shifts brought about by the ILM on the EG. Even so, the traditional methods failed to effect shifts on item 5 on the CG while the ILM produced significant learning gains on the EG on the same item. This shows that the ILM was hugely a success in the teaching of Vertical projectile motion.

While the ILM was generally found to be effective on the EG in this study, a lot of research must be done extending to other schools and provinces so that a large enough sample is covered.

5.3 Limitations

The current study had contextual limitations. Firstly, the study was conducted towards the end of third term when learners and teachers were preparing for the preparatory examinations. At that time of the year teachers were worried more about completing the syllabus as well as revising different sections of physical sciences more than in engaging in the study. From this research I picked up that the best time to conduct research is probably during the first and second terms of the school calendar.

Secondly, we cannot completely ignore and rule out the impact of different attributes of the teachers concerned in the intervention strategies in influencing the study, notwithstanding the fact that both teachers had more or else comparable experience as well as degree qualifications in education.

Last, but by far the most important factor is the issue of language which Vygotsky (1978) asserts as being the medium through which cultural heritage is transmitted. Yet for all the centrality of language as a cultural tool in science learning, it can, nevertheless, pose as barrier to learning to the extent that some participants might have failed to express themselves in explaining their choices, resulting in what Driver and Oldham (1986) refer to as children's imprecise use of language.

In addition to the contextual factors above, the instruments used in this study had limitations. The pre-post test had some questions that were not answered by some learners. Learners preferred the multiple choice questions more than open-ended questions.

5.4 Implication of the findings

In this study, learners in both groups were found to be in possession of common pre-instructional ideas about VPM, which any teacher must consider in designing a teaching programme, especially considering some of the learners' ideas were found to be resistant to change in this study. The ILM is a starting point in enhancing better comprehension of VPM since it has been found to be beneficial.

This is because, to the teacher, the ILM presents a good platform for teachers to (1) elicit for learners' pre-conceived ideas on VPM and (2) to use the pre-conceived ideas to plan an instruction modeled along the ILM – found to be beneficial in this study.

5.5 Conclusions

The ILM employed in this study proved more beneficial than the traditional method in learners' comprehension of physics concepts. However, the ILM was found to be time consuming considering practicing teachers are more worried with syllabus completion than in the conceptual understanding of concepts by learners.

5.6 Recommendations

Teachers must be trained on how to actively engage learners in science lessons so that learners can effectively make arguments in sense-making. In addition, learners must be explicitly taught how to make claims, warrants, data, backings, qualifiers and rebuttals since it is the foundation upon which the intervention strategy proposed herein is anchored. Thus, learners will be in a better position to accept scientifically accepted views considering the resistant nature of some misconceptions.

The ILM proposed in this study may be extended to other science topics. Since the research was carried out in one school, it would be interesting to see the results that could be obtained if this research could be extended to other schools, districts and provinces. Hopefully, a larger sample could provide interesting results that are generalizable. Equally and potentially interesting would be extending the same study to different racial groups to see if different learners from different racial and social backgrounds hold the same prior-instructional knowledge about Vertical projectile motion.

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Effects of an Integrative Learning Model on Grade 12 learners' conception of vertical projectile motion.

APPENDIX A

Projectile motion pre-post test

`Name:	Code:

Instructions and information.

1. The test consists of 3 sections. Answer all questions on spaces provided.

2. Use g =9.8 ms^{-2}.

3. In all questions, **ignore** the effects of air friction/resistance.

Section A: Projectile motion terms

Question 1 Projectile, *Free fall, Gravitational field and Acceleration due to gravity (g)* are important terms in the study of Projectile Motion. Match the terms in column X with the correct description of their definitions in column Y.

Column X: Terms	Column Y: Definitions
1.1 Projectile	A. The acceleration of a falling object as a result of the attractive gravitational force of the earth, in the absence of other forces such as air resistance.
1.2 Free fall	B. This is the space around an object of mass (e.g. the earth) in which another mass experiences a gravitational force.
1.3 Gravitational field	C.Is an object that is thrown or shot through the air and the only force acting on it is gravitational force.
1.4 Acceleration due to gravity(g)	D. The unhindered movement of an object in the gravitational field of the earth, when only the gravitational force is acting on it.

Write your answers (**only** the letter A, B, C or D in column Y) in the table provided below:

Column X: Terms	Column Y: Definitions
1.1	
1.2	
1.3	
1.4	

Section B: Multiple choice questions

For questions 2 up to 15, **circle** the letter of the correct answer from the possible answers given. In each case explain your answer.

Question 2

Which of the following is not a projectile?

    A. A rock thrown upwards.

    B. A ball kicked into the air by a player.

    C. A flying bird.

    D. A bullet from a gun.

Explain your answer:

_____

_____

_____

Question 3

An object is projected upwards. Which of the following is true regarding its *acceleration*?

    A. It has a constant acceleration of 9.8 ms^{-2} upwards.

    B. It has a constant acceleration of 9.8ms^{-2} downwards.

    C. The object's acceleration is zero at the highest point.

    D. The object's acceleration decreases as it moves upwards.

Explain your answer:

_____

_____

_____

Question 4

Acceleration, velocity, time taken and displacement are terms commonly used to describe an object's projectile motion. Which of these terms is a scalar quantity?

   A. Velocity.

   B. Displacement.

   C. Time of flight.

   D. Acceleration.

Explain your answer:

_____

_____

_____

Question 5

An object is thrown vertically upwards. Which ONE of the following regarding the object's velocity and acceleration at the highest point of its motion is correct?

	Velocity	Acceleration
A	Zero	Zero
B	Zero	Upwards
C	Maximum	Zero
D	Zero	Downwards

Explain your answer:

_____

_____

Question 6

Choose the most appropriate words to fill in the space below:

The time taken by an object to reach its highest point is ----- the time that it takes to fall from its highest point back down to where it started.

    A. Less than.

    B. More than.

    C. The same as

    D. Different from.

Explain your answer:

_____

_____

Question 7

A ball is thrown vertically upwards with an initial speed of 20ms^{-1}. At what point is the **magnitude** of the acceleration at a minimum?

    A. Just after leaving the thrower's hand.

    B. At the top of the trajectory.

    C. On its way down.

    D. Acceleration is constant during entire trajectory.

Explain your answer:

_____

_____

Question 8

When an object that was thrown upward reaches its highest point, which statement is true?

    A. The acceleration switches from positive to negative.

    B. The acceleration is zero.

    C. The total displacement is zero.

D. The velocity is zero.

Explain your answer:

_____

_____

Question 9

An object is thrown vertically upwards with an initial speed of 19.6 ms^{-1}. The object latter returns to the thrower's hand after some time. Which of the following is true regarding the object's net displacement? Take the thrower's hand as the point of reference.

A. 19,6m

B. -19,6m

C. 9.81m

D. 0

Explain your answer:

_____

_____

Question 10.

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

E. About half as long for the heavier ball.

F. About half as long for the lighter ball.

G. About the same time for both balls.

H. Considerably less for the heavier ball, but not necessarily half as long.

Explain your answer:

_____

_____

_____

Question 11

A jetfighter travelling due west drops a bomb. In the picture below, draw a line that best describes the path of the bomb as it drops to the ground?

Ground_____

Provide a reason:

_____

_____

Section C: Structured questions

Question 12

Draw a free body diagram for an object in freefall.

Question 13

Paratroopers jump out of planes, latter using parachutes to land safely on the target ground. In your opinion, explain why paratroopers jump off a plane before reaching target area.

Explanation:

_____

_____

_____

Question 14

Consider the following velocity-time graph.

Velocity-Time graph
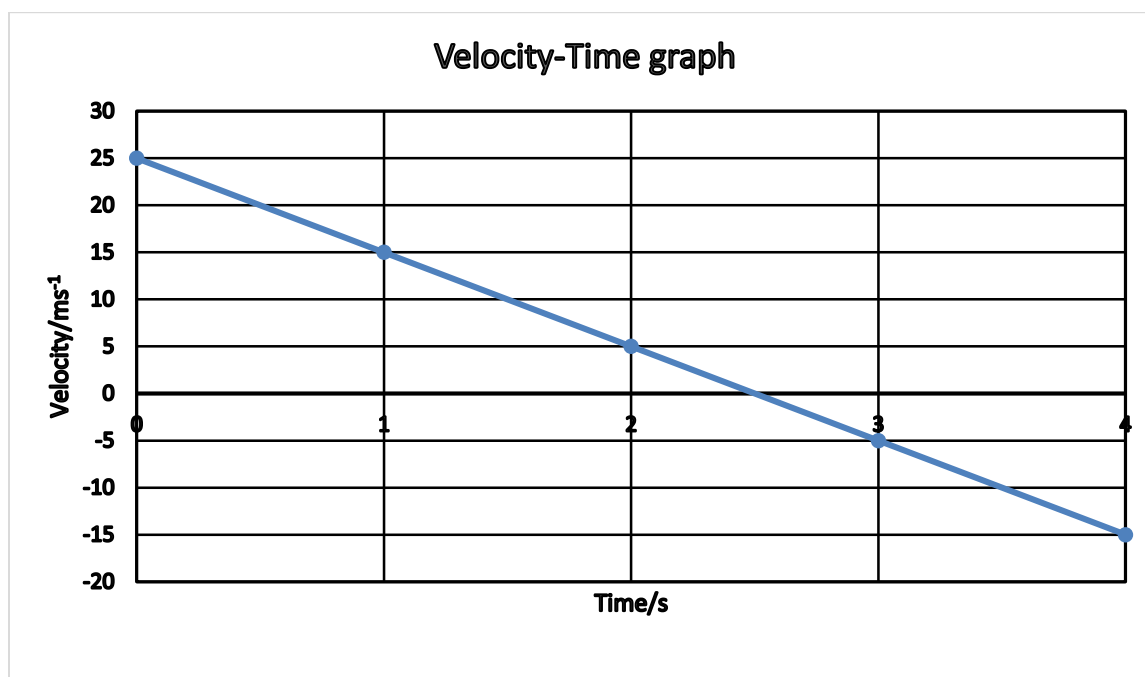
14.1 Write down the initial velocity of the object?

_____

14.2 How long does the object take to reach its maximum height?

_____ _____

_____

_____

14.3 At what time(s) is the velocity of the object 10 ms^{-1}?

_____

_____

14.4 Calculate the acceleration of the object.

14.5 Determine the position of the object relative to the ground (original position) at t=2s and at t=4s.

_____

_____

_____

14.6 Taking the initial position as a reference point; draw a position-time graph for the motion of the ball during the first 4s.

Question 15

A hot air balloon travels upwards at a constant velocity. At a height of 80m above the ground, someone drops his cellphone from the balloon. It hits the ground after 5 seconds.

15.1 Calculate the velocity at which the balloon travels upwards.

_____

_____

_____

15.2 Calculate the maximum height above the ground reached by the cell phone.

_____

_____

15.3 How long after the cell phone falls, does it pass the point from where it started to fall?

_____

_____

_____

15.4 How long after the cell phone has been dropped does the distance between the balloon and the cell phone equal 20m?

APPENDIX B: WITS CLERANCE LETTER

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa.

Tel:

+27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website:

www.wits.ac.za

18 July 2016

Student Number: 1126692

Protocol Number: 2016ECE037M

Dear Henry Chinorumba

Application for Ethics Clearance: Master of Science

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty

Of Humanities, acting on behalf of the Senate has considered your application for ethics clearance

for your proposal entitled:

Effects of an Integrative Learning model on Grade 12 learners' conception of projectile motion

The committee recently met and I am pleased to inform you that **clearance was granted**. However,

there were a few small issues which the committee would appreciate you attending to before embarking on your research.

The following comments were made:

☐☐Remove the data collection methods not applicable to this study from the consents forms (teachers in particular).

Effects of an Integrative Learning Model on Grade 12 learners' conception of vertical projectile motion.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

Wits School of Education

011 717-3416

Cc Supervisor: Dr. Emmanuel Mushayikwa

APPENDIX C

| GRADE | 12 | SUBJECT | Physical Sciences | WEEK | TOPIC | Vertical Projectiles | Lesson | 1 |

LESSON SUMMARY FOR: DATE STARTED: | DATE COMPLETED:

LESSON OBJECTIVES

At the end of this lesson learners should know
- The meaning of projectile motion

The following results will be the outcome of this lesson
- Learners must be able to explain that projectiles
  - fall freely with gravitational acceleration "g"
  - accelerate downwards with a constant acceleration whether the projectile is moving upward or downward.
  - have zero velocity at their greatest height
  - take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. This is known as time symmetry.
  - can have their own motion described by a single set of equations

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TEACHER ACTIVITIES	LEARNER ACTIVITIES	TIMING	RESOURCES NEEDED
1. TEACHING METHOD USED IN THIS LESSON • Question and answer, Explanation **2. LESSON DEVELOPMENT** **2.1 Introduction** • Lesson starts with the educator asking the learners the baseline questions. Baseline questions • Define and give the unit for the following ▪ Distance ▪ Displacement ▪ Speed ▪ Velocity ▪ Acceleration • Educator and learners discuss the following answers to the baseline questions ▪ Distance is the actual path length covered. **Unit:** m ▪ Displacement is defined as the shortest, straight line distance from start to finish. **Unit:** m and direction ▪ Speed is defined as a rate of change in distance. **Unit:** $m \cdot s^{-1}$ ▪ Velocity is defined as the rate of change in displacement. **Unit:** $m \cdot s^{-1}$ and	1. Learners answer the baseline questions. 2. Learners take notes from the board. 3. Learners do classwork **CLASSWORK** One word/term items 1. The force that acts on a body in free fall. 2. Motion of an object near the surface of the earth under the influence of the earth's gravitational force alone. Multiple Choice 3. Which of the following is a correct statement? Gravitational force is	15 min 30 min 10 min	Chalkboard

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Effects of an Integrative Learning Model on Grade 12 learners' conception of vertical projectile motion.

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SOLUTIONS
1. Gravitational force
2. Free fall
3. C
4. B
5.
5.1 Initially the stone has a velocity of 24 m•s⁻¹ upwards. Throughout the motion it experiences a constant downward acceleration of 9,8m•s⁻². its velocity decreases to zero at the turning point. There its direction of motion changes and the velocity increases while moving downwards.

5.2 4s
5.3 0 m•s⁻¹
5.4 9,8 m•s⁻²

Reflection/Notes:

HOD:

Sign:

Date:

Name of Teacher:

Sign:

Date:

direction

- Acceleration is defined as the rate of change in velocity. **Unit:** m•s⁻² and direction

2.2 Main Body (Lesson presentation)

Educator discuss and explain the following to the learners:

Vertical Projectile Motion

- Vertical projectile motion deals with <u>objects that get thrown upwards and and then and then go down.</u>

- An object is in free fall when the only force acting on the object is the gravitational force of the earth pulling it downwards.

- The acceleration of this object due to gravity is called **gravitational acceleration, g, and is equal to 9,8 m•s⁻²** on earth.

- An object projected vertically upwards
  - Consider an object that is thrown vertically upwards.
  - As it gets higher and higher, it slows down until it stops momentarily at its highest point.
  - It has an initial velocity, vᵢ, with which it was projected i.e. vᵢ is not 0 m•s⁻¹
  - The acceleration is 9,8 m•s⁻² downwards.
  - At the highest point the object stops and therefore its final velocity v₁ = 0 m•s⁻¹, but the acceleration is still 9,8 m•s⁻² down.
  - The object's speed decreases as it moves up and increases as it moves down.
  - The time taken for an object to reach its maximum height is the same as the time it takes to come back.

2.3 Conclusion

- Give learners classwork.

A. applicable only in our solar system

B. both an attractive and repulsive force

C. directly proportional to the product of the masses involved.

D. Directly proportional to both the masses and the radius of the earth.

4. A golf ball is hit vertically upwards. What is the acceleration of the ball at the highest point? Ignore the effects of friction.

   A. 9,8 m•s⁻² upwards
   B. 9,8 m•s⁻² downwards
   C. 0 m•s⁻²
   D. 9,8 m•s⁻¹ downwards

Long question

5. A stone is thrown vertically upwards at an initial velocity of 24 m•s⁻¹. It reaches its maximum height after 2s.

5.1 Describe the motion of the stone in terms of velocity and acceleration.

5.2 How long from the time it is thrown upward, will it take to come back into the thrower's hand?

5.3 What is the velocity of the stone at the turning point?

5.4 What is the acceleration of the stone at the turning point?

- Distance: **scalar.** Symbol: d
- Displacement: **vector.** Symbol: Δx-horizontal or Δy-vertical
- Speed: **scalar.** Symbol: v
- Vector: **vector.** Symbol: v
- Acceleration: **vector.** Symbol: a

Acceleration

- At any point during the motion the acceleration of the object is equal to the gravitational acceleration, g.
  - g is equal to 9,8 m•s⁻² downwards.
  - g is independent of the mass of an object.
- Use equations of motion
  - $v_f = v_i + g\Delta t$
  - $\Delta y = v_i\Delta t + \frac{1}{2}g\Delta t^2$
  - $v_f{}^2 = v_i{}^2 + 2g\Delta y$
  - $\Delta y = \frac{(v_i + v_f)\Delta t}{2}$

- Tips to help you use the equations of motion for the projectile motion
  - Choose a direction as positive or negative for example make upward positive.
  - Write down the values of the known v_f; v_i; g; Δy and Δt
  - If an object is released or dropped by a person that is moving up or down at a certain velocity the initial velocity of an object equals the velocity of that person.
  - Identify which formula to use.
  - Substitute into the equation.
  - Interpret the answer.
- Apply your knowledge

A bullet is fired vertically upwards with a velocity of 200 m•s⁻¹ to reach its maximum height. Ignore the effects of air resistance and calculate

a) the maximum height reached

Take up as positive

v_i = + 200m•s⁻¹

v_f = 0 m•s⁻¹

g = - 9,8 m•s⁻²

Δy = ?

$v_f{}^2 = v_i{}^2 + 2g\Delta y$

$0^2 = (200)^2 + 2(-9,8)\Delta y$

Δy = 2040, 82m

b) at what height it will be moving at 100 m•s⁻¹ upwards?

---

of the school building. He projects a stone vertically upward so that it reaches the top of a building. The stone leaves a learner's hand at a height of 1,25m above the ground, and he catches the stone again at a height of 1,25m above the ground. He finds the total time the stone is in the air is 2s. Calculate the height of the school building if air resistance is ignored.

SOLUTIONS

1. Take up as positive

a) $v_f = v_i + g\Delta t$

0 = v_i + (-9,8)(2)

v_i = 19,6 m•s⁻¹ up

b) $\Delta y = v_i\Delta t + \frac{1}{2}g\Delta t^2$

= 19,6 (2) + ½ (-9,8)(2)²

= 19,6 m up

c) $v_f = v_i + g\Delta t$

= 0 + (-9,8)(2)

= 19,6 m•s⁻¹ down

2.
Take the upward motion as positive

$v_f = v_i + g\Delta t$

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| GRADE | 12 | SUBJECT | Physical Sciences | WEEK | | TOPIC | Vertical Projectiles | Lesson | 2 |

LESSON SUMMARY FOR: DATE STARTED:

DATE COMPLETED:

LESSON OBJECTIVES

At the end of this lesson learners should know
- That the gravitational acceleration is a constant.
- That the velocity of an object is 0 m·s⁻¹ at the maximum height.

The following results will be the outcome of this lesson
- Learners must be able to do calculations, using equations of motion for projectile motion:
  - greatest height reached, given the velocity with which the projectile is launched upward (initial velocity)
  - time at which a projectile is at a particular height, given its initial velocity
  - height relative to the ground of the position of a projectile shot vertically upward at launch, given the time for the projectile to reach for the ground

TEACHER ACTIVITIES	LEARNER ACTIVITIES	TIMING	RESOURCES NEEDED

1. TEACHING METHOD USED IN THIS LESSON
• Question and answer, Explanation
 	
2. LESSON DEVELOPMENT
2.1 Introduction
• Lesson starts with the educator asking the learners the baseline questions.
Baseline questions
• What is the initial velocity of an object falling from rest?
• What is its acceleration?
• An object is thrown upwards and returns to the thrower's hand in 6s. How long did it take for the object to reach its maximum height? What is the velocity of the object at the maximum height?
• Educator and learners discuss the following answers to the baseline questions
  ▪ 0 m·s⁻¹
  ▪ 9,8 m·s⁻² down
  ▪ 3 s; 0 m·s⁻¹
 	
2.2 Main Body (Lesson presentation)
Educator discusses and explains the following to the learners:
Equations of motion
• Projectiles can have their own motion described by a single set of equations for the upward and downward motion.
	1. Learners answer the baseline questions.
	2. Learners take notes from the board.
	3. Learners write the classwork
	
	CLASSWORK
	1. A ball is thrown vertically upwards and returns to the thrower's hand 4 s later. Calculate
	a) the velocity with which the ball left the thrower's hand.
	b) the height reached by the ball.
	c) the velocity the ball returned to the thrower's hand.
	2. A grade 12 learner wants to determine the height
		10 min
		
		25 min
		
		25 min
			Chalkboard

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Take up as positive

$v_i = 200 \text{ m} \cdot \text{s}^{-1}$

$v_f = 100 \text{ m} \cdot \text{s}^{-1}$

$g = 9,8 \text{ m} \cdot \text{s}^{-2}$

$\Delta y = ?$

$v_f{}^2 = v_i{}^2 + 2g\Delta y$

$(100)^2 = (200)^2 + 2(-9,8)\Delta y$

$\Delta y = 1530,61\text{m}$

2.3 Conclusion

- Give learners classwork

	$0 = v_f + (-9,8)(1)$
	$v_f = 9,8 \text{ m} \cdot \text{s}^{-1}$ upward
	$\Delta y = v_i \Delta t + \frac{1}{2} g \Delta t^2$
	$= (9,8)(1) + \frac{1}{2}(-9,8)(1)^2$
	$= 4,9 \text{ m}$
	Therefore total height $= 4,9 + 1,25$
	$= 6,15 \text{ m}$

Reflection/Notes:

Name of Teacher:		HOD:
Sign:		Sign:
Date:		Date:

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| GRADE | 12 | SUBJECT | Physical Sciences | WEEK | | TOPIC | Vertical Projectiles | Lesson | 3 |

LESSON SUMMARY FOR: DATE STARTED: **DATE COMPLETED:**

LESSON OBJECTIVES

At the end of this lesson learners should know
- The meaning of projectile motion

The following results will be the outcome of this lesson
- Learners must be able to explain that projectiles
  - fall freely with gravitational acceleration "g"
  - accelerate downwards with a constant acceleration whether the projectile is moving upward or downward.
  - have zero velocity at their greatest height
  - take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch.
  - can have their own motion described by a single set of equations

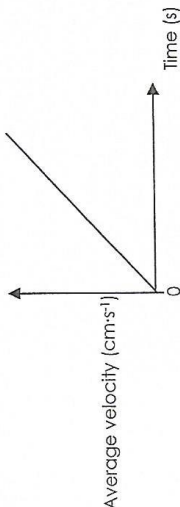| TEACHER ACTIVITIES	LEARNER ACTIVITIES	TIMING	RESOURCES NEEDED
TEACHING METHOD USED IN THIS LESSON • Question and answer, Explanation **LESSON DEVELOPMENT** .1 Introduction re-knowledge • Vertical projectile motion .2 Main Body (Lesson presentation) Practical Task- Vertical motion **Aim: To investigate the motion of a falling body.** Method Before starting the experiment, determine what the frequency is of the ticker timer, using the equation: $T = \dfrac{1}{f}$ Once you have determined the period of the ticker timer, calculate what the time would be between 5 consecutive dots. 1. Clamp the ticker timer in a vertical position as high as possible facing downward, such as on top of a door.	1. Learners perform the experiment. 2. Learners write and submit the experimental write-up.	.	Ticker timer; Mass piece; Ticker tape; Clamp; Prestik

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2. Cut off a length of ticker tape slightly longer than the distance from timer to floor.

3. Thread the end of a ticker tape through the timer.

4. Attach the ½ kg mass piece to the lower end of the tape using Prestik.

5. To reduce friction between the tape and the ticker timer, a learner can stand on a table and hold the tape up to allow it to run smoothly through the ticker timer.

6. Switch on the timer then allow the weight to fall freely to the ground.

7. Switch off the ticker timer and remove the tape.

8. Once the ticker timer has been switched off, detach the ticker tape from the trolley and ticker timer.

9. Ignore the first section of the ticker tape where all dots are very close to one another.

10. Find a point on the ticker tape at which to start measuring and draw a line through the dot.

11. Then draw a line through every 5th dot thereafter, numbering the segments until you have about 8 -10 segments.

Suggested questions

1. Calculate the average velocity for each segment by measuring the displacement for each segment and using the equation $v = \dfrac{\Delta x}{\Delta t}$.

2. Plot a velocity-time graph using the calculated velocity values.

3. Draw a smooth line of best fit through the top point of each segment. Describe in words what the graph tells us about the motion of the mass piece.

4. Calculate the gradient of the graph. What does the gradient of the graph represent?

5. Calculate your percentage error for your calculations in which you calculated the acceleration due to gravity.

6. Give a conclusion based on the results.

7. Reflect on the practical procedure and suggest possible reasons for inaccuracy in your results.

Suggested answers

1. Learners will need to do separate calculations to calculate the average velocity for each segment and will then fill these calculated values on the y-axis.

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2. The graph drawn should look like the one below:

Average velocity (cm·s⁻¹)

Time (s)

Mark the following when checking the graph:

- Heading
- Axes labelled and contain units
- Consistent scale is used on both axes
- Origin is indicated on the graph
- Line of best fit is drawn.

3. Calculate gradient using any 2 points on the graph. Answer will be in cm·s⁻².

4. The learner will be required to convert the answer from question 3 above to m·s-2 before doing a percentage error calculation. This is done by dividing the answer in question 3 by 100. A percentage error can then be calculated using the formula:

$$\% \; error \; \frac{difference \, between \, answer \, from \, Q3 \, and \, 9,8}{9,8} \times 100$$

5. Conclusion: The object is accelerating uniformly, as the graph of average velocity-time is a straight line through the origin.

6. Possible reasons for inaccuracy:
   - Friction on the ticker tape
   - Measuring distances incorrectly on the ticker tape
   - Frequency of the ticker timer is not exactly the frequency given
   - If the ticker time runs off batteries, the batteries could be flat.

[Solutions for all – Physical Sciences]

2.3 Conclusion

- Tell learners you require a full experimental write-up from them. Revise what this means.
- Get the learners to perform the experiment and complete a full experimental write-up

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which must be handed in for marking.

Reflection/Notes:

Name of Teacher:		HOD:	
Sign:		Sign:	
Date:		Date:	

APPENDIX D
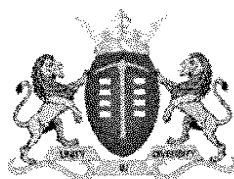
GAUTENG PROVINCE

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REPUBLIC OF SOUTH AFRICA

GDE RESEARCH APPROVAL LETTER

Date:	22 June 2016
Validity of Research Approval:	22 June 2016 to 30 September 2016
Name of Researcher:	Chinorumba H.
Address of Researcher:	77 Westside Complex; 34 Westburg Avenue; Castleview; Germiston; 1401
Telephone / Fax Number/s:	011 860 2592; 078 352 0477; 011 860 2592
Email address:	hchinorumba@yahoo.com
Research Topic:	Effects of the Integrative Learning Approach on learners' conception of projectile motion.
Number and type of schools:	ONE Secondary school
District/s/HO	Ekurhuleni South

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved. A separate copy of this letter must be presented to the Principal, SGB and the relevant District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted. However participation is VOLUNTARY.

The following conditions apply to GDE research. The researcher has agreed to and may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

1. The District/Head Office Senior Manager/s concerned, the Principal/s and the chairperson/s of the School Governing Body (SGB.) must be presented with a copy of this letter.
2. The Researcher will make every effort to obtain the goodwill and co-operation of the GDE District officials, principals, SGBs, teachers, parents and learners involved. Participation is voluntary and additional remuneration will not be paid;

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Office of the Director: Education Research and Knowledge Management ER&KM)
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506

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3. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal and/or Director must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.

4. Research may only commence from the second week of February and must be concluded by the end of the THIRD quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.

5. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.

6. It is the researcher's responsibility to obtain written consent from the SGB/s; principal/s, educator/s, parents and learners, as applicable, before commencing with research.

7. The researcher is responsible for supplying and utilizing his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institution/s, staff and/or the office/s visited for supplying such resources.

8. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research title, report or summary.

9. On completion of the study the researcher must supply the Director: Education Research and Knowledge Management, with electronic copies of the Research Report, Thesis, Dissertation as well as a Research Summary (on the GDE Summary template). Failure to submit your Research Report, Thesis, Dissertation and Research Summary on completion of your studies / project – a month after graduation or project completion - may result in permission being withheld from you and your Supervisor in future.

10. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned;

11. Should the researcher have been involved with research at a school and/or a district/head office level, the Director/s and school/s concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

(signature)

Dr David Makhado

Director: Education Research and Knowledge Management

DATE: 2016/06/23

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