INVESTIGATING GRADE 11 LEARNERS' MISCONCEPTIONS ABOUT FORCE IN MARABA CIRCUIT, LIMPOPO PROVINCE

By

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Declaration

I declare that **INVESTIGATING GRADE 11 LEARNERS' MISCONCEPTIONS ABOUT FORCE IN MARABA CIRCUIT, LIMPOPO PROVINCE** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institutions

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Full names Date

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Abstract

This study investigated Grade 11 learners' misconceptions about force. An exploratory design was used with six schools. A purposive sample of 190 learners studying Physical Sciences was tested for common misconceptions using the Force Concept Inventory (FCI). Furthermore, the prevalence of the misconceptions was also determined. Focus group discussions were used to determine the origin of learners' misconceptions. Descriptive analysis of the FCI revealed extensive misconceptions about Newtonian physics amongst Grade 11 learners with a prevalence range of 70% to 90%. The researcher surmised that the origins of these prevalent misconceptions are inherent of the sources of misconceptions that learners encounter in the formal physics classrooms: teachers and textbooks. Textbooks used by learners do not take into account possible misconceptions that learners might have. Thus, it might be difficult for teachers to identify possible misconceptions-prone topics based on their own background. The researcher recommends interactive teaching strategies.

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CHAPTER ONE – INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

Physical Science learners in South Africa display extensive misconceptions about force that emerge more clearly at the exit of secondary education (DBE, 2012). This implies the crucial need to identify and confront misconceptions in everyday teaching and learning in science classrooms (Köse, 2008; Williams, 2009). Worldwide studies related to overcoming learners' misconceptions have been conducted (Deshmukh & Deshmukh, 2007). Consequently, innovative ways have been developed to address issues of misconceptions in the learning and teaching of science (DeHaan, 2009; Knight, Smith, & Wood, 2008). One such innovation in science is the 'Concept Inventory' by David Hestenes (Miller, Santiago-Roman, Streveler, & Yang, 2011). Concept inventories are diagnostic assessment tools intended to measure learners' conceptual understandings of topics for which they share common alternate conceptions and faulty reasoning (D'Avanzo, 2008). Specifically, they are powerful tools that support iterative improvement in teaching and they enhance scientific literacy of learners (Smith & Tanner, 2010). Equally important, concept inventories are research-based conceptual assessment instruments designed to circumvent various test-taking strategies by using learners' misconceptions (Gavin-Doxas & Klymkowsky, 2008a). The twofold benefit of concept inventories is brought to light: for the learner and for the teacher (Knight, Smith, & Wood, 2008). Results from the use of concept inventories provide information on levels of learner understanding and also allow an assessment of the effectiveness of teaching (Anderson, Costa, Hamilton, & Wright, 2008). A variety of concept inventories have been developed for different disciplines over the years, namely in biology, chemistry, physical science and others (Gavin-Doxas & Klymkowsky, 2008a).

Physics has the Force Concept Inventory (FCI) as the most widely used assessment instrument of learner understanding of mechanics (Martin-Blas, Seidel, & Serrano-Fernandez, 2010). The FCI is a tool designed to probe learner understanding of force in its various dimensions (Caballero, et al., 2012). For example, the FCI has revealed that physics learners can solve common types of quantitative problems without the basic understanding of the concepts that are involved (Benckert, Luangrath, & Petterson, 2011). As a result, concept inventories are increasingly appreciated because they tie learning and teaching to effective assessment (Knight, Smith, & Wood, 2008). The idea that learners' misconceptions must be dealt with systematically can be a daunting task for teachers if they do not know what exactly those misconceptions are (Deshmukh & Deshmukh, 2007). Literature shows that learners' initial ideas would usually persist unless those ideas are directly challenged in an interactive format (Williams, 2009).

Teachers must carefully consider what to teach and how to assess (Oberg, 2009). It is emphasised that teachers need to know their learners in order to teach them and align thoughtfully directed concepts to them (Oberg, 2009). When teachers are fully informed about their learners, they are better prepared to make appropriate instructional decisions so as to adapt their teaching practice to ensure success for all learners (Williams, 2009). Therefore, to learn about the learners, teachers must rely on data collected from learners through a variety of methods (Köse, 2008). Such learners' data must be rich enough in detail and breadth to provide teachers with the necessary information to connect instructional strategies to their needs and skills (Oberg, 2009). The collected data must provide information about learners' current ability and knowledge within the subject matter as well as information about learners' interests, learning styles and pace (Köse, 2008; Williams, 2009). Can the FCI be exploited in the South African context to gauge learners' conceptual understanding of the Newtonian physics?

In an attempt to improve teaching and learning in South Africa, the Minister of Basic Education releases an annual diagnostic report on Grade 12 learners' performance. The report "provides a detailed, per-question, analysis of the responses of learners on items in selected question papers" (DBE, 2014, p. 11). The exercise aims at isolating teaching and learning weaknesses for focused classroom level interventions (DBE, 2014). One can deduce that there are concerns within South African classrooms that need intervention as revealed through the National Diagnostic Report on Learner Performance (NDRLP). Another inference could be that the NDRLP has little or no effect on the Grade 12 performance as the same per topic misconceptions are reported annually. In fact, the Department of Education itself admits that the quality of performance in science is below desirable levels despite achieving a high pass rate of Grade 12 learners in 2013 (DBE, 2014). As such, the Department intended establishing an intervention program for improvement.

The question of how much attention is given to the identification and confronting of misconceptions in South African classrooms can be asked. Evidently, the Ministry of Education in the country is making attempts to alert teachers on issues of concern at classroom level. Are teachers making a concerted effort in addressing issues of misconceptions in their everyday teaching? What means of intervention/s is/are adopted in South African schools to address misconceptions? Whether the NDRLP reaches science teachers remains a question. Also, are the recommendations from the NDRLP which are based on summative results of Grade 12 learners heeded by teachers in everyday teaching?, Clearly, a gap exists in South Africa for formatively and innovatively identifying and addressing misconceptions as they occur daily in our classrooms. Hence, this study will investigate misconceptions about force with special focus on Grade 11 learners in Maraba Circuit of Limpopo Province.

1.2 STATEMENT OF THE PROBLEM

A misconception is identified by the teacher when what is known and believed as fact by the learner does not match what is known to be scientifically correct (Deshmukh & Deshmukh, 2007). The key to good teaching is to identify misconceptions, understand how they arise, and then how to challenge them and move the learner towards the currently accepted position (Kowalski & Taylor, 2009). Misconceptions have a serious impact on learning (Deshmukh & Deshmukh, 2007). The NDRLP report states that there are extensive misconceptions that emerge from the Grade 12 final examination. Misconceptions snowball from earlier years of science learning and propagate through the years, disturbing the development of correct concepts. They are sometimes never detected or belatedly realised at the end of secondary education. Thus, the problem is misconceptions about force that go unidentified before learners can write their Grade 12 final examination. Teachers usually do not know exactly what these misconceptions are or how to address the misconceptions when teaching about (Anderson, Costa, Hamilton, & Wright, 2008). Teachers should be able to recognise learner misconceptions for the topics that they teach (Cook-Smith, Coyle, Miller, Sadler, & Sonnert, 2013).

1.3 PURPOSE OF THE STUDY

The purpose of this study was to investigate Grade 11 learners' misconceptions about force, in Maraba Circuit of Limpopo province.

1.4 RESEARCH QUESTIONS

There are three issues which were investigated in this study – firstly, to identify misconceptions about the force concept that Grade 11 learners hold, secondly, to determine the most prevalent misconceptions about the Force Concept, and thirdly, to determine the origin of these common misconceptions.

As such, the research questions that guided this study were:

1. What are the misconceptions held by learners in Maraba Circuit in Limpopo Province on the force concept?
2. How prevalent are the misconceptions?
3. What are the origins of these misconceptions?

1.5 SIGNIFICANCE OF THE STUDY

Throughout science education, science teachers are continuously exploring ways of evaluating the effectiveness of their teaching (Oberg, 2009). It should be the desire of each teacher to improve their teaching and their pedagogical content knowledge (Kowalski & Taylor, 2009). Teachers need effective assessment tools that would not only inform their teaching, but also the learning of their learners (Oberg, 2009). The FCI has been determined to be an effective tool in informing teachers about misconceptions harboured by learners on force as a concept, thereby giving teachers the opportunity to treat these misconceptions (Cummings, Kuhl, & Marx, 2009; Anderson, Costa, Hamilton, & Wright, 2008; Benckert, Luangrath, & Petterson, 2011). Science teachers need to be cautious about the misconceptions their learners may have about specific topics in order to address them as part of their everyday teaching. An effort needs to be made to diagnose learners' misconceptions on a frequent basis. This study will contribute to this effort. This study further intends to use concept inventories as invaluable tools that can work for both teaching and learning in South Africa.

Thus this study has the potential significance and importance as follows:

1.5.1 Recognition of common misconceptions

Firstly, this study will stress the importance of identifying and recognising common misconceptions that Grade 11 learners hold about Newtonian physics. My view is that the identification of common misconceptions could prove valuable to everyday teaching of science in South African schools and can be beneficial to both teachers and learners alike. Such misconceptions could become common knowledge to science teachers such that teachers consciously address them in their daily teaching of force as a concept.

Also, recognition of misconceptions could prompt teachers to address them so as to improve conceptual understanding of the force concept by the learners (Hamza & Wickman, 2008). If something is declared common, should it not be known by all affected by the issue? It might be ambitious, but there might just be a chance that South African Grade 11 physics textbooks might have a list of these misconceptions as well. Such an initiative could prompt teachers to be better prepared to present science that is free of any misinterpretations or misconceptions to their learners (Marek & Yates, 2013).

1.5.2 Prior knowledge and misconceptions

Secondly, this study may invigorate the importance of prior knowledge when teaching science as a measure of probing and dispelling misconceptions.

Researchers assert that the way learners handle ideas that have been presented to them is highly dependent on their prior knowledge (Horton, 2007). Prior knowledge as a learner characteristics interact with levels of successful learning (Anderson & Lee, 2013). Sometimes that knowledge is inaccurate or has gaps, and sometimes it is complex and robust (Fisher, Frey, & Lapp, 2012). Activating preconceptions can be achieved through prior knowledge cues (Booth, Klahr, & Koedinger, 2013). The natural domain for investigating prior knowledge that has no empirical evidence and its effect on learning, comprehension and reasoning is science (Catley & Novick, 2014). Teachers need to probe the prior knowledge of learners with the intention of unearthing misconceptions. Teaching without probing the prior knowledge of learners is but an exercise of encoding new memories according to the principles of episodic memory (Barber, Fazio, Marsh, Ornstein, & Rajaram, 2012).

Research has over the years alluded to the role that prior knowledge plays in learning (Svinicki, 2010; Anderson & Lee, 2013; Crichton, 2000; Fisher, Frey, & Lapp, 2012). Such knowledge is critical in the construction and reconstruction of new information for successful learning (Oberg, 2009). The knowledge that is already possessed by learners, fragmented though it might be, as well as the misconceptions they hold affect understanding of new information by learners (Svinicki, 2010). Levels of prior knowledge are different from one learner to another: anticipative responders have a relatively high level of prior knowledge, whereas principle-based explainers have a low level of prior knowledge (Anderson & Lee, 2013).

The level of a learner’s prior knowledge has a direct effect on the intensity of misconceptions that learners hold (Catley & Novick, 2014). In fact, some researchers argue that prior knowledge does not guarantee any protection against wrongful interpretation of new knowledge (Barber, Fazio, Marsh, Ornstein, & Rajaram, 2012). It has also been determined through investigative studies that comprehension of new information is drastically reduced where learners strongly hold a prior belief which is in conflict with the new information (Kowalski & Taylor, 2009). Basically, misconceptions within the conceptual change framework emphasise the importance of assessing the prior knowledge of learners (Kowalski & Taylor, 2009). This asserts prior knowledge as the primary resource for acquiring new knowledge (diSessa, Roschelle, & Smith, 1994).

An important step for teachers in the process of developing needed background knowledge involves anticipating misconceptions (Fisher, Frey, & Lapp, 2012). When learners do not have sufficient prior knowledge, they are more prone to misconceptions: learners appear to need sufficient prior knowledge in order to benefit from new information (Anderson & Lee, 2013). From the perspective of a science teacher in Grade 11, I find that it is crucial to know what prior knowledge the learners bring to the learning setting. Misconceptions are lessened when the teacher affords learners opportunities to build on their prior knowledge (Rockinson-Szapkiw & Wendt, 2014). Teachers ought to anticipate the kinds of misconceptions learners hold so that they can devise instructional strategies to address them.

1.5.3 Importance of concept inventories

In order to determine how much learners understand what is being taught and to also identify misconceptions held by learners, concept inventories are used (Martin, Mitchell, & Newell, 2003). Concept inventories are a reliable method of rapidly gauging areas of conceptual difficulty, and reveal the form in which these difficulties manifest themselves (East, Herman, Kaczmarczyk, & Petrick, 2010). This study may present concept inventories as invaluable instruments that can work for both teaching and learning in South African classrooms. Evidence from previous studies shows the benefits of concept inventories (Anderson, Costa, Hamilton, & Wright, 2008; Benson , et al., 2010; Knight, Smith, & Wood, 2008; Martin-Blas, Seidel, & Serrano-Fernandez, 2010).

These benefits include the reconciliation of the learning of learners with teacher expectations, measuring the effect of instructional strategies on learning, correlating learning of learners with background variables, to mention but a few (Benson , et al., 2010). Results from the use of a concept inventory can be used to change the instructional strategies to overcome learners' misconceptions (Martin, Mitchell, & Newell, 2003). Going forward in improving learning experiences of learners, teachers may recognise the need for concept inventories as assessment tools that measure learner understanding of fundamental science concepts (Benson , et al., 2010). As a result, any teacher who desires to improve their instruction and the quality of assessment may venture into concept inventory development for any science topic.

1.5.4 Personal significance

Lastly, this study is also important to me as a Physical Science teacher in Grade 11. The information collected from this study could result in my knowing and being able to identify misconceptions in my everyday teaching, not only on force but other topics as well. Knowledge about these misconceptions allows for an improved approach when teaching force as a concept (Hamza & Wickman, 2008). Without sounding clichéd, the saying that teachers are lifelong learners holds true for me. This study may potentially inspire me to determine ways of addressing the very same misconceptions investigated in this study as a lifelong learner.

CHAPTER 2 – LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 INTRODUCTION

This chapter presents a literature review around the issue of misconceptions. The literature review provides explanations of what conceptions are; and hence what misconceptions are. It further discusses the role of prior knowledge where misconceptions are concerned. Furthermore, the chapter offers a discussion of the theoretical framework upon which this study is grounded.

2.2 LITERATURE REVIEW

2.2.1 What are concepts?

Concepts are mental representations of a set of ideas that can be labelled with a single word or be described by a few words (Zirbel, 2004). In addition, concepts help us understand the world around us (Logue & Thompson, 2006). Some view concepts as ideas that are stable over time, the result of a constructive process, connected to other aspects of the knowledge system of learners (Broughton, Nussbaum, & Sinatra, 2012). To further elaborate, a concept is synonymous with a construct. A construct is an idea that comprise diverse and numerous conceptual elements, characteristically considered to be subjective and not necessarily based on empirical evidence (Udo-Akang, 2012). The dictionary defines a concept as an idea of something formed by mentally combining all its characteristics or particulars. Other knowledge that is acquired as learners learn is based on core concepts which are the building blocks of knowledge (Zirbel, 2004). Hence, core concepts are “available within our genetic fabric” (Zirbel, 2004).

2.2.2 What are misconceptions?

Secondary school learners do not enter into science classrooms as blank slates: they already hold conceptions that explain some of the scientific phenomena before they are taught in class (diSessa, Roschelle & Smith, 1993; Kowalski & Taylor, 2009). Although this may be true, varying levels of inaccurate or incomplete knowledge and beliefs about the core concepts mar these preconceptions (Hughes, Kaplan & Lyddy, 2013). Over the years of research, other terms have been used synonymously with misconception, namely, preconceptions, naïve beliefs, alternate conceptions, personal models of reality, unfounded beliefs, etc. (Zirbel, 2004). What is clear is that learners have their own private knowledge which is complex and not consensual (Zirbel, 2004).

Misconceptions are inaccurate prior knowledge or they are conceptual fallacies (Duffy, Franco, Muis, Ranelluci, Sampasivam, & Wang, 2013). They are fundamental errors in reasoning and have a cascading effect that influences subsequent learning (Fisher, Frey, & Lapp, 2012). One of the destructive consequences of misconceptions is their multiplier effect whereby "the learner retrofits new concepts onto these misconceptions in an attempt to preserve incorrect background assumptions" (Fisher, Frey& Lapp, 2012 p.22). Regardless, misconceptions are central to understanding how people learn.

Furthermore, a misconception is a concept that is not in agreement with the current understanding of science (Zirbel, 2004). These are instances where what the learner knows and believes clashes with what is known to be scientifically correct (Birgin & Gurbuz , 2012). In simple terms, a misconception is an incorrect answer given by learners when confronted with a situation wherein their knowledge does not bear empirical evidence (Geban & Uzantiryaki, 2005). Hence, in this study the term misconception is used to label learner conception that produces a systematic pattern of errors (Williams, 2009).

By their nature, misconceptions have been found to be both widespread and resistant to change where standard instructional strategies are employed (diSessa, Roschelle & Smith, 1993; Hughes et al., 2013). Furthermore, the complexity of misconceptions makes them very difficult for teachers to correct (Fisher, Frey, & Lapp, 2012). In addition, most learners who hold misconceptions do not even know that their ideas are erroneous (Corkins, et al., 2009). As such, a majority of learners leave science classrooms with most of their misconceptions intact (Kowalski, & Taylor, 2009). However, when misconceptions are challenged directly and learners are provided with opportunities to re-construct their world-view, the proportion of learners able to use science conceptions to explain phenomena increases significantly (Deshmukh & Deshmukh, 2008).

Teachers should know the common learner misconceptions for the topics that they teach (Cook-Smith et al., 2013). Furthermore, teachers should devise means to reveal learners' preconceptions in their classrooms (Kowalski, & Taylor, 2009). It is important to identify these unscientific conceptions so as to devise strategies to remediate them hence teaching will be more effective (Anderson et al., 2008).

Misconceptions can be categorized as follows:

1. Preconceived notions

   These are popular conceptions rooted in everyday experience (National Academy Press, 1997).
2. Non-scientific beliefs

   They include views that learners learn from sources such as religious and mythical teachings (NAP, 1997).
3. Conceptual misunderstandings

   These are faulty models constructed by learners to deal with confusion about scientific concepts (NAP, 1997).
4. Vernacular misconceptions

   They arise from use of words that have one meaning in everyday life and another in scientific context (NAP, 1997).
5. Factual misconceptions

   These are falsities that are often learned at an early age and remain unchallenged (NAP, 1997).

2.2.3 Role of the FCI in identifying misconceptions

Concept inventories, in general, are designed to circumvent various test-taking strategies by using learners' own language and misconceptions (Anderson, et al., 2008). They are multiple-choice instruments that explore learners' conceptual understanding in a given subject area, providing researchers with a map of their learners' conceptual landscape, which can be used to inform instruction in that area (Guiseppe, 2010). Although concept inventories bear a strong resemblance to standardized tests, their intended use differs from that of tests in crucial ways, which results in significant differences between the way concept inventories and standardized tests are constructed (Garvin-Doxas & Klymkowsky, 2008a).

The FCI focuses on learners' understanding of Newtonian physics (Cummings, Kuhl & Marx, 2009). The disappointing level of understanding, evidenced by learners taught through traditional lecture methods, helped trigger the current reform movement in physics education (Halloun & Hestenes, 1985). Literature reveals supporting evidence on the use of the FCI to identify misconceptions held by learners on force as a concept in physical sciences (Benckert, et al., 2011). The findings from the use of the FCI confirm the conclusion of educational researchers, that the problem of common sense misconceptions in physics is a serious one (Griffin, et al., 2007). In the first study in which the FCI was used to assess learners understanding of the Newtonian concept of force, it was found that only a few learners consistently used the Newtonian framework across different tasks (Halloun & Hestenes, 1985).

FCI data revealed that less than 15% of learners who were able to state Newton's Law could apply the law in answering FCI questions (Halloun & Hestenes, 1985). Furthermore, a group of undergraduate university learners scored an average of 20% overall on the FCI while their honours counterparts scored an average of 23% (Hestenes, Swackhamer & Wells, 1992). These low gains of learners' basic knowledge indicate that throughout formal lessons learners operate with a defective belief system (Anderson, et al., 2008). In essence, this implies that learners continually misunderstand what is being taught in class (Hughes, 2013). Furthermore, learners' interview responses reflect reliance on everyday life experiences in answering the FCI questions (Benckert, et al., 2011). It is also revealed in other studies that some learners show surface understanding in mechanics, which results in their inability to apply their knowledge to different contexts (Griffin, et al., 2007). It would seem that learners respond differently to different types of tasks involving the same concepts (Guiseppe, 2010). The low FCI gains from the few mentioned studies above suggest that learners' knowledge in mechanics is often incomplete, fragmentary, and still contains significant errors and misconceptions (Griffin, et al., 2007). The reason was determined to be a result of the fragmented organisation of knowledge where each fragment refers to a specific idea or situation (Guiseppe, 2010).

Altogether, the FCI is a compelling tool that can be used to pin-point common misconceptions of Newtonian physics (Cummings, 2009). Evidently, the FCI has been widely used to demonstrate the need for improving learners' conceptual understanding of mechanics. Granted that performance trends from 2009 to 2012 reflect the improved quality of responses from candidates in the final Grade 12 examination, misconceptions are still prevalent in South African learners to date (DBE, 2012). Certainly, the FCI must be used as one of the innovative tools in physical science education to diagnose and identify misconceptions.

2.3 THEORETICAL FRAMEWORK

This research project concerns learners' misconceptions: a misconception is a derivative of a conception. Hence, the basis of this study is how learners conceptualise and why 'mis-conceptualisation' arises. How learners form concepts depends on how they accumulate information, organize it and construct own views (Zirbel, 2004). Evidence suggests that there are inconsistencies in learners' reasoning approaches to mechanics problems (Grosz, Kryjevskaia, & Stetzer, 2014). The emerging evidence suggests a reliance on intuitive reasoning strategies by learners when confronted with physics problems (McCloskey, 1983). Indeed, it has been observed from similar studies that learners exhibit intuitive reasoning tendencies towards Newtonian physics (Benckert, et al., 2011; Catley & Novick, 2014; Devecioglu, et al., 2010; Halloun & Hestenes, 1985; Martin-Blas, et al., 2010). Additionally, it has been determined that learners apply their correct ideas selectively (Grosz, et al., 2014). Contrary to Newtonian explanations of motion, there exist discrepancies between intuition and knowledge about force and motion accepted by the physics community amongst physics learners (McCloskey, 1983).

As already explained in this study, physics learners have striking misconceptions about motion. It is important to note that understanding learners' inaccurate conceptualisation is essential in order to move them toward an accurate conceptualization (East, Herman, Kaczmarczyk, & Petrick, 2010). These misconceptions are grounded in a systematic intuitive theory that is inconsistent with the Newtonian framework (McCloskey, 1983). Whereas many learners possess the required knowledge in mechanics, they still struggle to build reasoning chains from the fundamental principles (Grosz, et al., 2014). Instead, they often rely on a variety of intuitive reasoning strategies. Consequently, this study is grounded in intuitive physics theory.

It can be claimed that most in physics have an intuitive understanding of physics that works surprisingly well (McCloskey, 1983). In the case of learners construct, intuitive ideas tend to persist despite evidence contrary to the ideas (Braun & Mislevy, 2005). For this reason, the notion that poor learner performance in physics tasks stem from a lack of content knowledge is erroneous (Grosz, et al., 2014). In fact, physics learners have the requisite formal physics knowledge (Grosz, et al., 2014). However, learners' differ from physics experts in that physics experts organise their knowledge around deeper principles and relationships: learners' knowledge is fragmented and shallow (Braun & Mislevy, 2005). Hence, when asked simple scientific questions, learners often get them wrong in regular, patterned ways across every aspect of science education (Heckler & Scaife, 2014).

Intuitive physics knowledge is described as one that is not based strictly on content discussed in class and is thus not formal knowledge (Grosz, et al., 2014). Intuitive knowledge can also be described as the knowledge of the worlds that learners bring to the formal physics that is based upon experience relevant to the study of physics (Sherin, 2006). Consequently, intuitive physics is not a random process of reason, but rather it is "a fragmented collection of ideas, loosely connected and reinforcing, having none of the commitment or systematicity that one attributes to theories" (diSessa, 1988 p. 50).The worry about intuitive physics knowledge is that it does pose a threat to successful learning of expert physics knowledge (Sherin, 2006). As such, misconceptions that are embodied within intuitive physics knowledge result in erroneous judgement about Newtonian mechanics (McCloskey, 1983).

2.4 SUMMARY

Literature provided information that could lead to the understanding of misconceptions about force. Information about what concepts and misconceptions are could broaden knowledge around the topic. Also, intuitive physics theory was identified as the theory upon which the study is based. The next chapter describes the procedures followed to meet the purpose of this study.

CHAPTER THREE – RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of this study was to investigate Grade 11 learners' misconceptions about force using the 'force concept inventory', in Maraba Circuit of Limpopo province. Further inquiry was made into the most prevalent misconceptions. Also, the origin of these prevalent misconceptions was investigated. In this chapter, the research approach is outlined. The sample selection, data collection techniques, tools, actual implementation, data analysis and statistical tests form the fundamental nature of this chapter. Furthermore, the chapter aims to explain the quantitative and the qualitative methodology used in the study to collect data on the purpose of the study. Both qualitative and quantitative research approaches were used in this study.

3.2 QUANTITATIVE RESEARCH

Quantitative research involves a number of respondents with the aim of confirming the cause of phenomena or the existence of relationships so as to generalise results to the whole population (Cohen, Manion, & Morrison, 2007). Quantitative approach is desirable because it allows for generation of numerical data across groups of people (Neuman, 2011; Sibanda, 2009). One of the main attractions of quantitative research is that the researcher can conduct the inquiry in an unbiased, objective manner (Cohen, Manion & Morrison, 2007).

3.3 QUALITATIVE RESEARCH

Qualitative research aims to understand the meaning that individuals attach to everyday life (McMillan & Schumacher, 1993). Qualitative research adopts natural settings in an attempt to make sense of phenomena through the meanings from individuals (Cohen, et al., 2007). Qualitative research assumes a holistic view, an inductive approach as well as naturalistic inquiry (Schulze, 2000). As such methods of data collection in qualitative methods involves recording real events to capture what people say with “words, gestures and the tone of their voices” (McMillan & Schumacher, 1993 p.372). Qualitative research was also used to bring out information which the quantitative approach could not bring in when addressing the research questions. The qualitative paradigm was used through Focus Group Discussions (FGD). FGDs were used in order to obtain personal convictions, prior knowledge underlying these convictions which are also called misconceptions.

3.4 DESIGN OF THE STUDY

An exploratory research design was used in this study. Exploratory research is mostly concerned with the discovery of insights into a problem of which little is known about (Kothari, 2004). Furthermore, exploratory research aims at increasing familiarity with the problem area (Chen, Nunamaker & Purdin, 1990). Also, the aim is to look for patterns or ideas that can be tested and will form the basis for further research (Kothari, 2004).

3.5 POPULATION

A population is any group that is the subject of research interest. A population is a generally large collection of individuals that is the main focus of scientific query (Cohen et al., 2007). The population for this study will comprise of all secondary schools in the Maraba Circuit of Limpopo. The Maraba Circuit has twelve secondary schools.

3.6 SAMPLE

A sample is a subset of a population chosen to take part in the study (Cohen et al., 2007). The purpose of this study was to investigate Grade 11 learners' misconceptions about force. Hence, I purposefully selected learners studying Physical Sciences in Grade 11 so as to maximize the understanding of the underlying phenomenon of misconceptions about force (Collins & Onwuegbuzie, 2007). A total of 190 Grade 11 physics learners from five schools who offer physics formed part of the sample. This purposive sample of 190 Grade 11 physics leaners has the greatest potential for advancing the understanding of misconceptions about force

Table 3.1 shows a summary of the number of participants of the study. This number was divided in terms of gender as well. The sample size (N) is therefore 190.

TABLE 3.1: Summary of the number and gender of participants in the study

School	Boys	Girls	Total
A	47	0	**47**
B	13	17	**30**
C	0	82	**82**
D	14	12	**26**
E	3	2	**5**
TOTAL	77	113	**190**

3.7 DATA COLLECTION

3.7.1 Instrument

The Force Concept Inventory (FCI) instrument was used for data collection. The FCI is a multiple choice test that requires choice between Newtonian concepts and common-sense alternatives (Benkert et. al., 2011). The FCI classifies the Newtonian concepts into six categories each essential for the complete force concept (Hestenes, Swackhammer, & Wells, 1992). It includes 30 multiple choice questions, which address six conceptual dimensions of force. The dimensions are kinematics, first law, second law, third law, superposition principle and kinds of forces. Among the five alternative answers, corresponding to a question, only one is correct, while four others represent possible learners' misconceptions.

The instrument was administered to five different schools over a period of two days. The FCI questionnaire was completed under formal examination conditions, that is, there was no communication allowed amongst learners during administration of the questionnaire. The researcher ensured this by conducting the invigilation herself with the assistance of the physics teacher at schools with more than 40 learners. This took place during school hours, requiring approximately an hour to complete. The number of learners ranged from a minimum of five learners in one school to a maximum of eighty-two learners in another school. All learners managed to complete the test before the one hour was complete.

The inventory-nature of the FCI is outlined by the following tables:

- Table 3.2 maps out six conceptual dimensions of force. The dimensions are kinematics, first law, second law, third law, superposition principle and kinds of forces.
- Table 3.3 shows a breakdown of the dimensions and the inventory item which probes knowledge of the dimension.
- Table 3.4 presents taxonomy of misconceptions probed by the FCI.

TABLE 3.2: Newtonian concepts in the FCI adopted from Hestenes (1992)

	Inventory Item, Correct Response
1. Kinematics • Velocity discriminated from position • Acceleration discriminated form velocity • Constant acceleration entails ▪ Parabolic orbit ▪ Changing speed • Vector addition of velocities	19E 20D 12B;14D;21E 22B 9E
2. First Law • With no force ▪ Velocity direction constant ▪ Speed constant • With cancelling forces	6B, 7B, 8B, 11D 23B 10A, 24A 17B, 25C
3. Second Law • Impulsive force • Constant force implies constant acceleration	8B, 9E 21E, 22B, 26E
4. Third Law • For impulsive forces • For continuous forces	E, 28E 15A, 16A
5. Superposition Principle • Vector sum • Cancelling forces	8B, 9E 11D, 17B, 25C
6. Kinds of force • 6S – Solid contact ▪ Passive ▪ Impulsive ▪ Friction opposes motion • 6F – Fluid contact ▪ Air resistance ▪ Buoyant (air pressure) • 6G – Gravitation ▪ Acceleration independent of weight ▪ Parabolic trajectory	11D, 29B 5B, 18B 27C 30C none 3C, 5B, 11D, 12B, 3D, 17B, 18B, 29B, 30C 1C, 2A 12B, 14D

TABLE 3.3: A breakdown of FCI questions

	INVENTORY ITEM
1. Newton's Second Law free fall, no air resistance	1, 3, 13
2. Newton's Second Law (Impulse)	8
3. Newton's Second Law (a = 0)	9, 10, 11, 17, 23, 24, 25, 29
4. Newton's Second Law (a is non-zero)	21, 22, 26, 27, 29, 30
5. Circular motion, or circular to linear motion	5, 6, 7, 18
6. Projectile motion	2, 12, 14
7. Newton's Third Law	4, 15, 16, 28
8. Constant and changing velocity particles (Kinematics)	19, 20

TABLE 3.4: Taxonomy of misconceptions probed by the FCI adopted from Hestenes, Swackhammer & Hestens (1992)

MISCONCEPTIONS	INVENTORY ITEM
1. Kinematics	
• K1 – Position-velocity undiscriminated	19B,C,D
• K2 – Velocity-acceleration undiscriminated	19A;20B,C
• K3 – Nonvectorial velocity composition	9C
• K4 – Ego-centered reference frame	14A,B
2. Impetus	
• I1 – Impetus supplied by hit	5C,D,C;11B,C;27D;30B,D,E
• I2 – Loss/recovery of original impetus	7D,8C,E;21A;23A,D
• I3 – Impetus dissipation	12C,D;13A,B,C;14E;23D;24C,E;27B
• I4 – Gradual/delayed impetus build-up	8D;10B,D;21D;23E;26C;27E
• I5 – Circular impetus	5C,D,E;6A;7A,D;18C,D
3. Active Forces	
• AF1 – Only active agents exert forces	15D;16D;17E;18A;28B;30A
• AF2 – Motion implies active force	5C,D,E;27A
• AF3 – No motion implies no force	29E
• AF4 – Velocity proportional to applied force	22A;26A
• AF5 – Acceleration implies increasing force	3B
• AF6 – Force causes acceleration to terminal velocity	3A;22D;26D
• AF7 – Active force wears out	22C,E
4. Action/Reaction Pairs	
• AR1 – Greater mass implies greater force	4A,D;15B;16B;28D
• AR2 – Most active agent produces greatest force	15C;16C;28D

5. Concatenation of Influences • CI1 – Largest force determines motion • CI2 – Force compromise determines motion • CI3 – Last force to act determines motion	 17A,D;25E 6D;7C;12A;14C;21C 8A;9B;21B;23C
6. Other Influences on motions • CF – Centrifugal force • Ob – Obstacles exert no force • Resistance ▪ R1 – Mass makes things stop ▪ R2 – Motion when force overcomes resistance ▪ R3 – Resistance opposes force/impetus • Gravity ▪ G1 – Air pressure-assisted gravity ▪ G2 – Gravity intrinsic to mass ▪ G3 – Heavier objects fall faster ▪ G4 – Gravity increases as objects fall ▪ G5 – Gravity acts after impetus wears down	 5E;6C,D,E;7C,D,E;18E 4C;5A;11A,B;15E;16E;18A;29A 27A,B 25A,B,D;26B 26B 3E;11A;17D;29C,D 3D;11E;13E;29C 1A;2B,D 3B;13B 12D;13B;14E

**Belief in the misconceptions is suggested by selection of the corresponding FCI item*

3.5.1.1 Validity

Validity establishes that items or questions are relevant to what is being studied and that the interpretation of both questions and answers matches what is actually intended (Dennick & Tavakol, 2011; Neuman, 2011). The FCI was developed and validated by Hestenes, Wells and Swakhamer (1992). However, since the instrument was designed for use with undergraduate learners at tertiary level, the researcher sought the expertise of other Physics academics, specifically two secondary school physical science teachers and one university physics lecturer, to check its suitability to use with secondary school learners. The Content validity index was determined to be 1.00 and was computed using the formula:

$$\text{CVI} = \frac{\text{number of items judged as right}}{\text{number of items on the questionnaire}}$$

Additionally, the coefficient Kappa was used to represent the proportion of agreements remaining after chance agreement computed using CVI is removed (Schaefer, Schmidt & Wynd, 2003). Schaefer, et al. (2003) explain coefficient kappa as an improved measure of interrater agreement over CVI's proportion agreement. Kappa was computed using the formula:

$$k = \frac{P_o - P_e}{1 - P_e},$$

The determined value (k = 1) showed that the experts were in complete agreement about the relevancy of the questions to Grade 11 learners.

3.5.1.2 Reliability

Reliability can be measured using Cronbach's alpha reliability coefficient which is a rating of reliability on a scale from 0 to 1.0. Reliability shows that the instrument results are reproducible for a given group of subjects (Neuman, 2011). Also, reliability is concerned with the ability of an instrument to measure consistently (Dennick & Tavakol, 2011). The FCI is considered one of the most reliable and useful physics tests available for physics teachers with reports of an alpha of 0.86 on the pre-test and 0.89 on the post test (Allen, Murphy, Rhoads, & Stone, 2004).

Reliability shows that the instrument results are reproducible for a given group of subjects (Neuman, 2011). Also, reliability is concerned with the ability of an instrument to measure consistently (Dennick & Tavakol, 2011). The principle of using a pilot test extends to replicating the measures other researchers used (Neuman, 2011). Cronbach's alpha coefficient (α) was drawn from the results of the pilot study to determine the relevance of items in the instrument to the content of the study (Cohen et al., 2007).

The pilot on the FCI was performed with 26 Grade 11 learners at one school within Maraba Circuit who did not form part of the sample. The administration of the pilot study took 30 minutes. Cronbach's alpha reliability coefficient (α) was drawn from the results of the pilot study to determine the relevance of items in the instrument to the content of the study (Cohen et al., 2007). Cronbach's alpha reliability coefficient normally ranges between 0 and 1. Internal consistency of items on a questionnaire is deemed most acceptable if the Cronbach's alpha coefficient is closer to 1.0 (Gliem & Gliem, 2003). Using SPSS software package, Cronbach's alpha coefficient (α) was determined to be .724. This reliability result shows that the FCI test is suitable and relevant to secondary school learners at Grade 11. In addition this is consistent with studies on the reliability of the FCI by other researchers which revealed that "FCI total score is a precise metric" (Dahana, Dedic, Lasry, Reshef & Rosenfield, 2011 p. 912). As such, the FCI questions on force were relevant and clear for Grade eleven learners.

3.7.2 Focus Group Discussions

Given the free atmosphere and the need to elicit underlying cognitive constructs and to further amplify the power of the collected data on the FCI, focus group discussions (FGDs) were conducted as a means of triangulation. Triangulation is a strategy for achieving more comprehensive understandings of phenomena (Lambert & Loiselle, 2008). Furthermore, triangulation counteracts the limitations and biases that stem from using a single method, thus increasing the reliability of findings (Ehlers, King, & Ziyani, 2004).These follow-up FGDs were held with a sample of learner participants after the FCI had been administered and analysed, to determine the origin of the misconceptions.

FGDs are a qualitative method for data collection in which a small group of people led through an open discussion by the researcher (McLafferty, 2004). The purpose of focus group in this study was to obtain perceptions of learners on the identified common misconception about force in a non-judgemental and non-threatening setting. This rich discussion is generated in an open and unconstrained format (Cohen, et al., 2007). In this manner, participants challenge and probe each other's positions and views in a non-threatening and relatively naturalised social context (McLafferty, 2004). Focus group interviews generate complex information about what participants really think at a low cost and with the minimum amount of time (Birch, Jessop, Mauthner, & Miller, 2012). In these discussions multiple lines of communication are achieved at once (Cohen, Manion, & Morrison, 2007).

Learners were asked to volunteer for a focus group discussion, and the first fourteen to put up their hands were chosen. The rationale for this size of the group stems from the goal that the focus group should include enough participants to yield diversity of information provided (McLafferty, 2004). Also, the size of the groups was determined on the basis that the groups should be small enough to elicit responses from all the members, yet large enough to allow for learners to feel at ease (Cohen, Manion, & Morrison, 2007). The focus group discussions enriched the data gathered from the FCI. The group discussions were semi-structured. Semi-structured FGDs are a more flexible version of structured interviews that allow for a depth of feeling to be ascertained by providing opportunities to probe and expand the interviewee's responses (McLafferty, 2004). It also allows for deviation from a prearranged text (McLafferty, 2004). An interview schedule was used to guide the discussion. The discussions took place in an informal setting outside in a school laboratory, each lasting approximately thirty minutes. A video was taken. The rationale for a video is that when used, there is no need to address the interpersonal, interactive, communicative and emotional aspects of the interview (Cohen, Manion, & Morrison, 2007). Learners in the focus group could communicate non-verbally by facial and bodily expression which may convey whether the people are interested, agreeing or disagreeing.

3.6 DATA ANALYSIS

3.6.1 FCI Questionnaire

Descriptive analysis based on mode, percentages and frequency tables were used to analyse data collected in order to determine the misconceptions that learners have about force. The mode is appropriate because it tells the answer per question which most leaners chose; whereas the frequency tables determine how many times the most chosen answer was chosen. Descriptive statistics help to describe or summarise data in a meaningful way such that patterns might emerge from the data (Cohen et al., 2007). The patterns that were sort were the common misconceptions that learners hold about force.

3.6.2 Focus Group Discussions

Qualitative data requires logical reasoning and makes use of inductive reasoning, organizing data into categories and identifying relationships among the categories (Dickinson, Leech, Onwuegbuzie, & Zoran, 2009). Transcript-based analysis was used to analyze the qualitative data. This mode includes the transcription of the video tape of the FGD meeting. The researcher coded the transcribed data and presented the emerging themes. Sentences from transcribed discussions that supported the themes were identified. Findings were presented in a descriptive and narrative form supported by direct quotations from FGD transcripts.

3.7 ETHICAL CONSIDERATIONS

Ethics refer to the morality and accountability on the part of the researcher throughout the research process (Birch, Jessop, Mauthner, & Miller, 2012). These are principles which are self-binding to the researcher during the entire research. Ethical clearance for this study was obtained from the Limpopo Department of Education (LDoE). Thereafter the permission to carry out the study was sort and granted by the principals of sampled schools who were given the copy from the LDoE. Furthermore, the purpose of the study was explained fully to the participating and their co-operation was requested. The following is a summary of the procedures followed:

3.7.1 Informed consent

Participants of a research study should be given enough information about the study in an understandable manner to enable them to exercise their right to make an informed decision whether to participate or not (Social Science Research Ethics, 2006). The participants of this study are minors (under the age of 18). The minors' consent to participate was sort thereafter the consent of the parent or guardian was also sought (Section 71 of the Health Act of South Africa, 2012). An information sheet written in English and the mother tongue (Sepedi) of the participants that summarised key information about the study was prepared and presented to parents of the participants. The participating learners were given adequate information on the purpose of the research, the procedures which would be followed, the credibility of the researcher and the way in which the results of the study were to be used. This enabled the participants to make an informed decision on whether they wanted to participate in the study or not.

3.7.2 Respect

Respect requires that the equal worth of all people be respected (Cohen, Manion, & Morrison, 2007). It requires that people be regarded as free and rational. Also, that people are entitled to the same basic rights as others. Respect for all participating and for democratic values was maintained. Respect was promoted amongst the participants, especially during the focus group discussions. The researcher was prepared to intervene in a non-threatening manner should there have been instances whereby individuals disrespected others.

3.7.3 Anonymity and confidentiality

Anonymity refers to concealing the identities of participants of a study in all documents resulting from the research (Social Science Research Ethics, 2006). On the other hand, confidentiality is concerned with who has the right of access to the data provided by the participants (Social Science Research Ethics, 2006). In this study, anonymity and confidentiality was ensured through the structuring of questionnaires by excluding personal information of the participants and quantitatively analysing data. All participants were kept anonymous and pseudonyms were used.

3.7.4 Discontinuance

Research participants have the right to withdraw from the research study without penalty (Schaefer & Wertheimer, 2011). Hence, this right was made known to participants by the researcher at the start of the research (Schaefer & Wertheimer, 2011). None of the participants withdrew from writing the multiple choice test as well as from the focus group discussions.

3.7.5 Securing data

Data collected from the participants were kept in a safe place to prevent them from falling into the wrong hands and the researcher will not carelessly discuss such information with any other person. The data would be kept there for five years (Section 71 of the Health Act of South Africa, 2012).

3.8 SUMMARY

The chapter outlined the research design. Methods of data collection were outlined and explained together with the envisaged data analysis. Also, the rationale for triangulation was provided. Ethical issues were also dealt with as well.

CHAPTER FOUR – RESULTS

4.1 INTRODUCTION

There were three issues which this study sought to investigate – firstly, to identify misconceptions about force that Grade 11 learners hold, secondly to determine the prevalence of misconceptions, and thirdly to determine the origin of these common misconceptions. The main points emerging from the results of the data gathered during this investigation are revealed in this chapter.

Data from all the five schools were combined to increase *N* (the number of participants of the study) thus decreasing the chances of inauthentic results (Cohen, et al. 2007).

The data is presented in the form of three tables:

- Table 4.1 maps out wrong responses to the misconceptions probed by the instrument.
- Table 4.2 presents the overall per question achievement of the sample on the FCI.
- Table 4.3 shows the prevalence of identified misconceptions within the sample.

4.2 GRADE 11 MISCONCEPTIONS ABOUT FORCE

TABLE 4.1: Mapping of wrong responses to the misconceptions probed by the FCI with reference to research question 1: "What are the misconceptions held by learners in Maraba Circuit in Limpopo Province on the force concept?"

INVENTORY ITEM	A	B	C	D	E	CORRECT ANSWERS	MISCONS
1.	27.4	15.8	23.2	23.2	10.5	C	G3
2.	19.5	32.1	26.8	13.7	7.9	A	G3
3.	7.4	37.9	24.7	2.6	27.4	C	AF5,G4
4.	41.1	4.7	8.9	10.0	35.3	E	AR1
5.	14.7	15.3	28.9	20.5	20.5	B	I1,I5,AF2
6.	18.9	14.2	13.7	13.2	40	B	CF
7.	17.9	18.4	18.9	7.9	36.8	B	CF
8.	28.9	27.9	18.4	14.7	10.0	B	CI3
9.	11.6	36.8	14.7	10.0	26.8	E	?
10.	15.3	16.8	6.3	47.4	14.2	A	I4
11.	4.7	33.2	41.6	13.2	7.4	D	I1
12.	17.4	33.7	26.3	22.1	0.5	B	-
13.	18.4	40.0	20.5	8.4	12.6	D	I3,G4
14.	30.0	42.1	13.7	9.5	4.7	D	K4
15.	38.4	24.7	21.1	14.2	1.6	A	-

16.	38.9	14.7	23.7	10.5	12.1	A	-
17.	36.3	21.1	17.4	15.3	10.0	B	CI1
18.	11.6	15.3	38.4	33.7	1.1	B	I5
19.	41.6	10.5	6.8	33.2	7.9	E	K2
20.	30.5	10.5	35.3	7.4	16.3	D	K2
21.	15.3	51.1	20.0	8.4	5.3	E	CI3
22.	26.3	35.3	6.3	23.2	8.9	B	-
23.	20.5	10.5	36.3	21.1	11.6	B	CI3
24.	37.9	15.8	27.9	8.4	10.0	A	-
25.	28.4	23.2	20.5	16.3	11.6	C	R2
26.	35.3	24.7	13.2	12.1	14.7	E	AF4
27.	28.4	40.0	21.6	5.3	4.7	C	R1
28.	6.3	22.1	11.6	35.3	24.7	E	AR1
29.	27.4	37.9	17.9	3.7	13.2	B	-
30.	10.5	21.1	11.6	25.8	31.1	C	I1

**The percentage of the correct answers are shaded whilst the percentage of most wrong responses are underlined*

Table 4.1 shows that most learners responded correctly to only questions 12, 15, 16, 22, 24, and 29. It can be said that 30% of learners have a fair grab on kinematics (question 12), Newton I (question 24), Newton II (question 22) and Newton III (question 15 and 16) as well as other kinds of forces (question 29). From the analysis a majority of learners (30%) managed to respond correctly to only six (6) unrelated questions (in terms of dimensions) on the FCI and the majority of learners respond incorrectly to twenty-four (24) questions. Hence, it can be said that 80% of the time, learners respond incorrectly to the inventory items. Thus, there is a significant indication that learners in Grade 11 hold misconceptions across all the six dimensions of Newtonian physics.

There are seven categories of misconceptions that are identified in Table 4.3:

1. Misconception about gravity (questions 1, 2, 4, 13)
2. Misconception about active forces (questions 3, 5, 26)
3. Misconception about impetus (questions 1, 5, 10, 11, 13, 18, 30)
4. Misconception about concatenation of influences (question 8, 17, 21, 23)
5. Misconception about other influences on motion (questions 6, 7, 25, 27)
6. Misconception about kinematics (questions 14, 19, 20)
7. Misconceptions about action/reaction pairs (questions 4, 28)

TABLE 4.2: Overall achievement on the FCI

Correct Answer	% Achievement
C	23,2
A	19,5
C	24,7
E	35,3
B	15,3
B	14,2
B	18,4
B	27,9
E	26,8
A	15,3
D	13,2
B	33,7
D	8,4
D	9,5
A	38,4
A	38,9
B	21,1
B	15,3
E	7,9
D	7,4
E	5,3
B	35,3
B	10,5
A	37,9
C	20,5
E	14,7
C	21,6
E	24,7
B	37,9
C	11,6
AVERAGE	21,1

As can be read from Table 4.2, the overall performance on the FCI was poor. The average FCI pretest score was about 21%, just slightly above the random guessing level of 20%.

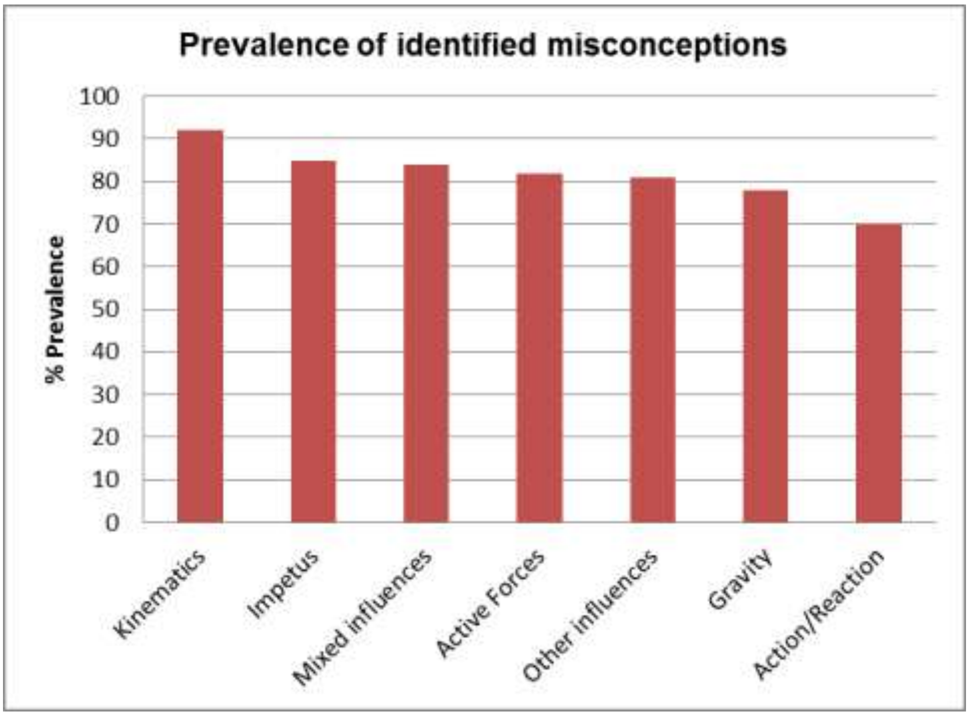
Table 4.3: Prevalence of identified misconceptions with reference to research question 2: "How prevalent are these misconceptions?"

Misconception	Inventory Item	Frequency of incorrect responses	Prevalence (%)	Average Prevalence (%)
1. Gravity	1 2 4 13	146 153 123 174	76.8 80.5 64.7 91.6	78
2. Active forces	3 5 26	143 161 162	75.3 84.7 85.3	82
3. Impetus	1 5 10 11 13 18 30	146 161 161 165 174 161 168	76.8 84.7 84.7 86.8 91.6 84.7 88.4	85
4. Concatenation of influences	8 17 21 23	137 150 180 170	72.1 78.9 94.7 89.5	84
5. Kinematics	14 19 20	172 175 176	90.5 92.1 92.6	92
6. Other influences on motion	6 7 25 27	163 155 151 149	85.8 81.6 79.5 78.4	81
7. Action/Reaction pairs	4 28	123 143	64.7 75.3	70

**Average prevalence was rounded off to zero decimal place because the data refers to individual learners: people are represented as whole numbers.*

**The formula used to determine the average prevalence for the FCI is* $\frac{\sum p_i}{n}$ *where* p_i *is the individual prevalence for each of the 30 items and n is the number of items*.

Figure 1: Average prevalence of identified misconceptions with reference to research question 2: "How prevalent are these misconceptions?"



Prevalence was calculated according to the following formula:

$$\text{Prevalence} = \frac{\text{number of occurences of most wrong response}}{\text{size of the population}} \quad 100\%$$

The prevalence for the identified misconceptions ranges from 70% for action/reaction forces to 90% for kinematics. The combined prevalence for all misconceptions identified above was calculated using the following formula:

$$p = \frac{\sum p_{avg}}{n}$$

Overall, for every 10 learners in Grade 11, 8 of them hold misconceptions about force.

4.3 DATA COLLECTED FROM FGDs

The researcher used scenarios to start the discussions.

4.3.1 Background knowledge about Isaac Newton

In line with the Newtonian content focus of the FCI, learners were asked what they knew about Isaac Newton; where and when the knowledge was acquired. Learners appeared to know who Newton was and what contributions he made to Physical Sciences. Newton is known to learners as the discoverer of gravity. This is evidenced in the following response from one learner:

> *He is the first person to discover that there's gravitational force by seeing an apple fall when there was no wind*

Also, Newton's contributions to physics are recognized through some of the laws he formulated to explain physics concepts. This knowledge is reflected through the following comment by one learner:

> *I know Newton to be a person who came about with four laws of physics. Newton first law, Newton's second law… of motion, Newton's third law of motion and Newton's law of universal gravitation*

The knowledge became new to learners when they were learning about forces in their previous studies before Grade 11 as evidenced by this comment:

> *We were studying about forces and found that gravitational force is a type of force. Then we came to know Newton.*

According to learners, this knowledge was acquired at different levels of their education, namely in Grade 8, Grade 9 and even in their present Grade 11.

> *Learner 1: These laws I learnt them this year*

Learner 2: in grade 9

The purpose of the questions posed by the researcher was to ascertain that learners did have historical knowledge about Newton. Also, that knowledge about force was acquired in earlier years. Learners do have information about when they first heard new concepts about Newton. The level of understanding and conceptual grasp of the information probed here is brought to light in the subtopics which follow.

4.3.2 Newtonian Knowledge

Scenario I: A box is being pushed along a smooth horizontal surface with constant force. The applied force is removed. Describe the motion of the box.

This scenario was probing learners' knowledge and application of Newton's first law. Some learners said the box will move for a little while before stopping:

It will move constantly until it stops.

When asked to explain further, a medley of responses were offered. This evidence is reflected from the following responses:

Response 1: because it's a smooth surface and there's less friction

Response 2: It depends on the size of the applied force. If I apply a lot of force when it is here, it may stop over there

Response 3: It will move a little then stop because, in my understandin, there is less friction on a smooth horizontal surface. So if it goes forward it will not stop immediately. It will move before friction stops it

Some of the arguments from learners are as follows:

Response 1: It will stop immediately. Because we did not exclude friction and other forces

Response 2: Because I know that friction acts opposite to the applied force. And immediately when you leave it, friction opposes its motion. So it will just stop. Unless if it was on a steep way.

Response 3: Friction has been removedt. It was removed, so there is nothing that pushes it. And when there is friction,it acts opposite to the applied force. Since theapplied force has been removed, there's no way that it can continue moving

Scenario 2: A person runs on a smooth, clean and polished platform. The person realizes when he is a small distance from the end of the platform that at the end of the platform, there is a poodle of muddy water. Will the person be able to stop?

All learners chorused a "No" to the question. This response exposes an inconsistent knowledge that learners have of Newton's first law. Furthermore, explanations around the issue exhibit the misconception that inertia is the force that keeps objects in motion. In addition, learners unveil the most common misconception about Newton's first law that sustaining motion requires a continued force. This is in sharp contrast to earlier responses in Scenario 1. One learner offered the following explanation:

Because of inertia. The body is already used to moving with that constant velocity. It is just like when you are inside a car, we would be moving with it when it is moving. And when it stops we move forward.

Scenario 3: It's on a rainy day, thus friction is negligible. A car moves with constant velocity along a straight level (tarred) road that curves sharply towards the end. Explain the motion of the car.

This scenario was probing knowledge of both Newton's first law and Newton's second law. While learners correctly responded that if the driver does not "do something" the car will go straight and not curve with the road, there seemed to be measures of confusion and uncertainty regarding Newton first law and second law.

Because of Newton's 2nd law which state that when a resultant force is exerted on an object, it causes the object to move in the direction of the exerted force
Both Newton 1 and Newton 2 apply

Scenario 4: A big truck collides head-on with a Toyota Tazz. What can you say about the force that the truck exerts on the tazz when compared to the force that the car exerts on the truck?

The scenario was examining knowledge of and the understanding of Newton's third law. Responses were better than those for the other laws of motion. Learners confidently responded as follows:

They're equal but opposite in direction

However, one learner exhibited a misconception that action force applied to a small object by a big object is bigger than the reaction force applied to big object by the small one. This learner answered that the small car would be crashed. In explanation, one learner answered as follows:

The mass of the truck is high and the mass of the Tazz is small

Whereas learners could state the laws and applicable concepts to the scenarios, they could not reach to the same success in the questions related to the understanding. Generally speaking, it was apparent that most of the concepts of Newtonian mechanics were lacking from the learners.

Scenario 5: An object is thrown vertically upwards. Identify the forces acting on the object after it has left the thrower's hand. Also, compare the speed of the ball when it is going upwards and its speed when it comes downward.

A response from one learner:

> *When it is up there, it will have a speed limit. When it gets up it will stop somewhere because there is nothing that pushes it anymore. Then it will return because of gravity*

Secondly, learners think that only active agents exert forces:

> *By throwing the object up, you exert a force on it. When it returns there is no person or anything that is pushing it down. Only the force of gravity is pulling it. But it will not return with the same speed as when it was going up because of force of gravity*

Thirdly, it came out that some learners think that velocity is proportional to applied force

> *Because it was given a start, a push, when it goes up it goes with a certain velocity, with a high speed. Then when it comes back because gravity will be pulling it, it will come down but the speed is not the same it is smaller than when you threw it up*

Learners were also asked about the forces acting on the projectile.

> *Applied force goes in the same direction as normal force. Normal force acts perpendicular to the surface. It goes from here going upwards and it act in the same direction as normal force and force applied*

CHAPTER FIVE: DISCUSSION OF FINDINGS

The purpose of this study was to investigate Grade 11 learners' misconceptions about force. Results show that Grade 11 learners have extensive misconceptions about force across the dimensions of mechanics as per the FCI (Table 4.1). The results show poor performance on the diagnostic test at an average of 21, 1% (Table 4.2). Also, the prevalence rate of 80% implies high commonness of misconceptions about force amongst learners. As a result, the study identified seven categories of misconceptions held by grade 11 learners about Newtonian mechanics (Table 4.3). The origins of misconceptions are discussed by reviewing the sources of information learners used to answer the diagnostic test.

This study has established that learners choose non-Newtonian answers that are based on commonly held misconceptions. Ideally, this result is a reflection of how much Newtonian physics content learners have mastered. Thus, the low FCI score average suggests that learners do not master the mechanics content. This result strongly replicate the first findings in which one group of learners scored an average of 20% on the FCI while another group scored an average of 23% (Hestenes, Swackhamer & Wells, 1992). However, these results are in stark contrast to the 2014 NDLRP wherein the average marks on Newton's laws of motion and vertical projectile motion were 45% and 63% respectively. Nevertheless, the same NDLRP elucidates that "candidates' performance in this questions did not correlate with their performance in the rest of the paper" (DBE, 2014, p. 144). This analysis is not surprising as it shows the inconsistent and defective nature of misconceptions. It could also mean poor conceptual understanding of mechanics content, hence the seven categories of misconceptions.

The first misconception concerns gravity (questions 1, 2, 4, 13 on the FCI) and is somewhat extensive. A scenario that probed for knowledge and understanding of gravity raised issues that prove the extensive presence of gravity-related misconceptions. Firstly, learners hold the misconception that gravity acts after a certain instant. This notion is in contradiction to the Newtonian framework wherein the effect of force of gravity on a projectile is not delayed but rather "the projectile begins to deviate downward from the direction in which it was aimed the instant it is fired" (McCloskey, 1983 p125).

Secondly, learners believe that there is more than one force acting on a projectile when it is thrown upwards. Learners identified applied force, normal force and force of gravity as forces acting on the projectile during its motion. This contradicts Newtonian physics, which explains that the force of primary importance acting on a projectile is force of gravity. However, learners have a difficulty with the concept that the only force acting upon a projectile is gravity. This difficulty may stem from the wrong conception of motion that prompts learners to think that if an object is moving upward, then there must be an upward force.

Furthermore, findings reveal that even though learners know of force of gravity, they are confused about how it works. It emerged that learners commonly perceive force of gravity as a "push" force. This notion indicates that learners have a faulty definition of what force of gravity is. It can be inferred that learners do not know that force of gravity draws object towards the centre of a planet; and that specifically on Earth, force of gravity is experienced as a "pull" force. Consequently, learners were not able to identify that projectiles accelerate due to force of gravity. This inconsistency is brought about by the next misconception concerning active forces (questions 3, 5, 26 on the FCI).

Inconsistencies about active forces are reflected from the common perspective by learners that a 'forceless' object does not move. It is evident that Newton's first law is perceived only to object is stopping or object tends to stop. Also, the concept of constant force is not taken into consideration when explanations are given by learners. Nonetheless, the interpretation of a smooth surface to imply less friction was factored in to the explanations offered by learners. However, the fragmented state of learners' ideas disabled them from offering clear explanations. Consequently, it was difficult for learners to explain the principle of inertia as per Newton's first law. Subsequently, when an applied force, whether constant or not, is removed from a moving object, the object will stop immediately. Hence for learners who go along with this notion, an object requires a force to sustain its motion. Thus, learners consider force to be a property that keeps objects moving. Hence, according to learners if an object stops, it means force has been taken away from the object, conversely if an object continues moving, there is a force responsible for that state of motion.

Other learners argue that the box will stop immediately upon the removal of the applied force. These learners have a perception that in order for an object to move it must be under the influence of a force. While the learners are able to state the related Newton I law, they do not understand it. Learners are unable to apply the fact that the object will continue to move unless it is acted upon by a force. Also, by not factoring in the ‘smooth horizontal surface’ altogether in their explanations, it could be said that learners are at times not aware of meaning of science language. While learners can recite these popular laws verbatim, they are not able to apply the laws when it is required to do so. However, the concern is not the ability to recite the laws, but rather the ability to understand the meaning and to actually believe in their implications. Newton’s first law states that an object in motion stays in motion with the same speed and same direction unless an external force acts on it, or an object at rest remains at rest unless an external force acts on it. Newton’s second law, on the other hand, explains that when an external force acts on an obejct (whether moving at a constant velocity or at rest), the object will accelerate in the direction of the force. The findings of this study reveal inconsistencies on Newton I and II by learners.

Closely related to the preceding misconception, is the third misconception category on impetus (questions 1, 5, 10, 11, 13, 18, 30 on the FCI). Impetus is conceived to be an inanimate intrinsic force that keeps things moving (Hestenes, Swackhammer, & Wells, 1992). The preceding discussion shows that learners are prone to impetus misconception whereby learners tend to invent a cause that would keep an object moving. In the belief of learners an object tends to stop when an applied force is removed. According to the learners sustaining motion requires a continued force. Learners offer varying explanations such as a moving object will stop immediately because friction and other forces are not ignore as well as friction will stop the object from moving because it opposes motion.

The fourth misconception category is misconception about concatenation of influences (question 8, 17, 21, 23 on the FCI). The wrongful conception of forces emanates from the erroneous thought the natural state of objects is to be at rest. In this case, learners do not know that there is no need for a force to keep an object moving. Learners think that when an object is in motion, there is a force that has 'won' over others. The common sense is reflected by the explanation given by learners that "gravity always wins" and "everything always comes down". Closely related to this misconception is the fifth misconception about other influences on motion (questions 6, 7, 25, 27). There seems to be a common belief of learners that "mass makes things stop", learners explain that between a truck and a small car, the truck will stop easily because "it is big". This explanation is surprising when it comes from Grade 11 learners because it is assumed that the learners know Newton's laws. Hence the sixth misconception about action/reaction pairs (questions 4, 28) wherein learners exhibit a misconception that action force applied to a small object by a big object is bigger than the reaction force applied to big object by the small one. This learner answered that the small car would be crashed: thus the common sense belief is that the big mass implies greater force.

Whereas learners could state the laws and applicable concepts to the scenarios, they could not reach to the same success in the questions related to the understanding. Generally speaking, it was apparent that most of the concepts of Newtonian mechanics were lacking from these learners. The near-correct explanations by learners indicate serious knowledge gaps regarding Newtonian mechanics. Consequently, a prevalence range of 70% to 90% is common to learners, especially in South Africa (Table 4.3). This prevalence range emphasizes the commonness of misconceptions about force. Furthermore, this prevalence indicates that learners are more likely to hold misconceptions about force. We interpret the prevalence statistic as an indication of how deep common-sense beliefs and difficulties are in learners. Thus, 70% to 90% of learners have wrong Newtonian mechanics conceptions, do not master the content and are confused about what is taught in class. Indeed, this was confirmed to be the case during the FGDs which revealed learners' erroneous explanations to questions about force which were in stark contradiction to what is scientifically acceptable.

It is clear from this discussion that there exist discrepancies regarding learners' conceptions of Newtonian physics. Learners exhibit so many inconsistencies in their application of Newtonian framework. These findings replicate similar studies which showed that learners have a reliance on intuitive reasoning strategies when engaged in Newtonian discussions (diSessa, Roschelle & Smith, 1993; Halloun & Hestenes, 1985; McCloskey, 1983). For instance, the common sense belief held by learners about gravity is that as this impetus wears down, the projectile slows down and gravity takes over. The common belief held by learners is that gravity acts on the projectile after impetus has faded.

This is consistent with an intuitive physics whereby learners believe that there must be something keeps a projectile in motion until it dissipates. In view of intuitive physics, learners believe that forces cause motion, hence the rationale that if there is upward motion then there must be an upward force. Intuitive physics theory posit that naïve explanations for vertical projectile motion can be generated by a combination of p-prisms, namely, force as a throw or mover and a continuous force (Chi, 2005). During the FGDs, most learners provide answers to science questions by using correctly memorised words, hence when asked for explanations, these learners show failure to understand the underlying scientific concepts (Sciences, 1997). As explained by intuitive physics, the task of deleting an intuitive model completely and undoing a whole mental framework of knowledge is daunting for learners (Braun & Mislevy, 2005).Hence, to better understand the prevalence and commonness of the misconceptions, the origins of the misconceptions were probed.

It should be stated unequivocally that identifying the origins of learners' misconceptions is difficult at best. Nonetheless, it emerged from the FGDs with the learners that teachers have a high reliance on textbooks. Teachers and textbooks are commonly suggested to influence the development of misconceptions in science. These results validate previously voiced concern about how teachers and textbooks, amongst other sources, fuel learners' misconceptions (Simanek, 2014). Hence, we surmise that the origins of these prevalent misconceptions are teachers and textbooks. Although this study did not investigate the teachers of the learners within the sample nor the textbooks that learners use, we hold the opinion that the teacher factor is highly likely based on literature. For one, a learner made mention that the teacher “knows physics”, thus reflecting the teacher as an exceptional model in the eyes of learners. Certainly, one of the roles of a teacher is to be a learning area specialist. Similarly, it can be deduced that learners’ ideas have their roots from what they have been taught or from what the teacher has told them. Additionally, textbooks used by learners do not take into account possible misconceptions that learners might have. Thus, it might be difficult for teachers to identify possible misconceptions-prone topics based on their own background. Indeed, literature does reveal that teachers may be sources of misconceptions or propagators of misconceptions as determined by knowledge possessed by the teachers themselves (Marek & Yates, 2013). Consequently, what teachers teach and textbooks present barely convince learners because learners have not had sufficient experience with the ideas. This most likely leads learners to revert back to their intuitive science knowledge. Certainly, findings show that learners’ experiences and preconceptions are in contradiction to what they read in their textbooks and/or are told by their teachers. Beliefs resulting from personal experience, intuition, and “common sense” also lead learners to form their own ideas and models.

CHAPTER SIX: SUMMARY, RECOMMENDATIONS AND CONCLUSION

6.1 INTRODUCTION

In chapters four and five, an analysis and discussion of the data collected on learners' misconceptions about force were presented. This was done to answer the research questions of the study. The purpose of the study has been achieved by the presentation of a literature study on misconceptions about force and the analysis and interpretation of the results of the investigation.

This chapter presents a summary of the study. Conclusions are drawn about misconceptions held by learners, the prevalence of these misconceptions and the origin of the misconceptions. This is followed by recommendations on how to address misconceptions. The limitations of the study are pointed out and suggestions for future research are made.

6.2 CONCLUSIONS

An examination of the information gathered in the results of the study, indicates the following:

- Learners fare poorly on conceptual questions about Newtonian physics.
- Grade 11 learners hold extensive misconceptions about motion and force that are incompatible with Newtonian framework. These misconceptions are causal factors of poor performance on the FCI.
- There is a high prevalence of misconceptions about force concept amongst learners.
- A range of sources of misconceptions are indicative of deep-rooted origins which could be the determinants of the high prevalence of misconceptions amongst the learners

- It can be claimed to a certain extend that the high prevalence of misconceptions affected the performance on the FCI such that the two variables are directly proportional.
- Intuitive ideas that learners have are in disagreement with the Newtonian force concept and motion. Hence, there is more reliance on naïve physical beliefs. Also, learners mix expert physics with intuitive physics.

6.3 RECOMMENDATIONS

This study has exposed some areas of concern in the learning of force as a concept. As such, further investigation that might shed more light on the results of this study is suggested as follows:

- Innovative teaching strategies that teachers use to teach force as a concept need to be investigated.
- A similar study may be carried out in a school from a higher socio-economic, urban background.
- The same study may also be performed on physics teachers within the same population to determine misconceptions that teachers hold about force as a concept.
- An ethnographic study that spans two to three years that will study a cohort of learners from early physics might bring more light on teaching strategies versus prevalence of misconceptions.

In conclusion, more in-depth investigations are required to confirm or refute the findings of this research project.

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ANNEXURE A: Ethical Clearance of the University

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TURFLOOP RESEARCH ETHICS COMMITTEECLEARANCE CERTIFICATE

MEETING: 28 January 2015

PROJECT NUMBER: TREC/05/2015: PG

PROJECT:

Title:	Investigating Grade 11 learners' misconceptions about force in Maraba Circuit, Limpopo Province
Researcher:	Ms MD Mamashela
Supervisor:	Prof I Kibirige – University of Limpopo
Co-Supervisor:	N/A
Department:	Mathematics, Science and Technology Education
School:	Education
Degree:	Masters in Science Education

PROF TAB MASHEGO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**.

Note:
i) Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee.
ii) The budget for the research will be considered separately from the protocol.
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

Finding solutions for Africa

ANNEXURE B: Request for permission to conduct research

Enquiries: Mamashela MD
Contact : [redacted]
Email: temp4dina@gmail.com

P.O Box 5375
POLOKWANE NORTH
0750
03 June 2014

The Head of Department
Department of Education: Limpopo Province
POLOKWANE
0699

Sir/Madam,

<u>REQUEST TO CONDUCT A RESEARCH IN MARABA CIRCUIT</u>

Kindly, receive this letter as a request for permission to conduct research in schools attached to Maraba Circuit in the Capricorn District.

I am an MEd student at the University of Limpopo for the current year (2014). I am also a physical science teacher at Mphatlalatsane High School within Maraba Circuit. I have chosen six schools within the circuit for the research. The research is titled "**Investigating Grade 11 learners misconceptions about force in Maraba Circuit, Limpopo Province**"
I am available for any clarity at your convenience and I do hope that my request would be granted.

Yours faithfully,

……………………
Mamashela MD
[redacted]

ANNEXURE C: Approval from Department of Education

LIMPOPO

PROVINCIAL GOVERNMENT

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF

EDUCATION

Enquiries: Dr. Makola MC, Tel No: 015 290 9448. E-mail: MakolaMC@edu.limpopo.gov.za

P O BOX 5375
POLOKWANE NORTH
0750

MAMASHELA

RE: Request for permission to Conduct Research

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct a research has been approved- **TOPIC: INVESTIGATING GRADE 11 LEARNERS MISCONCEPTIONS ABOUT FORCE IN MARABA CIRCUIT,LIMPOPO PROVINCE.**
3. The following conditions should be considered

   3.1 The research should not have any financial implications for Limpopo Department of Education.

   3.2 Arrangements should be made with both the Circuit Offices and the schools concerned.

   3.3 The conduct of research should not anyhow disrupt the academic programs at the schools.

   3.4 The research should not be conducted during the time of Examinations especially the fourth term.

   3.5 During the study, the research ethics should be practiced, in particular the principle of voluntary participation (the people involved should be respected).

   3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

4. Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.

Page 1 of 2

Cnr. 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X9489, POLOKWANE, 0700
Tel: 015 290 7600, Fax: 015 297 6920/4220/4494

The heartland of southern Africa - development is about people!

5. The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes.

[signature] 25/07/2014

Dederen K.O Date

Acting Head of Department

ANNEXURE D: Validation of questionnaire form and experts responses for validating questionnaire

NEWTONIAN PHYSICS QUESTIONNAIRE

EVALUATION & REVIEW SHEET

This form must be used in conjunction with the NEWTONIAN PHYSICS QUESTIONNAIRE. Use the following ratings to review and evaluate the relevance of the question items to grade 11 (CAPS) content represented in the FCI instrument.

1 Not relevant

2 Somewhat relevant

3 Quite relevant

4 Very relevant

Place a CROSS (X) in the cell representing your evaluation. Provide comment for a score of 1, 2 or 3.

Question Item	**1**	**2**	**3**	**4**	COMMENT
1.					
2.					
3.					
4.					
5.					
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30.					

Thank you for your time and your expertise in reviewing and evaluating the questionnaire.

ANNEXURE E: Force Concept Inventory (Newtonian Physics Questionnaire) and Answer Sheet

Newtonian Physics Questionnaire

Please:

- Do NOT write on the questionnaire
- Mark your answers on the ANSWER SHEET that is provided to you.
- Mark only ONE answer per item.
- DO NOT skip any question.
- Avoid guessing. Your answers should reflect what you personally think.
- Plan to finish this questionnaire in **1 hour.**

Thank you for your cooperation.

1. 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 balls to reach the ground below will be:

   (A) about half as long for the heavier ball as for the lighter one.
   (B) about half as long for the lighter ball as for the heavier one.
   (C) about the same time for both balls.
   (D) considerably less for the heavier ball, but not necessarily half as long
   (E) considerably less for the lighter ball, but not necessarily half as long

2. The two metal balls in QUESTION 1 roll off a horizontal table with the same speed. In this situation:

   (A) both balls hit the floor at approximately the same horizontal distance from the base of the table.
   (B) the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
   (C) the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
   (D) the heavier ball hits considerably closer to the base of the table than the lighter ball, but not necessarily half the horizontal distance.
   (E) the lighter ball hits considerably closer to the base of the table than the heavier ball, but not necessarily half the horizontal distance.

3. A stone dropped from the roof of a single story building to the surface of the earth:

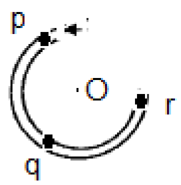
   (A) reaches its maximum speed quite soon after release and then falls at a constant speed thereafter.
   (B) speeds up as it falls, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.
   (C) speeds up because of the constant gravitational force acting on it.
   (D) falls because of the intrinsic tendency of all objects to fall toward the earth.

(E) falls because of the combined effect of the force of gravity and the air pressure pushing it downward.

4. A large truck collides head-on with a small compact car. During the collision:
   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car doesn't exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

USE THE STATEMENT AND THE FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (5 and 6).

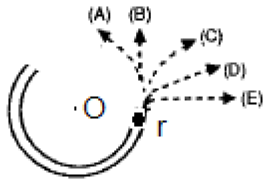
The accompanying figure shows a frictionless channel in the shape of a segment of a circle with centre at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r".



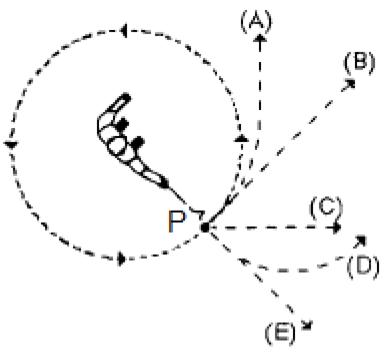
5. Consider the following distinct forces:
   1. A downward force of gravity.
   2. A force exerted by the channel pointing from q to O.
   3. A force in the direction of motion.
   4. A force pointing from O to q.

   Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?
   (A) 1 only.
   (B) 1 and 2.
   (C) 1 and 3.
   (D) 1, 2 and 3.
   (E) 1, 3 and 4.

6. Which path in the figure on the right would the ball most closely follow after it exits the channel "r" and moves across the frictionless table top?

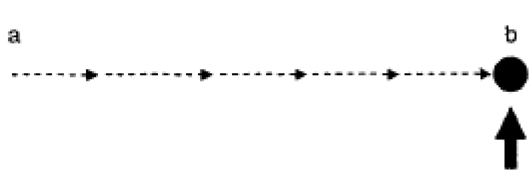


7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure.
At the point P indicated in the figure, the string suddenly breaks at the ball.
If these events were observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?

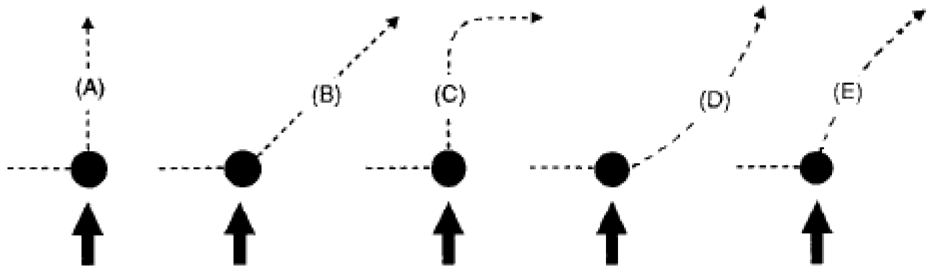


USE THE STATEMENT AND THE FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 to 11).

The figure shows a hockey puck sliding with a constant velocity v_0 from point "a" to point "b" along a frictionless horizontal surface. When the puck reaches point "b", it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point "b", then the kick would have set the puck in horizontal motion with a speed v_k in the direction of the kick.



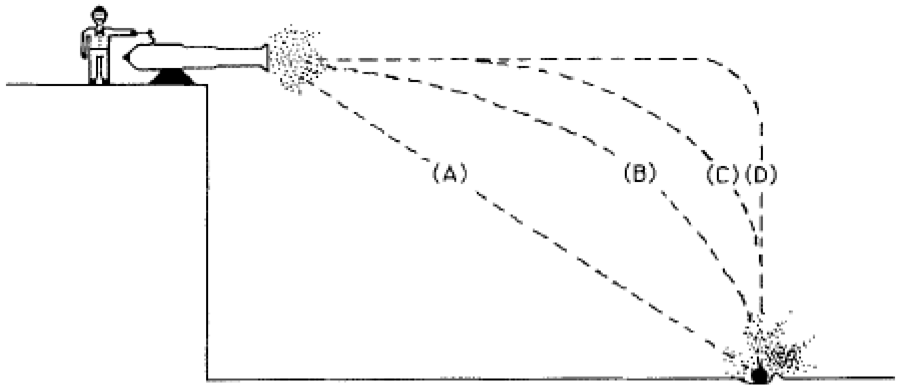
8. Which of the paths below would the puck most closely follow after receiving the kick



9. The speed of the puck just after it receives the kick is:
   (A) equal to the speed "v_0" it had before it received the "kick".
   (B) equal to the speed "v" it acquires from the "kick", and independent of the speed.
   (C) equal to the arithmetic sum of speeds "v_0" and "v_k".
   (D) smaller than either of speeds "v_0" or "v_k".
   (E) greater than either of speeds "v_0" or "v_k", but smaller than the arithmetic sum of these two speeds.
10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick:
    (A) is constant
    (B) continuously increases.
    (C) continuously decreases.
    (D) increases for a while, and decreases thereafter.
    (E) Is constant for a while, and decreases thereafter.

11. Along the frictionless path you have chosen in QUESTION 8, the main force(s) acting on the puck after receiving the kick is (are):
    (A) a downward force of gravity.
    (B) a downward force of gravity, and a horizontal force in the direction of motion.
    (C) a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
    (D) a downward force of gravity and an upward force exerted by the surface.
    (E) none. (No forces act on the puck.)

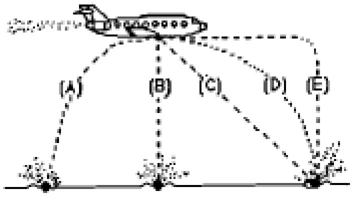
12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?



13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

(A) the downward force of gravity along with a steadily decreasing upward force.
(B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.
(C) An almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on th way down there is only the constant downward force of gravity.
(D) a almost constant downward force of gravity only.
(E) none of the above. The ball falls back down to the earth because of its natural tendency to rest on the surface of the earth.

14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. A seen from the ground, which path would the bowling ball most closely follow after leaving the airplane?



USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16)

A large truck breaks down out on the road and receives a push back into town by a small compact car.

15. While the car, still pushing the truck, is speeding up to get up to cruising speed:

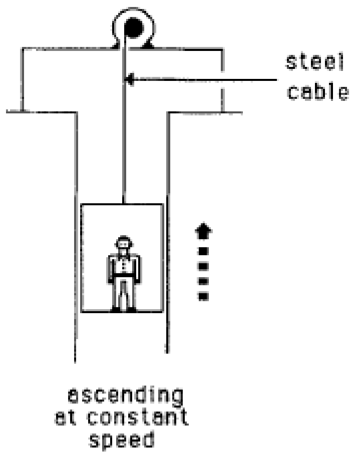
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
    (E) neither the car nor the truck exerts any force on the other. The truck is pushed forward simply because it is in the way of the car.

16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is the way of the truck.
    (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

17. An elevator is being lifted up an elevator shaft by a steel cable as shown in the accompanying figure.

All frictional effects are negligible.

In this situation, forces on the elevator are such that:



(A) the upward force by the cable is greater than the downward force of gravity.

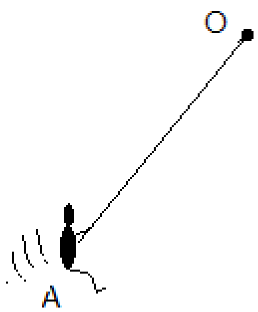
(B) the upward force by the cables is equal to that of the downward force of gravity.

(C) the upward force by the cable is smaller than the downward force of gravity.

(D) the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to air.

(E) none of the above. The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable.

18. The accompanying figure shows a boy swinging on a rope, starting at a point higher than A.



Consider the following distinct forces:

1. A downward force of gravity.
2. A force exerted by the rope pointing from A to O.
3. A force in the direction of the boy's motion.
4. A force pointing from O to A.

Which of the above force(s) is (are) acting on the boy when he is at position A?

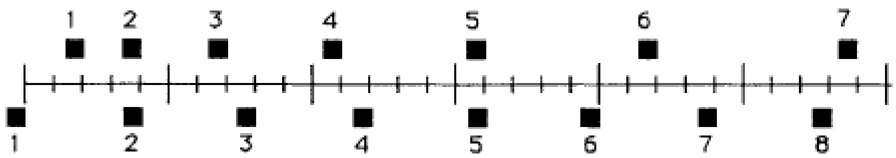
(A) 1 only.

(B) 1 and 2.

(C) 1, 2 and 3.

(D) 1, 3 and 4.

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



Do the blocks ever have the same speed?

(A) No.

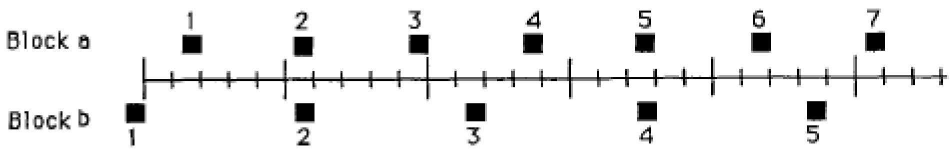
(B) Yes, at instant 2.

(C) Yes, at instant 5.

(D) Yes, at instant 2 and 5.

(E) Yes, at some time during interval 3 and 4.

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



The acceleration of the blocks are related as follows:

(A) The acceleration of "a" is greater than the acceleration of "b".

(B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.

(C) The acceleration of "b" is greater than the acceleration of "a".

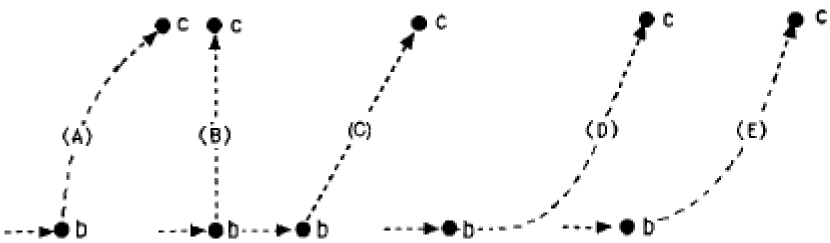
(D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.

(E) Not enough information is given to answer.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (21 TO 24)

A rocket drifts sideways in outer spaces from point "a" to point "b" as shown below. The rocket is subject to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to line "ab". The constant thrust is maintained until the rocket reaches point "c" in space.

21. Which of the paths below best represents the path of the rocket between "b" and "c"?



22. As the rocket moves from position "b" to position "c" its speed is:

(A) constant

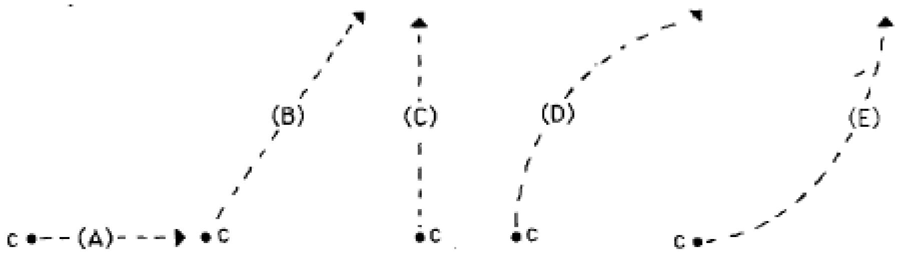
(B) continuously increasing.

(C) continuously decreasing.

(D) Increasing for a while and constant thereafter.

(E) constant for a while and decreasing thereafter.

23. At "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond "c"?



24. Beyond "c", the speed of the rocket is;

(A) constant.
(B) continuously increasing.
(C) continuously decreasing.
(D) Increasing for a while and constant thereafter.
(E) constant for a while and decreasing thereafter.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed "v_0".

The constant horizontal force applied by the woman:

(A) has the same magnitude as the weight of the box.
(B) is greater than the weight of the box.
(C) has the same magnitude as the total force which resists the motion of the box.
(D) is greater than the total force which resists the motion of the box.
(E) is greater than either the weight of the box or the total force which resists its motion.

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:

(A) with a constant speed that is double the speed "v_0" in the previous question.

(B) with a constant speed that is greater than the speed "v_0" in the previous question, but not necessarily twice as great.

(C) for a while with a speed that is constant and greater than the speed "v_0" in the previous question, then with a speed that increases thereafter.

(D) for a while with an increasing speed, then with a constant speed thereafter.

(E) with a continuously increasing speed.

27. If the woman in question 25 suddenly stops applying the horizontal force on the box, then the box will:

(A) immediately come to a stop.

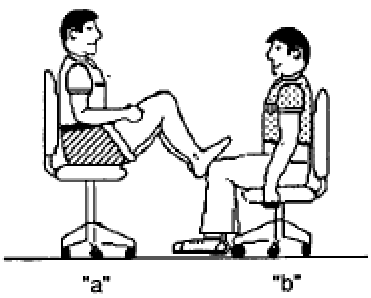
(B) continue moving at a constant speed for a while and then slow to a stop.

(C) immediately start slowing to a stop.

(D) continue at a constant speed.

(E) Increase its speed for a while and then start slowing to a stop.

28. In the figure below, learner "a" has a mass of 95 kg and learner "b" has a mass 77 kg. They sit in identical office chairs facing each other. Learner "a" places his bare feet on the knees of learner "b" as shown. Learner "a" then suddenly pushes outward with his feet, causing both chairs to move.



During the push and while the learners are still touching one another:

(A) neither learner exerts a force on the other.

(B) learner "a" exerts a force on learner "b", but "b" does not exert any force on "a".

(C) each learner exerts a force on the other but "b" exerts the larger force.

(D) each learner exerts a force on the other but "a" exerts the larger force.

(E) each learner exerts the same amount of force on the other.

29. An empty office chair is at rest on a floor. Consider the following forces:

    1. A downward force of gravity.
    2. An upward force by the floor.
    3. A net downward force due to air.

    Which of the following force(s) is(are) acting on the office chair?

    (A) 1 only

    (B) 1 and 2

    (C) 1, 2 and 3

    (D) 1, 2 and 4

    (E) None of these. (Since the book is at rest there are no force acting on it.)

30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.

    Consider the following forces:

    1. A downward force of gravity.
    2. A force by the "hit".
    3. A force exerted by the air

    Which of the above force(s) is (are) acting on the tennis ball after it left contact with the racquet and before it touches the ground?

    (A) 1 only.

    (B) 1 and 2.

    (C) 1 and 3.

    (D) 2 and 3.

    (E) 1, 2 and 3.

NEWTONIAN PHYSICS ANSWER SHEET

SCHOOL ____________ ☐ FEMALE ☐ MALE

Place a CROSS (X) on the letter representing your answer.

1.	**A**	**B**	**C**	**D**	**E**
2.	**A**	**B**	**C**	**D**	**E**
3.	**A**	**B**	**C**	**D**	**E**
4.	**A**	**B**	**C**	**D**	**E**
5.	**A**	**B**	**C**	**D**	**E**
6.	**A**	**B**	**C**	**D**	**E**
7.	**A**	**B**	**C**	**D**	**E**
8.	**A**	**B**	**C**	**D**	**E**
9.	**A**	**B**	**C**	**D**	**E**
10.	**A**	**B**	**C**	**D**	**E**
11.	**A**	**B**	**C**	**D**	**E**
12.	**A**	**B**	**C**	**D**	**E**
13.	**A**	**B**	**C**	**D**	**E**
14.	**A**	**B**	**C**	**D**	**E**
15.	**A**	**B**	**C**	**D**	**E**
16.	**A**	**B**	**C**	**D**	**E**
17.	**A**	**B**	**C**	**D**	**E**
18.	**A**	**B**	**C**	**D**	**E**
19.	**A**	**B**	**C**	**D**	**E**
20.	**A**	**B**	**C**	**D**	**E**
21.	**A**	**B**	**C**	**D**	**E**
22.	**A**	**B**	**C**	**D**	**E**
23.	**A**	**B**	**C**	**D**	**E**

24.	**A**	**B**	**C**	**D**	**E**
25.	**A**	**B**	**C**	**D**	**E**
26.	**A**	**B**	**C**	**D**	**E**
27.	**A**	**B**	**C**	**D**	**E**
28.	**A**	**B**	**C**	**D**	**E**
29.	**A**	**B**	**C**	**D**	**E**
30.	**A**	**B**	**C**	**D**	**E**

ANNEXURE F: Letter of Consent (English)

PARENTAL or GUARDIAN PERMISION FORM for RESEARCH INVOLVING a MINOR

TITLE OF RESEARCH: Investigating Grade 11 learners' misconceptions about force in Maraba Circuit, Limpopo Province

RESEARCHER: Dina Mamashela, Bed. (Hons), University of Limpopo Turfloop Campus

Dear Parent/Guardian,

Your permission is sought to have your child participate in the above study. Please read the following information carefully to help you decide.

Purpose of Study: The purpose of this study is to investigate grade 11 learners' misconceptions about force using the 'force concept inventory', in Maraba Circuit of Limpopo province.

Procedure to be followed: In stage one of the study, a 30 minute multiple choice test will be administered to your child. In stage two, your child will be interviewed within a focus group. This interview will be taped for the sole purpose of understanding the origin of common misconceptions about force, and will in no way be used negatively against your child.

Discomfort/risks: There are no foreseeable discomforts or dangers to either you or your child in this study.

Benefits for participants: There are no direct benefits to your child. However, the results of this study will add more knowledge on misconceptions about force to the general teaching fraternity.

Statement of confidentiality: All records are kept confidential and will be available only to professional researchers. If the results of this study are published, the data will be presented in group form and individual children will not be identified.

Voluntary participation: Your child's participation is voluntary. When the study commences, your child will once again be reminded of this by the researcher.

Termination of participation: If at any point of the study you or your child wishes to terminate the session, we will do so.

Signing the form below will allow your child to participate in the study without your presence. Please return by ______________. If you do not return the form, the researcher will understand that you do not wish to allow your child to participate.

PARENT SIGNATURE BOX

I, the parent or guardian of ________________________________, a minor,_____ years of age, <u>permit</u> his/her participation in the research study mention herewith.

__________________________________ __________________________

Signature of Parent/Guardian ***Date***

____

Please print your name here

ANNEXURE G: Letter of Consent (Vernacular)

FOROMO YA TUMELELO YA MOTSWADI GOBA MOHLOKOMEDI GO DIRA NYAKIŠIŠO LE NGWANA WA MENGWAGA YA KA TLASE

HLOGO YA NYAKIŠIŠO: Investigating Grade 11 learners' misconceptions about force in Maraba Circuit, Limpopo Province

MONYAKIŠIŠI: Dina Mamashela, Bed. (Hons), Unibesithi ya LimpopoTurfloop

Motswadi goba Mohlokomedi,

Tumelelo ya gago e a kgopelwa gore ngwana wa gago a tšee karolo go nyakišišo ye. Badišiša ka hloko tshedimošo yeo e latelago gore o kgone go tšea sephetho.

Morero ya nyakišišo: Morero wa thuto ye ke go nyakišiša ka dikwešišo tšeo di phošagetšego tša barutwana ba mphato wa lesometee ka ga kgapeletšo mo sedikothutong sa Maraba, profentsheng ya Limpopo.

Lenaneo leo le tlogo latelwa: Legatong la pele la thuto ye, hlahlobo ya kgetho ya dikarabo e tla lebišwa go ngwana wag ago tekano ya metsotso e masometharo. Legatong la bobedi, ngwana wa gago o tla botšišwa dipotšišo a gatišwa ka segatišamedumo e le leano la gore go kwešišwe hlolego ya dikwešišo tšeo di phošagetšego ka kgapeletšo gomme se ga se tlo šomišwa gampe kgahlanong le ngwana wag ago.

Go se iketle goba kotsi: Ga gona ponelopele ya go se iketle goba kotsi tše di ka bago gona go ngwana wag ago.

Dipoelothwii go batšeakarolo: Ga gona dipoelothwii go ngwana wa gago. Le ge go le bjalo, dipoelo tša thuto ye di tla oketša tsebo ka dikwešišo tšeo di phošagetšego ka kgapeletšo go barutiši ka kakaretšo.

Setatamente sa sephiring: Dingwalwa ka moka di tla ba sephiri gomme di tla humanwa feela ke banyakišiši bao ba dumeletšwego. Ge dipoelo tša thuto ye di phatlalatšwa, dipalopalo di tla tšweletšwa ka mokgwa wa sehlopa gomme go go ngwana o tee yoo a ka tsebjago.

Boithaopo bja go tšea karolo: Go tšea karolo ga ngwana wag ago ke boithaopo. Ge thuto e thoma, monyakišiši o tla gopotša ngwana wa gago gape ka se.

Tlogelo ya go tšea karolo: Ge sebakeng se se itšego ngwana wa gago a ka nyaka go tlogela go tšea karolo, re tla mo lokolla.

Go saena ga foromo ye ka mo tlase go tla dumelela ngwana wa gago go tšea karolo mo thutong ye wena o sego. Ka kgopelo bušetša morago foromo ye ka ______________________. Ge o se wa buša foromo ye, monyakišiši o tla kwešiša gore ga o nyake ngwana wag ago a tšea karolo mo thutong ye.

MOSAENO WA MOTSWADI

Nna, motswadi goba mohlokomedi wa _____________________________, wa mengwaga ya ka tlase ye __________, ke mo dumelela go tšea karolo mo dinyakišišo tša thuto ye e bolelwago mo.

_____________________________________ _____________________________

Mosaeno wa motswadi/mohlokomedi ***Tšatšikgwedi***

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Hle, ngwala maina a gago ka dihlaka tše kgolo mo

ANNEXURE H: Interview schedule

For starters, do you guys know who Isaac Newton is?

Scenario I: A box is being pushed along a smooth horizontal surface with constant force. The applied force is removed. Describe the motion of the box.

Scenario 2: A person runs on a smooth, horizontal, clean and polished platform. The person realizes when he is a small distance from the end of the platform that at the end of the platform, there is a poodle of muddy water. Will the person be able to stop? Explain.

Scenario 3: It is on a rainy day, thus the road is slippery hence less friction. A car moves with constant velocity along a straight level (tarred) road that curves sharply towards the end. Explain the motion of the car.

Scenario 4: A big truck collides head-on with a Toyota Tazz. What can you say about the force that the truck exerts on the Tazz when compared to the force that the tazz exerts on the truck?

Scenario 5: An object is thrown vertically upwards. Identify the forces acting on the object after it has left the thrower's hand. Also, compare the speed of the ball when it is going upwards and its speed when it comes downward.

In conclusion, is there anything that you would like to explain or clarify?

ANNEXURE I: Interview transcripts

R: **For starters,** do you guys know who Isaac Newton is?

L 1: He is the first person to discover that there's gravitational force when he saw an apple fall even when there was no wind

R: And how do you know? Where did you hear that information?

L 1: I saw it in grade 12 book. *He wanted to I think he's the first person woo e leng gore o nyakile go tseba gore why apola e wa.*

R:okay. O'ryt and then what is everybody saying? Where did you, what is (inaudible) about Newton? Feel free. We're discussing a ke re. There's no right or wrong answers. Remember that a ke re. And I want you to be active a ke re. What do you know about gravity, I mean Newton?

L2: nna I know newton to be a person who came about with four laws of physics. Newton 1st law, newton's second law… of motion, newton's third law of motion and newton's law of universal gravitation

R: okay. And then what is your source of information?

L2: nna ntwe, these laws I learnt them this year.

R: okay and then before that you've never heard of newton?

L2: no

R:anyone who heard of newton before grade 11?

L3: in grade 9

R: in grade 9?

Ls:yes

R: what were you talking about in grade 9?

L3: ne re studisha diforce, then ra humana e le gore e nngwe ke gravitational force. Ee ke moo ra nampa re tsebile ka newton

R: okay. L4? O tsebile ka yona when?

L4:erm absolutely in grade 8 coz erm this guy o be a dia physics then that's the subject ye e lego gore kgale ke e rata coz… {video stopped}

{video resumed}

L4: maybe

L5:maybe they didn't check it

R: what if erm ka nako tsela a ke no re in the past neh before you knew about gravity and so on neh. You hold something and then you release it and then it falls. What would be your explanation in the past?

Ls:because of air

Because you released it.

Because o e lesitse yaw a

Ga e na balance

R:oyoo your hands di be di offera balance?

L4: and also e na le weight. Like weight, weight ya yona

R: weight ke eng? Go ya ka wena what is weight?

L4:weight ke… go ya ka nna like now goba ka nako tsela?

R: ka nako tsela? Ok, ka nako tsela and now neh

L4:ka nako tsela e be e le something that is big and huge, something that you can hold like it has weight.

R: okay. Go ra gore ka nako tsela feather e be e sena weight? Lefofa

L4: no e be e se na weight

R: okay. And then now?

L4: now just because of I know a lot about erm newton's law and other things I can see that… I can also differentiate between mass and weight

R: ok. So in the past this knowledge that you had it just came nje?

Ls:yes

R:I get that. Ok. Erm.. right. Let's look at this question now. Er, when a , a truck. A re boleleng ka ya SAB ya brewery, le a e tseba mos.

Ls:Ee

R:er e thulana le a tazz head-on. Okay. Can you tell me what would happen?

L1: The tazz will crash

R: will be squashed.

Ls:mm

R:okay. And now can you tell me about erm why?

L1: because of the weight of the truck.

R:weight?

L4: yes

R: what do you mean by weight?

L4:erm… I mean the mass of the truck is high, the mass of the tazz ke o monnyane

R: okay. Anyone else? Do you agree with her? Do you agree with her? Hmm? Do you agree with her?

L5: sometimes di tlo dependa ka speed se di tsweletseng ka gona like (clash/clap/crash sound with hands) di a squasha

R:ok. What can you say about the force that the truck exerts on the car when you compare it with the force that the car exerts on the truck?

Ls: they're equal but opposite in direction

R: okay. Do you understand what you're saying?

Ls: yes

R:are you sure

Ls:yes

R: okay. In the past. I'm always going to refer to in the past neh.

Ls: yes

R: especially when you were writing that test. Okay. Most of you said that the force of the truck… the force that the truck exerts on the car would be greater than the force that the truck…erm.. that the car exerts on the truck. Okay. Erm, how many of you chose that option?

Ls:we don't remember.

R:you don't remember?

Ls:yes

R:but were you likely to choose that erm option? Gore the force of the truck is greater than when koloi I mean truck e thulana le tazz the force ya truck e greater than the force ya nthwe ya the car?

L6:nna go ya ka nna if I didn't know newton third law of motion kgale ke tlo no chooza that option.

R:ok. Go bo chooza that option o be o informa ke eng?

L6:ke lebeletse gore trucka ke e kgolo e ne tazz ke e nnyan so kgale ke tlo re force ye lego gore trucka ya e exerta mo tazz ke e ntshi.

R:ok. L7?

L7: le nna go ya ka nna e ke tlo no re ka gore trucka ke e kgolo en koloi ke e nnyane e ke tlo no chooza option yela ke lebeletse mass wa tsona.

R:okay. I get it. Erm…will that information ye le sa tswang go mpotsa yona ya third law , will it apply between a truck ge e thula a cat?

Ls:yes

R:okay. What is your source of information? How do you know this?

Ls:because of third law

R:okay. When did you hear about newton's third law?

Ls:this year

R:you heard it from? You heard it or you read about it or?

Ls:we read about it

R:so your source of information is a book?

Ls:yes

R:ok. Right let's talk about er when you throw a ball up. Ok. A ball. Let's say this pen, a ke re. I throw it up. It goes up. Ok. After it… let's talk about the moment after it has left my hand, a ke re. A ke re ke e foshitje e tlogetse seatla sa ka?

Ls:ee

R:ok..er, ignore friction, a ke re. What are or what is the force…ok… what are the forces acting on the ball after it has left my hand? Or what is the force? Maybe go na le many maybe go na le … it's an individual

L8:er normal force

L2:le applied force e tsamaya in the same direction le normal force le normal force. Le, ee, normal force. Yo acta perpendicular to the surface. A ke re e tloga mo e ya godimo yo acta in the same direction normal force le, le, ba re ke eng? Force applied.

R:ok. O mongwe. So go ya ka wena ke two forces?

L2:Ae le force of gravity

R:ok there are three forces.

L2: force of gravity e acta downwards

R:and the other one?

L2:e acta upwards

R:eng le eng?

L2:force applied and le normal force

R:ok. O mongwe. Ka moka ga lena you're saying that?

Ls:Yes. (inaudible)

R:ee, we've ignored friction a ke re, air resistance. Right. How do you know? What is your source of information? Le tseba jwang se?

LP:We've learnt it from Study and Master grade11 book in grade 11.

LS: And the teacher

LP:O re boditse gore there's always a normal force

R:ok. The teacher and the book hey

Ls:Yes

R: what makes the ball to come back?

Ls:gravity. Gravitational force. Force of gravity

R:force of gravity?

Ls:yes

R:ok. Can you comment about…er wa compara a ke re. the speed of the ball, of that object ge e ya godimo le ge e boa

LM:ge e ya godimo a ke re tla be le e file start, e tla ya ka velocity, ka speed se se ntshi then ge e boa ka gore tla be e goga ke gravity e tlo boa mara tlabe e sa tshwane ka speed se sennyane go swana le ge le e fosha

R:how do you know? What is your source?

LM:a ke re go na le force, le exerta force ka go e fosha. Ge e boa a ke re ga gona motho wa go e phushetja fase mara force of gravity ya e goga e ka se boe ka speed sela sa ge e ya godimo because of force of gravity.

LP:ke gore ge e ile godimo speed sa gona a se gore ke se segolo, a se gore ke se sentshi like … jah ge e boa fase ke mo e lego gore e tla boa ka speed segolo than ge e ya godimo

R:why?

LS: because… ka gore ge e ya godimo ak ere friction , joh, le rile re ignore friction, ge e ya godimo ke fila o ka re e goga boima go ya godimo cos gravity e e phushetja fase.

R: o re o fila o ka re?

LS:ae, ke bona o ka re, ke bona o ka re

R:o bona o ka re?

LS:ee

R:o sure or you're not sure?

LS:ke sure

R:gape ge o re o bona o ka re

LS:mara ke sure

R:o sure. Ok

LP:le gona ge e fihla ko godimo go tloba le speed limit… jah… a ke re ge e fihla yo ema like..go tlo ba le mo e le go gore yo ema gona cos ga go sana motho wa go e phusha, then ya boa fase via gravity

R.ok.. LT? o agreeya le yena?

LT:ee

R:ge a reng?

LT:ge o foshetja ball yela kwa godimo a ke re e ka se sa boa ka speed sa go lekana le ye e tlo boang ka sona. Ye e yang ka sona e tlo ba fase se sennyane go ye e tlo boang ka sona.. ka gore ge e leka go ya godimo gravity yona e e gogela fase.

R:guys. Ka moka you have different thoughts? LTh?

Lth:same as that one cos…er ahem…like the way LP a boletseng ka gona the speed seo e lego gore like se yak o godimo like se tlo se tlo diang? Go na le gravity. Only if o release ball o e isha godimo gravity e acta on that ball and then that's the force yeo e lego gore e tlo e phushetja down and then ge e ya godimo e ka se be.. e ka se ye ka the speed se elego gore se tlo feta sa ge e e ya fase

R:how do you know this? What is your source of info? Le ya agria LD? How do you know? What is your source of information

LP:dibuka since from grade 9 we learnt ka gravity. Le our teacher maám. Like we learnt ka gravity. Grade 10 gravity. Grade 11 gravity. So now it makes sense. Re na le… ke gona re … re na le much information now. Gore re kgone go explaina more compared to before re fihla go grade 11.

R:ok. Before grade 9 hey. Of course things used to up le playa .. er..bathi yela ya go isha ball godimo, e sa ile godimo someone must come and catch it lena le a tshaba . When that ball goes up, ok, le e ishitje godimo ka mokgouwe le tshaba ke gore le ra gore ..er, er… le a tseba gore e tlo boa a ke re.

Ls:yes

R: e ne gora gore le determined gore ge e ya godimo e ya ka speed se se itjeng e re re kitime ka speed before e boa. I'm just asking a kere . so before grade 9 what was your explanation ka that thing?

LS:e tsea ke moya. Moya o tlo e busha.

R:Moya jwang?

LP:No ge e foshitje obviously swantje e no boa

R:oyoo, it was obvious

Ls:eng e ka se ele sa ruri. Ke nto e natural. Everything that goes up must come down

LTh:le weight ya yona. Including the weight.

R:ok. Gora gore ge nkebe e le lefofa ka le foshetja godimo le ka se boe?

Ls:aowa lo boa. Lo no boa maám.

R:le tlo no boa?

Ls:ka slow motionnyana so. Gannyane. Lo tjea nako gore le boe. Mara le tlo boa. Via what goes up comes down

R:so kgale le be le no tseba gore its natural, e obvious . ok. Right. Let's look at this one. I am pushing a box neh. On a smooth horizontal surface. Ok. I'm pushing this box, the box …er… obviously it will move a kere.

Ls:mm

R:why le moova?

LS:because there's an applied force to the box.

R:so I push this box ka a constant force. A ke re. Gora gore ke e phusha ka the same force throughout. A ke re. How will it move? How will it move? E tlo phakisha or how will it move?

LS: it will move constantly until it stops.

R:it will move constantly until it stops? E stopisha ke eng?

Ls: ke force e leng gore ke… ah ke friction

R:oh? Ke a e phusha a ke re. le ge nka e phusha jwang kapa jwang friction e tlo e fenya?

LS:ka gore applied force … go ya le gore force ye e aplailweng ke e kaakang. Ge nka re e le mo ka applaya force e ntshi e ka no stopa e e tla kua

R:maybe you do not understand my question neh. I am pushing a box starting from here. I am pushing this box with a constant force. What will happen to the box? …It will move how? Ka constant speed. Ok? E tlo ema?

LS:ge le ka e lesa e tlo ema.

R:e tlo ema ge nka e lesa ne.

Ls:Yes

R:now I leave it. Will it stop immediately? Remember ke rile on a smooth horizontal surface neh. Will it stop immediately or will it move for a while before it stops?

Ls:it will move for a while before it stops.

R:How do you know?

LP:because it's a smooth surface and there's less friction

LTh:it will stop immediately. Because maám a se re exclude difriction and er other forces a ke re.

R:go ra gore friction is part of the system it will stop immediately. How do you know?

LSe:friction le yona e removilwe a ke re. ba e tloshitje, ga go sa na nto ya go e phusha. E ne friction a ke re e gona e acta opposite le mo ntje e ya le applied force. And applied force e removilwe. There's no way e ka no tswela pele le go tsamaya

R:ok. How do you know? What is your source of information?

LTh:um..um..friction… my source of information ? The book. Cos of I know gore friction e acta opposite to the applied force a ke re. and maám immediately you leave it friction opposes it so friction is the one that …eish maám already e tlo no ema. Unless e le steep. But then even if its smooth.. eish maám. But le a nkweshisha a ke re.

R:buka e realo? Your book says that? Or ke ka mokgwa woo wena o iego wa ikweshisha ka gona?

LTH:Ee

R:ok. And those of you who say it will move gannyane before

LD:er,nna ke re it will move gannyane then ya stopa because go ya ka mokgwa wo ke kweshishang ka gona on a smooth horizontal surface gona le less friction. So ge e ya ko pele e tlo.. e ka se stope immediately. Friction ya gona a se gore … e tlo no ya namile friction ya kgona e le gona e

R:E ne o tseba se jwang? What is your source of information?

LD:a book.

R:the book. Yes LK

LK:nna ke re e tlo tsamaya gannyane . ge o se no fetja go e phusha a ke re e tlo tsamaya gannyane before e stopa ka gore le newton's second law ya bolela gore ge resultant force e exertiwa mo objecteng e tlo causa object yeo gore e accelerate ka direction yeo ya resultant force ak ere. And ntwekhi, a ke re friction e acta in opposite direction e ne friction e ka se no re ntwe e ye o e lesa so ya no thoma le go acta, e tjea nako gore e phushetje morago e istopishe

R:and um what is your source

LK:ke buka

R:ok. LP

LP: same answer ya LD via it's a smooth surface less friction but friction yona it's always there. A e depende gore.. er… tla be e thomile kae goba bjang as long as re se e ignore e gona kua but boroughness..if it's soft it will keep on moving le a bona mara on a less friction. Le gona if nka be ke sena mind yow a di friction and so on via it's soft e tlo no moova la bona maám ya fihla ya ema

R:ok I hear you…er ke nyaka go ya back to…er..LK. o nkwele gore ke rile constant force neh. Ba re g eke applaya constant force e tla moova with a constant velocity. O wa agrea?

LK:er…ee

R:are you sure

LK:ae

R:you're not sure. Go ya ka wen age ke applaya constant force yo moova jwang?

LK:a ke re maám ge le applaya constant force e ra gore le tlo ba le change in magnitude a ke re , namile change in magnitude e cause change in velocity ka mokgwa wo nna ke kweshishang ka gona

R:ge ke applaya constant force goba le change in?

LK:magnitude

R:magnitude ya eng?

LK:ya , eish, a ke tsebe

R:ga o sure

LK:a ke sure

R:what is your source? Ka mokgwa wo wena o kweshishang ka gona?

LK:ka mokgwa wo nna ke kweshishang ka gona. Nka no re ke buka

R:anything you want to say?

LS:Yes. Nna I think gore e tlo continua go moova in a constant velocity because there is no external force unbalanced force yeo e lego gore e acta on the box

R:mara e tlo ema?

LS:ee e tlo ema

R:ge ke seno e lesa e tlo ema?

LS:ae e tlo moova for a while ya kgona e stopa because ga go sana an external unbalanced force ye e lego gore e acta on the box

R:er... I want to talk about someone who is running on a.. let's say mo stupung. Se clean se pholishitjwe. Motho o tswela a kitima a ke re. then kua go na le meetse ka kua pele mo at the end go na le meetse a mantshi a maraga maybe ba lahletje le *mabotlelo ka mo gare. This person o lemoga a e tla mo grade 12 gore kua gona le…ai a re reng o lemoga a e tla mola …er…a etla mola lefastere la mafelelo la ofisi ya principal a ke re. ok stoep se se. yena o tla mo, o lemoga a e tla mo gore felo ka mo gona le meetse. O a ema. Will that person stop immediately?*

Ls:No

LS:because of inertia. Ee. Mmele wa gage o be o shetje o tlwaetse go tsamaya ka that constant velocity then go fihla kua…go no swana le ge o le ka gare ga koloi a ke re. A ke re re eme so ra ya ya sepela. Ge e fihla e ema ro ya kua ka moka, yona e ema

R:So motho ola o diang? O tlo wela ka kua gare ga meetse?

LS:ee, ga go no re a ka ya morago goba a ema o tlo wela ka kua

R:And how do you know this? What is inertia by the way?

LS:the tendency of an object to to maintain

LP:to maintain to resist to

LD:it's state of motion

LP:constant motion…velocity

R:ok. And what is your source? How do you know that?

LP:Newton first law

R:and where did you hear about inertia?

Ls:in grade 11

R:oh this year

Ls:yes

R:ok. And who or what is your source of information?

Ls:the book

LS:nna ke shomishitje study and master sela se sengwe se se blue plus the teacher

R:plus the teacher

Ls:yes

R:um, anyone else? Ok then, the last question neh. Ke yela ya curveng. A ke re. O'ryt? It's a rainy day. We want to ignore friction neh. Right. Koloi e tjwelela e sepela ka constant velocity. Ok? Right. E ya in this direction. O'ryt? Ge e fihla mola… e tjwelela, a ke re e tsamaya ka constant velocity ya 100 $m.s^{-1}$. A ke re. Ene it's on a rainy day. Ok. We've ignored friction. In other words on a rainy day gora gore friction is very little, negligible a kere. So we have ignored friction. Ok? So koloi yela ge e fihla at the start of the curve: can you say something about the motion of the car *when it gets at the start of the curve. .. E tjwelela e tsamaya ka constant velocity ya 100 $m.s^{-1}$. A ke re? Then ge e fihla at the start, ke nyaka o bolele ka motion of this car at the start of that curve.*

LP: e tlo moova ka… eh.. e tlo moova ka the very same ..mmm… e tla moova ka …er… if e tjweletje ka constant velocity if motho wa gona e se a dire tse a di dirileng, e tlo no moova via force.

R:e moova how? E tlo tsena curveng or e tlo ya straight?.

Ls:e tlo ya straight.

R:e tlo ya straight?

Ls:ee

R:why e e ya straight?

LP:because of Newton's second law which says when a … when a resultant force is exerted on an object, it causes the object to move in the direction of the exerted force

R:so this this car ya go tsamaya ka constant velocity , law ye e applayang ke second law?. I just want to understand.

LP:eerm. I think. Jah, I think ke second law.

R:ok. And what is your source of information?

LP:ka gare ga buka e ka go grade 11 mo go newton, ge re bolela ka newton re camile across Newton second law.

R: e hlalosa ka mokgwa yona wouwe gore koloi e tla moova like this

LP:According to my understanding.

R:oh it's your understanding?

LP:yes

R:of what you learnt in the book. O mongwe? Ge e fihla e tsamaya ka constant velocity … ge e fihla at the start of the curve: do you want to say something different from hers? Or?

LD:I think ke Newton First law… because e re an object will continue to move at constant velocity until an external force acts on it.

R:ok. So e tlo moova jwang?

LD:e tlo no sepela ka 100

R:$m.s^{-1}$. Ke ra gore ke curveng a ke re? e tlo tsamaya jwang.. so

LD:straight

R:oh straight

LD:ee

R:ok… right… er,now let's say this car at this point, ok, ya turna, ok e curva botse le this curve, ok. Ge e curva botse mola what can explain gore what makes that car gore e tsene botse mo curveng e tsene pila gabotse.

LSe:e ra gore speed se decreasitse

Ls: o fokoditje speed

R:o fokoditse speed?

Ls:ee

R:ok. O fokoditje speed feela?

LS: le direcshh…

R:so o changitje direction e bile o fokoditje speed?

LP:ee o fokoditse speed

R:oh? O sure gore o fokoditje speed? O ka se turna curveng without go fokotja speed?

LP:mara a ke re pula ya na? so for safety, swanetse a no turna botse maám

R:wa turna?

LP:yes

LSe:e ne o hafola speed a kgone …

R:oyo, o swanetse a fokotje speed before a curva botse

Ls:ee

R:ok. Go fokotja speed mola go affecta jwang that constant motion?

LS:yo decreasa, ga e sa ba speed sela sa 100

R:ke kwa le bolela ka di laws. Ke nyaka go tseba gore which law, which law applies there? And how do you apply that law to that situation?

LL:nna ke nagana o ka re e tlo ba newton second law… ee, a ke re wa bona tla be a fokoditje speed, that means e tlo no curva botse

R:ok. E ne your source ke eng:

LL:the book

R:the book? Ok.

LP:newton 1 , newton 2 di applaya ka moka.

R: newton 1 le newton 2 ka moka ga a curva mola? .

LP:ee, a ke re o movile ka constant velocity … ijoh, he? Ah, no comment

R:ok. Is there anything that you want to talk about? Anything else that you still want to talk about? None?

LP:is it allowed wrong if rena re le botjisha question e nngwe?

R:ee, botjisha

LP:yona ye le re botjishang yona. Ge rena re ka le botjisha yona, is it wrong? Is it allowed?

R: ee, it's allowed.

LP: lena le nagana eng maám?

LL:go ya ka lena maám

R:go ya ka nna?

Ls; ee

R:ok, I'll come back to that. Let's talk to

LTh: ee nna kgale ke nyako botjisha. A ke re le re ntwe e tjwelela like in a constant speed

R:ee speed

LTh:gwa ba le curve mokhwi, le nyaka gabotsebotse le nyaka bontjha eng?

R:ee, the curve. Ge a , ge a ka tsena botse mola curveng , I want to know gore what enables this car to be able to enter the curve nicely

LTh:ke kgopela go botjisha. Definition ya inertia e reng?

R:Ask them

LD:The tendency of an object resist its state of motion

LP:Ge a khona o curva ka the shape ya the curve

R:Ge a tsene botse ka mokgwa wola gora gore go diregileng? Like what yu're saying LTh o nyako kweshisha gore go diregileng

LL:mara swanetse a no ba prepared gore go na le curve mola a nne a ke tokisha . ke ra gore a tsebe gore go na le curve. Le ge e le gore speed sa gona ke se sentjhi o tla

R:ke ra gore o kgonne jwang gore a tsene botse mola curveng

LL:O iketlile

LK:tla be ntje a shomisha the same speed maám. Go no swana le mozwinki ola wa go sepela so. Le re ke eng? Roller coaster. A ke re o shomisha same speed go fihlela o fetja… ema pele… nto ela a ke re e tsa.. e thoma mola mathomong, o draya, o tlo no dray aka speed sela a thomileng go draya ka sona le mathomong go fihlela e fihla mafelelong

R:Is the situation the same as what we are explaining?

LK:a ke re mara maám

R: This is the road neh. The road še. E tjwelela kua from LK neh. It's a straight road form LK. The car moves with a constant velocity. A ke re. So nna I wanted to know gore this car e tle e tsene botse mo curveng without incidents what should happen?

LTs:A controle steering botse, a se tsentje mo tseleng

LK:mo e curving botse. Like . a ke re maám ke curve so. A ka approacha mo curveng, a ke re curve e so, a approache mo kgauswi so e tlo no tsamaya a the same speed

R:is that your understanding or its's that a source, go na le source e nngwe

LK:ke no nagana jwale

R:o no nagana jwale? Mhhm. Is there anything that you want to talk about?

LP:re nyaka ya lena

LSe:before le dira re kgopela go kwa ya lena ka mokgwa wo lena le e boning

R:ok, that means we have come to the end of the session. You can stop it.