Mapping Science Teachers' Knowledge of Force and Momentum to Classroom Practices in Selected Schools in Lesotho

by

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Declaration

I, 'Maphole Georgina Marake, declare that the Doctoral Degree research thesis, **Mapping Science Teachers' Knowledge of Force and Momentum to Classroom Practices in Selected Schools in Lesotho**, that I herein submit for the qualification of a Doctoral degree at the University of the Free State, is my own independent work.

All the references that I have used have been indicated and acknowledged by means of complete references.

I further declare that this work has not previously been submitted by me at another university or faculty for the purpose of obtaining a qualification.

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M.G. MARAKE DATE

Abstract

This study used a mixed methods explanatory sequential design to investigate physical science teachers' perceptions of their knowledge of force and momentum to establish how it shapes classroom practice, if at all. The study sought to determine the teachers' knowledge of: the science curriculum, how students understand science, instructional and assessment strategies, as well as their orientations towards teaching science. The research question that guided this study was, what is the knowledge base of science teachers in Lesotho on the topic of force and momentum and how does it shape classroom practice in grade 11? A survey of ninety-two physical science teachers, who were randomly sampled from five districts, was done. Out of the surveyed teachers, three were purposefully sampled and observed as they taught the concepts of force with the purpose of establishing the knowledge domains they realised when teaching. A follow-up interview was done with each of them in order to ascertain whether their classroom decisions were motivated by what they do or do not know. Moreover, the teachers' lesson plans and physical science syllabus were analysed. The findings of the study revealed that, although the teachers had positive perceptions of the knowledge needed to teach the concepts of force, their practices were not influenced by them; rather, various aspects in the field and during teaching determined what they did. Even within the knowledge domains that were found to influence their practice, there were variations in how the teachers realised them. The findings also revealed that the mismatch between perceptions and practice was the result of little or inadequate reflection-on-practice by the teachers, as it was found lacking. The study therefore suggests that teachers should be assisted in continuous reflection-on-practice, as that has been proved to assist teachers to develop their PCK, thereby being able to realise and integrate most of the knowledge domains during practice.

Keywords

Teacher knowledge; pedagogical content knowledge; force and momentum; classroom practices; perceptions

Dedication

I dedicate this thesis to my late father, Sentebale Cletus Kuleile, and my mother ‘Maliemiso Grace Kuleile, who gave me the opportunity to go to school and instilled in me the love for education.

I thank you very much for your unconditional love, support and prayers for me to succeed in life.

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List of Acronyms

CAP	Curriculum and Assessment Policy
CK	Content Knowledge
CM	Concept Maps
CoRes	Content Representations
CTR	Committee for Title Registration
FBD	Free Body Diagrams
FCI	Force Concept Inventory
ID	Interaction Diagrams
KSU	Knowledge of Students' Understanding
LCE	Lesotho College of Education
LGCSE	Lesotho General Certificate in Secondary Education
LP	Learning Progression
MoET	Ministry of Education and Training
NTL	Newton's Third Law
NTTC	National Teacher Training College
PCK	Pedagogical Content Knowledge
PD	Professional Development
PeP-eRs	Professional-experiences repertoires
pPCK	Personal Pedagogical Content Knowledge
RIMS	Research Information Management System
SD	Self-Diagnose
STC	Secondary Teachers' Certificate
TSPCK	Topic Specific Pedagogical Content Knowledge

Chapter 1.
Introduction

1.1. Introduction

It is commonly believed that science education is essential for all citizens as it has the potential to provide them with the necessary knowledge and skills to effectively participate in their communities (Aksoy, 2019; Şen& Sari, 2017). All science subjects, including physics, are essential as they provide students with the knowledge and skills that are essential to understanding the environment. However, teaching science depends on many factors, such as the teachers' knowledge base and their perceptions of that knowledge base (Moodley & Gaigher, 2017).

People experience most concepts in physics while interacting with the environment and this leads to the development of an intuitive understanding, most of which is incongruent with accepted scientific knowledge (Develi & Namdar, 2019; Hestenes et al., 1992). Moreover, physics is abstract in nature, hence most students find it difficult to understand (Maharaj-Sharma & Sharma, 2017). Among the concepts in physics that pose challenging for students to understand are the concepts of force. Students experience them in their daily lives; hence they bring their own unscientific understandings to class, which consequently become a barrier to their scientific understanding (Liu & Fang, 2016; Hammer, 2000).

Students' background knowledge about force, as well as the abstract nature of force concepts, pose challenges in teaching them, hence science education researchers probed into how best these concepts and the factors that affect how they are taught. Much research focused on teachers' knowledge to teach, perceptions of teachers' knowledge and how they relate to classroom teaching (Azam, 2018; Barendsen & Henze, 2017; Herman et al., 2015; Kapucu and Yıldırım, 2012). Nonetheless, researching teachers' perceptions of their knowledge base is challenging, because what teachers report to know or do, does not guarantee that it will translate into practice (Gess-Newsome & Lederman, 1995; Moodley & Gaigher, 2019; Park et al., 2016).

Despite the lack of relationship observed between teachers' perceptions of knowledge and practice, more research on the two constructs is still in progress, especially with pre-service science teachers (Aksoy, 2019; Du Plessis, 2020; Sadoglu & Durukan, 2018). Even while still learning to teach, pre-service teachers have their own teaching philosophies, though they are not yet fully developed (Du Plessis, 2020). Therefore, revealing these philosophies and helping teachers to develop those that promote effective teaching is mandatory, hence research on teachers' perceptions of their knowledge base is done mainly with pre-service teachers. In-service teachers have already developed perceptions about teaching. As such, establishing what they are and how they relate in practice are important to know so that their practice could be understood. For instance, Wei and Li (2017) investigated science teachers' perceptions of experimentation for the purpose of restructuring school practical work. Cheng et al. (2016) investigated in-service teachers' perceptions in order to inform teacher education.

As a physics school inspector, my work is mainly to monitor the teaching and learning of physics in schools. I have noticed that there are similarities in how physical science teachers teach physics. These include how they plan to present the lessons as well as the actual teaching. Their teaching is characterised more by the teacher talking while the students' participation comprise copying notes and responding to the teachers' questions.

The Lesotho Curriculum and Assessment Policy (Lesotho MoET, 2008:17) is a framework aimed at guiding the transformation of teaching and learning including assessment at primary and secondary levels. It highlights the competencies that students should be helped to develop. Some of those competencies are "effective and functional communication; problem-solving; scientific, technological and creative skills as well as collaboration and cooperation." A close inspection of these competences indicates that, in order for teachers to be able to assist students to develop these competencies, they should first have the knowledge and skills to enable them to do so. This research study arises from my personal but un-researched observation that physical science is mainly taught through traditional teacher-centred strategies that are unlikely to help teachers realise the role of helping students to develop the competencies as articulated in the Lesotho CAP. Accordingly, the present study intends to answer the following questions: What do physical science teachers believe they know about the teaching of force and momentum? Which knowledge domains are evident during teaching? and How do teachers bring different knowledge domains to the fore during instruction? The answers to these questions are important in shedding some light on the knowledge bases that inform their teaching so that appropriate support may be given.

1.2. Background to the study

Teachers are the key players in all education systems, because they play a central role in providing quality education (Zinn, 2017). Since provision of quality education is the main concern and ultimate goal globally and, for purposes of this study, specifically for Lesotho (Lesotho MoET, 2016; Park et al., 2011), education scholars have investigated what constitutes quality teaching. This has highlighted the teachers' knowledge base and how teachers perceive their knowledge as essential factors in determining how they teach.

1.2.1. Knowledge perceptions and knowledge base

Extant literature highlights that teachers impact students' achievement (Hill & Chin, 2018; Kratz & Schaal, 2015; Olasehinde-Williams, 2018). As a result, it is necessary to understand what teachers believe they know and how their perceptions relate to instruction. A teacher's knowledge base is the umbrella term that covers a variety of cognitions, beliefs and knowledge domains (Fischer et al., 2012). Conceptualising the knowledge base has proved to be complex, as it requires understanding the teaching and learning process (Guerriero, 2013). Guerriero further indicates that researchers need to know how teacher knowledge is put into practice in the classroom. Shulman (1987) categorised teacher knowledge into seven domains: 1) content knowledge; 2) curricular knowledge; 3) pedagogical content knowledge (PCK); 4) general pedagogical knowledge; 5) knowledge of learners and their characteristics;

6) knowledge of educational contexts; and 7) knowledge of educational ends, purposes and values. Out of the seven, PCK is regarded as the most essential because it identifies the competences necessary for effective instruction (Barendsen & Henze, 2017). Fischer et al. (2012) explain teacher competencies as the abilities to: organise, interpret and explain the subject matter concepts; encourage students to discuss and present their different ideas of a particular topic; and stimulate students' interest. There is consensus among the scholars that teacher competencies encompass their ability to represent the subject matter in diverse ways, thus putting students' needs at the centre of their decisions (Furwati et al., 2017; Mešić et al., 2017; Savinainen et al., 2013).

1.2.2. Pedagogical content knowledge (PCK)

PCK enables teacher effectiveness, because it allows teachers to blend pedagogical with content knowledge during teaching (Barendsen & Henze, 2017; Kratz & Schaal, 2015; Morrison & Luttenegger, 2015; Shulman, 1987). PCK is the knowledge of transforming content into teachable forms (Mazibe et al, 2018). Thus, it is closely related to teachers' professional knowledge and skills (Kratz & Schaal, 2015).

PCK is classified as professional knowledge that informs teachers during planning and teaching (Morrison & Luttenegger, 2015). Unlike physics specialists, who know much of the subject matter, a physics teacher goes beyond the knowledge of subject matter per se, to the knowledge of how to teach it. This combination constitutes PCK–the knowledge and skills that teachers use when planning for the lesson, and the actual teaching. It helps teachers to plan their lessons based on the nature of the students, what they need to learn and how best to learn it (Morrison & Luttenegger, 2015). It also affords teachers the opportunity to evaluate students' learning, to use a variety of techniques that allow them to make explanations, create demonstrations and to use analogies to support students' understanding (Morrison & Luttenegger, 2015). Thus PCK is not fixed, but depends on different factors, such as contexts and interactions with students.

Based on its conceptualisation, PCK has different forms, as highlighted by different scholars. For instance, Park and Oliver (2008) refer to PCK as knowledge-on-action and knowledge-in-action. Alonzo and Kim (2016) refer to PCK as being declarative and dynamic, while Mazibe et al. (2018) conceptualise PCK as reported and enacted PCK. Though they refer to it differently, what seems to be common is that PCK can be realised when teachers think about and plan for teaching and during teaching, as they make on-the-moment classroom decisions when responding to different classroom situations.

The teachers' knowledge and skills to identify classroom situations that need attention, as well as the strategies to respond to different classroom situations, developed over time. That is, PCK is developed through experience as teachers repeatedly teach the same concepts to different students (Lehane & Bertram., 2016). This gives rise to the teachers' unique ways of representing and transforming content, which some researchers call personal PCK (pPCK) (Henze & Barendsen, 2019).

Science education scholars took special interest in PCK so that further investigations resulted in different PCK models (Magnusson et al., 1999; Mavhunga & Rollnick, 2013; Park & Oliver, 2008). They added other components, such as curricular knowledge, which Shulman (1986) and Mazibe et al. (2018) regard as parallel. Shulman (1986:9) regards PCK as "…the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations..." Based on this conception, science education researchers such as Magnusson et al. (1999) categorised science teachers' PCK to constitute the knowledge of: the science curriculum; how students understand science; instructional and assessment strategies; and the teachers' knowledge and beliefs about the purposes and goals of teaching science (orientations towards teaching). Mavhunga and Rollnick's (2013) categories include knowledge of the context, students, subject matter and pedagogy. Common among the scholars is that they regard PCK as the transformation of the subject matter and blending it with other knowledge domains for the purpose of teaching (Mavhunga & Rollnick, 2013; Park & Oliver, 2008). It is what teachers know, do, and reason in their actions. As a result, teachers' PCK is realised through their practice as they plan and use different instructional and assessment strategies, student activities, teaching resources and sequencing of concepts within a topic. It is in this regard that this researcher adopted Park and Oliver's (2008:264) definition of PCK, which is:

> …teachers' understanding and enactment of how to help a group of students understand specific subject matter, using multiple instructional strategies, representations and assessment while working within the contextual, cultural, and social limitations in the learning environment.

The teachers' understanding entails, among others, their knowledge of the depth and breadth of the science curriculum; what makes students' learning of science easy or difficult, both topic- and subject specific instructional strategies; as well as how to assess scientific literacy (Park & Oliver, 2008). These knowledge domains are pertinent to teachers, because they include both pedagogical and content knowledge; hence they are foundational to the development of PCK and the competencies to teach.

As already highlighted, PCK constitutes the knowledge that teachers develop as they teach similar concepts, such as the concepts of force, to different groups of students and in different contexts over an extended period. That is, by repeatedly teaching the same concepts, the teachers acquire different representations, activities and strategies and they also understand how students think about these concepts and what their preconceptions are. As a result, PCK is regarded as being topic specific (Mavhunga & Rollnick, 2013).

1.2.3. Concepts of force

Physics, as a science discipline, is regarded by some scholars as a prerequisite for both chemistry and biology (Goodman & Etkina, 2008; Lederman, 1999). This is because most physics concepts, such as force and motion, and momentum and conservation of energy, are pivotal to understanding some of the physics concepts as well as other scientific phenomena (Singh & Schunn, 2016). Moreover, force concepts are central to the classical mechanics taught in schools (Savinainen et al., 2013). Savinainen et al. (2013) not only explain the interaction between two or more objects and the results of such interactions, but also the comprehension that is critical to students because it serves as the basis for understanding the natural phenomena as well as other science concepts (Zhou et al., 2015). Moreover, understanding the concepts of force provides students with knowledge and skills essential for engaging in scientific debates and issues that affect them in their daily lives (Carson & Rowlands, 2005).

However, as students experience force concepts in their daily experiences, they develop their own conceptions, some of which do not align with the established scientific knowledge (Zhou et al., 2015). In literature they are referred to as misconceptions or alternative conceptions (Fadaei & Mora, 2015; Fotou & Abrahams, 2016), depending on how they are interpreted. They become part of students' prior knowledge that they bring to physics classrooms. Depending on how teachers approach students' preconceptions during teaching, students sometimes do not change their understanding. Rather, they hold on to the preconceptions, even after the classroom instruction, and proceed to higher grades still holding onto them. Thus they experience problems with understanding other concepts.

As explained in the preceding paragraphs, PCK is domain specific and requires teachers to be knowledgeable about content and pedagogy and students' preconceptions of the concepts of force, which is also a content specific knowledge domain. PCK entails knowing the aspects of the subject matter to assess and how to assess them, as well as the instructional strategies that best make the subject matter comprehensible. It is therefore imperative for science researchers to establish science teachers' content-specific knowledge, as well as the accompanying pedagogical knowledge, so that their classroom practices can be understood.

The literature reveals two issues regarding teachers' knowledge and use of students' preconceptions (Hammer, 2000). On the one hand, teachers know that students have alternative conceptions about the concepts of force, but they do not see these as important aspects of students' learning. Therefore, they do not attempt to reveal and/or use these alternative conceptions during the classroom instruction. On the other hand, some teachers view students' preconceptions as building blocks and make a deliberate effort to reveal them before, during and after the instruction. They plan their lessons in order to address those naïve understandings (Rowlands et al., 1998). However, researchers have indicated that instruction that does not take students' prior knowledge into consideration is likely to be teacher-centred; students are expected to memorise what they are told. Nonetheless, this approach was found to be unhelpful in assisting students to change their naïve understandings. Such students experience some challenges understanding physics as they progress to higher grades.

Different strategies that teachers should use in order to help the students to comprehend the force concepts are reported. Analogical reasoning, argumentations, concept mapping and self-explanations are some of the research-based strategies that have proved effective in teaching abstract concepts such as force (Fadaei & Mora, 2015; Savinainen et al., 2013).

The force concepts have received special attention in physics teaching globally (Fadaei & Mora, 2015; Suh & Park, 2017; Zhou et al., 2015). More research is found to focus on the investigation of students' misconceptions, the effects of different instructional strategies on students' understanding as well as determining the pre-service physics teachers' knowledge of force concepts (Akçay & Doymuş, 2012; Hançer & Durkan, 2008; Sağlam-Arslan & Kurnaz, 2009; Savinainen et al., 2013).

In China, Fadaei and Mora (2015), as well as Zhou et al. (2015) investigated students' misconceptions of force concepts, while Suh and Park (2017) investigated the common patterns in the PCK of three primary school teachers who had sustained the implementation of an argument-based inquiry approach in the United State of America (USA). Zhou et al. (2015) investigated junior and senior high school and university students' difficulties in identifying Newton's Third Law (NTL) force pair in gravity interaction situations, while Fadaei and Mora (2015) investigated high school students' misconceptions of force concepts before and after receiving instruction through traditional strategies. In all these studies, students displayed some misconceptions about force. Even after they had been taught the force concepts through the traditional strategies, the misconceptions persisted and new misconceptions (which were not there before the classroom instructions were observed) emerged. This implies that teaching the concepts of force through traditional strategies is not effective in helping students understand the topic. This explains Zhou et al.'s (2015) findings that even university students have some misconceptions about force. These findings have several implications. For instance, Zhou et al. (2015) suggest that, when teaching students about NTL, teachers should present force in different contexts, such as gravity interactions, as the students portrayed difficulties identifying NTL force pairs in those situations. Moreover, this implies that teachers should have knowledge of these issues so that they design lessons that focus on what students find difficult to understand.

In the USA, Suh and Park (2017) investigated the pattern of PCK of three teachers who voluntarily sustained the implementation of an argument-based inquiry approach, while Robertson et al. (2017) describe a methodology for selecting and analysing classroom episodes showing content knowledge for teaching energy. Suh and Park found that the teachers' epistemological orientations have strong connections with their knowledge of instructional strategies and representations as well as how students understand science. That is, "…the teachers made decisions about instructional strategies and representations based on their understanding of students' prior knowledge, learning difficulties and current conceptions and misconceptions." (Suh & Park, 2017:251). This finding suggests that professional development activities should focus on changing the teachers' epistemological beliefs, because, as their orientations shift, teachers focus on how students learn in the classrooms. This, in turn, expands their knowledge of students' understanding of a science concept. Robertson and colleagues' methodology indicated that teachers' content knowledge for teaching can be ascertained by being attentive to students' responses and thus infer their knowledge models from their expressed ideas, re-voicing students' expressed ideas, selecting appropriate instructional strategies to address students' misunderstanding and evaluating their ideas. The methodology shows that different aspects of PCK or content for teaching can be identified when teachers engage in interactive classroom practices in which students are given opportunities to present their thinking. The methodology implies that classroom practices that are not interactive provide few opportunities for teachers to display their PCK, mostly because PCK, in the form of dynamic or knowledge-in-action PCK, is displayed when teachers make decisions on-the-moment (Alonzo & Kim, 2016; Park & Oliver, 2008).

In Southern Africa, Mavhunga and Rollnick (2015) have investigated whether there is a link between pre-service chemistry teachers' beliefs and student-centredness in relation to topic-specific PCK (TSPCK). They found that, when an intervention was implemented in the chemistry methodology classroom, pre-service teachers' quality of TSPCK increases, as evidenced in how the knowledge domains came to the fore, as the class discussed how to represent a chemistry concept. This finding implies that explicit development of pre-service teachers' TSPCK should be done at teacher education science education courses.

Mazibe et al. (2018) investigated physical science teachers' PCK about graphs of motion and found that physics teachers' scores on the enacted PCK were lower than or similar to the reported PCK. They concluded that developing the teachers' PCK does not necessarily warrant that they will enact it. Nonetheless, Mazibe et al. found that the teachers managed to put their knowledge into practice for some of the components. They therefore concluded that developing teachers' PCK may provide the basis for its enactment.

There is not much research of physics teachers' perceptions of their knowledge of force concepts in Southern Africa. However, Qhobela (2012) investigated the feasibility of success when argumentation is introduced as part of learning physics in Lesotho. The focus was on learning the topic of force. He found that argumentation is a feasible strategy for teaching physics, because students participated in argumentative discussions and drew on their prior knowledge at highest level. In another study on the general physics teachers' beliefs and knowledge, Qhobela and Moru (2014) identified the areas where the Lesotho teachers of physics may need professional development support. They observed that the teachers' views about the effective ways of teaching physics did not match their practices. That is, they seemed to have student-centred views, although their practices are reported to follow teacher-centred approaches because of contextual issues, such as availability of laboratory space and facilities as well as students' negative attitudes towards physics.

1.3. Problem statement

As reported in the literature reviewed above, teachers play a dominant role in the provision of quality education (Barendsen & Henze, 2017; Kratz & Schaal, 2015). Among teacher attributes, which have been observed to enable them to fulfil their mandate, is professional knowledge. However, there is insufficient research in Lesotho and regionally on physics teachers' perceptions of their knowledge to teach the concepts of force. This is despite the emphasis of science education scholars on the importance of teachers' knowledge, including their perceptions on effective teaching and teaching practices (Carlson et al., 2013; Mavhunga & Rollnick, 2013). Specifically, research on the teachers' perceptions of their knowledge base of particular physics topics, such as the concepts of force and its relationship with classroom practices, is limited.

Force concepts are critical for students to learn at school, because they are central to understanding the theory of mechanics and they equip students with knowledge and skills that are essential to understanding their environment (Fadaei & Mora, 2015; Savinainen et al., 2013). Nonetheless, most students find the concepts of force difficult to understand, because they are abstract in nature. Although students experience the concepts of force in their daily encounters, they are observed to have preconceptions, some of which serve as barriers to understanding. Moreover, Mazibe et al. (2018) reported that some of the South African physics teachers have insufficient knowledge to teach force concepts. They are reported to teach force concepts using approaches that are not effective in increasing students' comprehension. Similarly, in Lesotho, Qhobela and Moru (2014) reported that insufficient or under-developed knowledge about teaching, as well as the contextual factors encountered in schools and classrooms, impact how physics teachers teach.

In accordance with Qhobela and Moru's (2014) finding that physics teachers use teacher-centred strategies when teaching, my anecdotal observation also revealed that regardless of the availability of science laboratory space and materials and small class size, teachers continue to teach through teacher-centred strategies. The students participate by responding to the teachers' questions, copying teachers' notes and, to a limited extent, ask questions. This was observed across different physics topics, including force concepts, in the school curriculum. This is a problem because literature highlighted that teaching physical science, particularly physics, through teacher-centred strategies does not result in quality instruction (Fadaei & Mora, 2015; Kulgemeyer & Riese, 2018; Qhobela & Moru, 2-14). Low quality instruction affects students' understanding negatively because it deprives them the opportunity to acquire the necessary knowledge and skills as articulated in the Curriculum and Assessment Policy (Lesotho MoET, 2008). As a means to drive towards improving the quality of physics instruction, it is imperative to establish teachers' perceptions of their knowledge so that relevant stakeholders are informed.

It is against this background that the present study aimed to determine the physical science teachers' perceptions of their knowledge of the concepts of force and momentum and how it shapes the way they plan for their lessons; the choice of classroom activities and representations; the questions asked; when and how to assess students' understanding; as well as the aspects of force that they have to assess. That is, the study is intended to determine whether the physics teachers' perception of knowledge of the concepts of force shape their classroom practices.

1.4. Research questions

The key research question has two components: What are the Lesotho science teachers' perceptions of knowledge on the topic: force and momentum; and How does it shape practice in grade 11 classrooms?

The sub-questions of the study are:

1. What are the science teachers' perceptions of their knowledge base on the topic: force and momentum?
2. What is the knowledge base of science teachers when teaching force and momentum in grade 11 classrooms?
3. How do science teachers approach the topic: force and momentum in their teaching in grades 11 classrooms?
4. How can the teachers' perceptions of their knowledge base and practices be understood and/or explained?

The aim of the study is to explore and understand the perceptions of their knowledge base of the Lesotho high school teachers on the topic: force and momentum and how it shapes grade 11 classroom practice.

The objectives of the study are to:

1. Investigate the perceptions of science teachers about their knowledge bases on the topic of force and momentum.
2. Investigate the knowledge base which science teachers use when teaching force and momentum in grade 11 classrooms.
3. Describe how science teachers approach the topic of force and momentum in grade 11 classrooms in Lesotho
4. Construct an explanation of why the teachers' knowledge and classroom practice in Lesotho is the way it is.

1.5. Significance of the study

In Lesotho, there is limited research on physics teachers' perceptions of their knowledge bases for teaching force concepts and their relationship to classroom practices. Given that effective teaching involves integrating different knowledge domains with the purpose of making the subject matter comprehensible for students, it becomes necessary to investigate physics teachers' perceptions of their knowledge bases and their relationship with classroom practices. Nonetheless, most schools in Lesotho do not have adequate facilities, such as science laboratories and materials

(Qhobela & Moru, 2013). However, they are expected to enact effective instruction. It is therefore imperative to investigate the physical science teachers' perceptions of their knowledge base in order to understand whether and how it informs their classroom practice, if at all.

Supposedly teachers gain both declarative and dynamic pedagogical knowledge during their teacher training. It is therefore expected that, through their years of teaching and through experience, their knowledge for teaching improves as they accumulate various knowledge bases. During my review of the literature, I did not find studies which probed these aspects of science teaching in Lesotho, although it is widely reported that effective instruction can be measured by both declarative and dynamic teacher knowledge bases (Alonzo & Kim, 2016).

The fact that Lesotho physics teachers' perceptions of knowledge bases for teaching the concepts of force have not been explored may mean that the effectiveness of teachers in Lesotho is not known. This could mean that important information regarding the teachers' strengths and weaknesses is lacking, hence policy makers, curriculum developers and other supervisory authorities do not have adequate information about the professional strength of the teaching force. Thus, even professional development activities, may not focus on the issues of concern.

This study is therefore significant, because it may add some knowledge to the existing literature about Lesotho physical science teachers' perceptions of their knowledge base and how it relates to classroom teaching. Moreover, this study may enlighten the education stake holders, such as the policy makers, teacher-trainers, the teachers and the science education community about the state of science teachers' perceptions of knowledge and how it relates to their classroom practice.

1.6. Theoretical framework

There is agreement among the researchers that PCK constitutes teachers' professional knowledge, which is essential for teaching. As a result, extant research has been done on PCK and different models have been conceptualised. Among them, Magnusson et al.’s (1999) model of science teachers’ PCK is widely used (Aydin et al. 2017). In this model, PCK is seen as the transformation of several types of knowledge, including the subject matter, pedagogical and knowledge of educational contexts (Aydin & Boz, 2012; Magnusson et al., 1999).

Magnusson et al., (1999:97) conceptualise five components of science teacher knowledge: 1) Orientations towards teaching science. This refers to the knowledge and the belief of teachers about the purpose of teaching and learning science. 2) Knowledge of the science curriculum. This is the knowledge of the goals and objectives of the science curriculum, including the depth and breadth of each of the curricular topics. That is, knowing the subject content that students were taught in earlier grades, what should be learned in the current grade, what will be learned in the higher grades, as well as knowing how to relate the concepts within science (physics)to the others (such as those in chemistry and biology). 3) Knowledge of students’ understanding of science includes their difficulties with learning the concepts of force, preconceptions and common misconceptions related to the topic. 4) Knowledge of the assessment of science literacy, which constitutes knowing the aspects of science such as the concepts of force and to assess them within a particular topic. 5) Knowledge of instructional strategies. It encompasses knowing subject specific and topic specific strategies. Topic specific strategies include activities and representations that proved to be effective in helping students to comprehend particular concepts.

The model does not suggest how the components relate to each other except that they are all connected to the orientations towards science teaching (Melo-Niño et al., 2017). That is, orientations are at the top of the hierarchy, indicating that they guide the teachers’ everyday classroom decisions. This means that the teachers’ decisions to use a particular representation and/or to assess a particular skill are determined mostly by their views and purposes of teaching and learning science.

I found Magnusson et al.’s model of science teachers’ PCK suitable for this study, because it enabled me to study the teachers’ knowledge of each of these components openly and allowed it to unfold naturally as they teach. Moreover, the model of

Magnusson et al. (1999) was used to study both the generic and topic-specific PCK. This is because their model of science teachers' PCK includes components that indicate topic-specific PCK, such as the "topic-specific representations" under the components, knowledge of instructional strategies, "knowledge of areas of students' difficulties" under knowledge of students' understanding of science, and "knowledge of the dimensions of science to assess" under the knowledge of assessment methods. Even knowledge of the science curriculum is a topic-specific aspect, as it entails understanding the importance of a particular topic relative to the whole curriculum (Park & Oliver, 2008). Furthermore, studies that have used Magnusson et al.'s model probed science teachers' PCK in the context of particular topics, such as the electric field (Melo-Niño et al., 2017) and fluid pressure (Karışan et al., 2013). Consequently, I used this model to probe science teachers' PCK of the topic: force and momentum and how that knowledge is transformed during teaching.

1.7. Research design and methodology

The proposed study drew on the mixed methods approach with an explanatory sequential design (Creswell, 2012). In the first quantitative phase, I investigated the physical science teachers' perceptions of knowledge to teach concepts of force. The participants in this phase were selected by clustered random sampling. I clustered all high schools according to the districts. There are ten districts in Lesotho. However, the sample for this study consisted ofbphysical science teachers from high schools in five districts. Lesotho is a mountainous country, such that some of the districts and schools in particular, are hard to reach. Due to the constraints of time and finances, I decided to study teachers in the five districts that I could access with ease as compared to the other five. There was a total of 136high schools in the five districts. The numbers of schools in each of the five districts were 51, 30, 26, 17, and 12 respectively. I selected the schools with regard to the following criteria: The number of schools in a district divided by the total number of schools (136) in the five districts: 51/136; 30/136; 26/136; 17/136 and 12/136. Because I anticipated that there would be more than one physical science teacher in most of the schools, I divided the number of schools by two. Finally, sample of 100 physical science teachers were selected from 52 schools. Dividing the schools proportionally ensured that all the districts were represented so that the characteristics of the population were approximated (Bordens & Abbott, 2011; Creswell, 2012).

I delivered copies of the study questionnaire to the 100 physical science teachers and collected them when they had finished responding to the questions. However, some of the teachers did not complete the questionnaires, hence a total of 92 questionnaires were collected. Immediately after collecting them, I entered the data into an Excel spread sheet and when all the data had been collected and filled in the Excel spread sheet analysed it, using the SAS software.

The findings informed the researcher on the science teachers' perceptions of their knowledge to teach force and momentum. After analysing the quantitative data, I purposively selected four physical science teachers from those who participated in the survey and requested them to participate in the qualitative phase of this study. Because I anticipated that the teachers would teach the topic at around the same time, I used the following criteria to select the sample (Creswell, 2012):

1. The teachers had to be in the schools which were, at most, an hour walking distance apart. This decision was made in order to allow me to move from one school to the other if I had to observe teachers at two schools on the same day.
2. The teachers' teaching experience ranged from one year to ten years.
3. Their qualifications had to be at least a diploma and/or a first degree in education.
4. Their major subjects had tobbe physics and other sciences, as found in the survey.

This heterogeneity of the observed teachers made it possible to have rich qualitative data, because teachers develop most of their PCK during the first five years of teaching, as beyond that, little new learning occurs (Etkina, 2010).

I did classroom observations in order to ascertain whether the teachers' perceptions about their knowledge inform their classroom practices. In order to avoid misinterpreting the teachers' views, I interviewed them after they had covered the whole topic. I analysed the field notes, classroom observations and interviews with the purpose of developing an in-depth understanding of the teachers' classroom practices as they perceived and enacted it (Henninkbet al., 2011).

The ethical considerations were fully observed as I was supposed to guard against damage to human dignity and the environment. As a result, I ensured that the participants voluntarily agreed to participate in the study. I approached the teachers whom I thought would give rich data and then explained the purpose of the study and invited them to participate. If they agreed to participate in the study, I asked them to sign the consent form. I further informed them that they could withdraw their participation at any time they felt that they were uncomfortable. They were also informed that at no point in time would the data be linked to them personally or to their schools and that the data would be used solely for the purposes of this study (Creswell, 2012).

1.8. Limitations and delimitations of the study

The study, as indicated earlier, followed a mixed-methods approach. As the response rate of the questionnaires might not have been 100%, which might have affected the amount of data expected, I took the precaution to administer more than 100 questionnaires in order to increase the probability at which they would be returned. Moreover, the time when the teachers planned to teach the topic might possibly have overlapped, in which case it might not have been possible for the researcher to observe some or any of the teachers who initially volunteered to participate. To mitigate this situation, the researcher asked at least five teachers to volunteer, so that, in case one or two withdrew or encountered some unforeseen problem, the researcher would still have three or four teachers to observe. Furthermore, it was likely that the teachers would teach the topic at around the same time, so if the schools were far apart, it would not have been possible to observe them at the same time. It is possible that, in two schools whose teachers were participants, physics might have been allocated on the same day on the timetable. As a result, I would have to observe one teacher in a particular school and then rush to observe the other on the same day at another school.

These factors were limitations, because they impacted the selection of the teachers to observe.

The study was conducted at the schools in one town. These schools have similar environments and characteristics. As a result of the similarities of context, the study might possibly not have the benefit of embracing rich and diverse contexts and hence diverse findings. The aim was to select teachers whose major subjects included physics. However, in some schools, physics was taught by teachers who were not qualified to teach it.

1.9. Clarification of terms

Teacher knowledge is the umbrella term that refers to teachers' cognition and beliefs, and comprises different knowledge bases. Some scholars refer to it as professional knowledge for teachers (Meschede et al., 2017). After Shulman's (1987) enumeration of the domains of teacher knowledge, some scholars referred to teacher knowledge as pedagogical content knowledge (PCK). Some of the knowledge domains, which are referred to when talking about teacher knowledge, include content, pedagogy, instruction, assessment and students (Körhasan & Gürel, 2019). They entail all the knowledge bases that teachers use in planning and teaching.

Pedagogical content knowledge (PCK) is a form of content knowledge. It is the form of teacher knowledge that goes beyond knowing the subject matter. It represents the subject matter needed in order for students to easily comprehend it. This includes knowing different ways of representing a particular concept, what students find difficult when learning such concepts, what makes understanding such concepts easy or difficult to understand as well as the preconception and misconceptions that students have about the concepts. These aspects of teachers' PCK become evident during the planning, teaching and reflection stages (Carlson & Daehler, 2019).

Force and momentum are physics concepts that are central in the classical mechanics taught in schools (Savinainen et al., 2013). Force concepts refer to Newton's three laws of motion that are central in understanding a natural phenomenon. It constitutes the interaction between two or more entities that enable one to analyse a natural phenomenon such as why objects float or sink (Subramaniam et al., 2017). In the structure of school science, the concepts of force are central as they are prerequisites to understanding most of the science concepts (Zhou et al., 2015).

Classroom practices refer to both the teacher and students' actions during teaching and learning. On the part of the teacher, it entails the instructional and assessment strategies of teaching (Acar-Erdol & Yıldızlı, 2018; Tay & Saleh, 2019). The authors further indicate that classroom practices are the behaviours that the teachers find comfortable and consistently do when teaching. Classroom practices are characteristic of effective teaching; hence they are indicative of whether teaching is effective or not. Dancy and Henderson (2007) classified them into traditional and alternative practices in which they elaborate on both the teacher and students' activities, which are then characterised as either of the two.

Perceptions of science teachers refer to the views of science teachers about teaching, learning, science content and students. Perceptions drive the teachers' actions such as instructional and assessment strategies (Cheng et al. 2016). On the whole, they guide the teachers' classroom practices.

1.10. Organisation of thesis

Chapter 1: Background and orientation to the study

This chapter outlines the background to the teachers' knowledge bases and their classroom practices. It further presents the research questions, objectives, theoretical framework of the study and an outline of the research design and methodology, ethical considerations and the limitations and delimitations of the study.

Chapter 2: Literature review

Chapter 2 presents a review of studies that focused on the teacher knowledge base, their perceptions about different knowledge domains as well as the classroom practices.

In this chapter the researcher expands on the theoretical/conceptual framework that guided this study. This is followed by a review of the literature of previous research on teacher knowledge, particularly PCK, aspects of PCK which were studied, teachers' knowledge of teaching the concepts of force, the challenges that teachers encounter when teaching force concepts, as well as the suggestions given in previous studies regarding how to overcome them.

Chapter 3: Research methodology

The chapter on the literature review is followed by presenting and discussing the research design and methodology. It details the research design used, the sampling procedure, the data collection instruments and the way in which data were analysed. It then provides the details of the ethical issues which were observed.

Chapter 4: Presentation, analysis and interpretation of quantitative data

In Chapter 4, quantitative data pertaining to the teachers' perceptions of knowledge to teach the concepts of force as well as the observed classroom practices are presented, analysed and interpreted. This also includes the relationship between the teachers' perceived knowledge base and practices.

Chapter 5: Presentation, analysis and interpretation of qualitative data

In this chapter I present, analyse, and interpret the qualitative data. Data from each teacher are presented and there is a total of three cases. Data were collected from the lesson plans, the classroom observations and interviews. These data sets were related to the data from the LGCSE physical science syllabus as one of the main policies that guide instruction. Following the presentation of the cases, I compared and contrasted the three cases in order to summarise the findings on how teachers' perceived knowledge relates to practice.

Chapter 6: Summary, discussion of the findings, the conclusions and recommendations

The final chapter provides a summary of the study and integrates the quantitative and qualitative data analyses results in order to summarise the findings of the study. The findings of the study per research question are discussed. Lastly, the conclusions, limitations and delimitations, as well as the recommendations, are presented.

1.11. Summary of the chapter

This chapter started with delineating the teacher knowledge base and its vital role in teaching. Then it presented an argument on why teachers' knowledge to teach the concepts of force was investigated and how research about teacher knowledge to teach this topic was investigated internationally, regionally and locally. The problem statement on the interplay between knowledge and practice was explicated. The significance of the study, the research questions and objectives, an overview of the conceptual framework, the research methodology as well as the limitations and delimitations of the study were presented.

Chapter 2 presents a detailed review of the existing literature on the interplay between physical science teachers' knowledge base and practice.

Chapter 2.
Review of the literature

2.1. Introduction

This chapter reviews the literature and research about the knowledge base of science teachers and how it influences their classroom practices. It starts with an explanation of pedagogical content knowledge (PCK) as framed by Shulman (1987) and the explanation of the science teachers' PCK, as coined by Magnusson et al. (1999). This is followed by a review of the literature, which is organised into six themes, derived from the research questions. The sub-topics include the science teachers' knowledge bases, teachers' beliefs and their influence on classroom practices, what constitutes an understanding of force and momentum, the knowledge base needed to teach force and momentum, as well as classroom practices when teaching force and momentum. This study aims to understand physical science teachers' perceptions of their knowledge of force and momentum and how it influences their classroom practices.

2.2. Conceptual framework

My study on the physical science teachers' perceptions of knowledge to teach the concepts of force and how they relate to teaching practice is informed by the PCK framework. The conceptual foundations of this study revolve around science teachers' PCK, as articulated by Magnusson et al. (1999).

Shulman singled out PCK as the knowledge that is characteristic to teachers. It includes knowing "…the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations…" (Shulman, 1986:9). Similar to practical and craft knowledge, PCK is the knowledge germane to teaching and it develops with practice. Therefore, it differs from formal knowledge, which is external to teaching and only taught at teacher institutions (Fernandez, 2014).

Pedagogical content knowledge caught the attention of most science scholars who then investigated it (Gess-Newsome, 2015; Magnusson et al., 1999; Mavhunga & Rollnick, 2013). Magnusson et al. (1999) examined its nature, sources and development, while Park and Oliver (2008) revisited it with the purpose of establishing how it could help others to understand teachers and their practices. Moreover, Rollnick et al. (2008) explored the influence of the subject matter knowledge on PCK. They all conceptualised PCK to be an amalgam of content and pedagogical knowledge developed from other knowledge bases (Neumann et al., 2019). Their analyses resulted in different PCK models. What is common among these models is that they all view PCK to be the result of the transformation of other knowledge domains, which is realised during teaching (Mavhunga & Rollnick, 2013; Park & Oliver, 2008). In addition to its defining features, scholars conceptualise PCK by identifying its components.

Grossman was the first scholar to categorise science teachers' PCK (Jing-Jing, 2014). However, Magnusson et al.'s (1999) reconceptualization of her model yielded five components: knowledge of the science curriculum, how students understand science, assessment strategies, instructional strategies and orientations towards science teaching. Figure 2.1 shows this model. Following Magnusson et al.'s model, others were developed. Park and Oliver (2008) added a sixth component, teacher efficacy, while Rollnick et al.(2008) note five components of topic specific PCK.

Magnusson et al.'s model is criticised for being generic instead of topic-specific and not being fit for use in other topics and curricula (Mavhunga & Rollnick, 2013). Moreover, it does not show interactions among knowledge domains except for the orientations towards science teaching (Park & Chen, 2012).They further argue that the model was proposed to be used by pre-service teachers in science education. However, there is evidence in the literature that Magnusson et al.'s model is applicable in exploring teachers' PCK on a specific topic and curriculum (Aydin et al., 2017; Melo-Niño et al., 2017).

Not disregarding the importance of the interaction among the knowledge domains, there is evidence in the literature that knowledge components can be investigated individually

(Henze et al., 2008). While it is important for the knowledge domains to interact when teaching, it is also imperative to ascertain whether teachers have the necessary knowledge or not. Moreover, the way teachers think about a topic, such as the concepts of force, and how to teach them, depends on their beliefs about physics, teaching, and learning, as well as their goals for teaching physics and/or that particular topic (Şen & Sarı, 2017). Consequently, orientations towards science teaching interact with the other knowledge domains in Magnusson et al.'s (1999) model. Furthermore, the teachers' belief system and the contextual factors serve as filters during instruction; that is, what teachers know is secondary to their beliefs. It is against this background that Magnusson et al.'s model is used as both the conceptual framework and the analytical tool in this study. The working definition of PCK in this study was adopted from Park and Oliver (2008:264) as the "…teachers' understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations and assessments while working within the contextual, cultural, and social limitations in the learning environment."

This model is widely used in science education research (Aydin et al., 2017; Demirdöğen, 2016; Soysal, 2017). In most studies, it is used as an analytical tool (Barendsen & Henze, 2017; Karışan et al., 2013; Melo-Niño et al., 2017), while in a few studies it is used as both data collecting and analytical tool (Soysal, 2017). The fact that the model is used for many purposes indicates that it provides an effective framework for studying PCK.

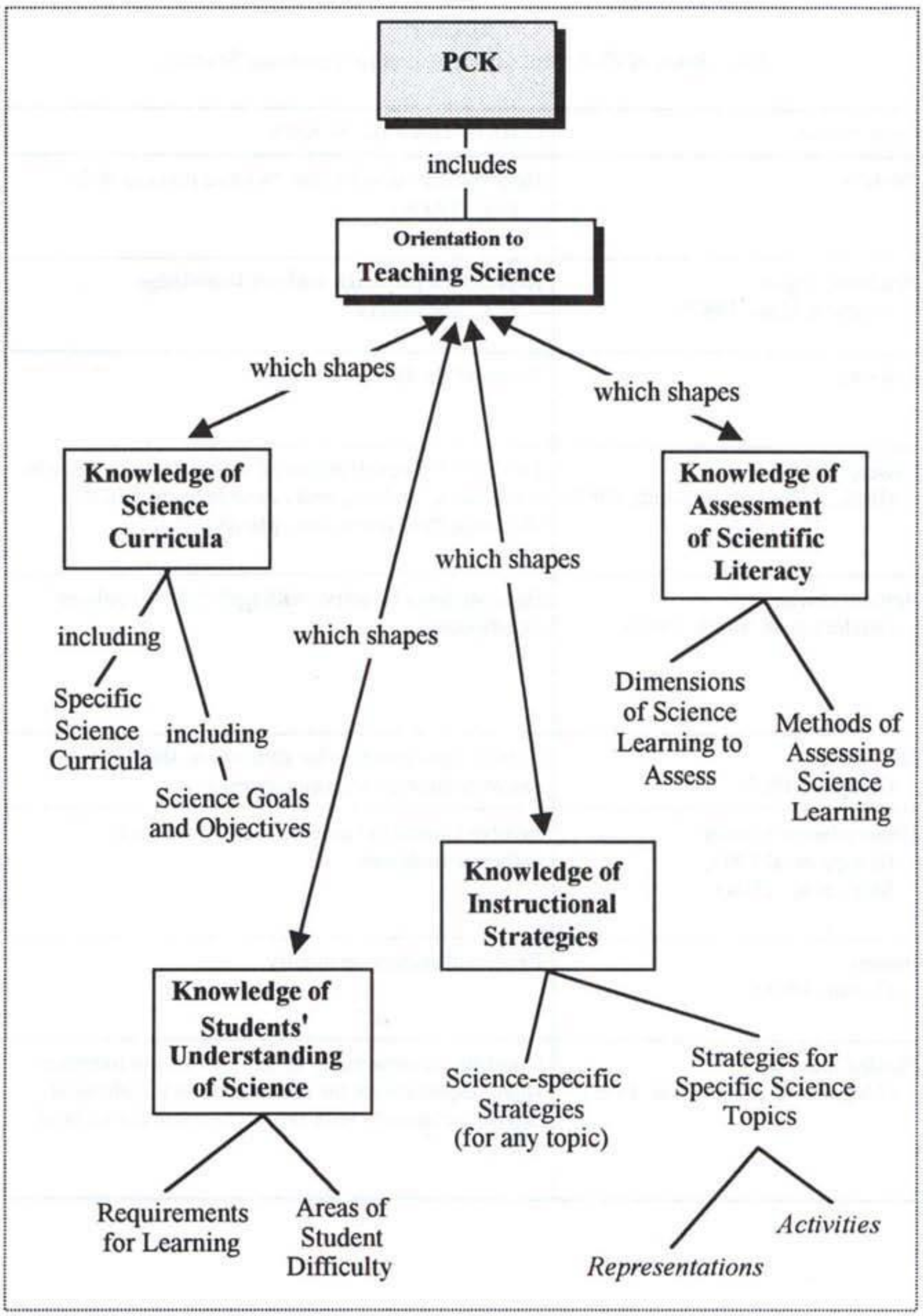


Figure 2.1 Model of science teachers' PCK (Adopted from Magnusson et al., 1999)

2.2.1. Components of science teacher PCK

2.2.1.1. Orientations towards science teaching

According to Magnusson et al. (1999:97), orientations towards science teaching"…refers to the teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level." It refers to what teachers know about the subject matter that is taught at a particular grade, including the purposes and goals of teaching it. However, the teachers' beliefs serve as filtered through which they realise their purposes and goals for teaching. Meschede et al. (2017:159) define beliefs as "... understandings or premises that are personally felt to be true." Şen and Sari (2017), refer to beliefs as "... an individual's deciding whether something is right or wrong on the basis of actions he intended to do or actually performed." In both cases, beliefs are viewed as personal and that they reflect what one believes to be true or wrong. Depending on what teachers know about the subject matter, such as the concepts of force, and what they believe to be their significance in the school curriculum, they develop general ideas about science teaching that are influenced by the teachers' beliefs about science teaching (Friedrichsen et al., 2010). Orientations, therefore, guide the teachers' decisions about the physics content to teach, and the instructional and assessment strategies to use when teaching particular content (Demirdöğen, 2016).

Magnusson et al. (1999) view orientations as having a hierarchical relationship with other components of PCK. That is, a change in one or more of the PCK components also modifies orientations. However, Park and Oliver (2008) do not consider the components to form a hierarchy. Rather, they see them as acting in the same plane, meaning that a change in one or more component may not necessarily modify orientations.

A teacher's orientation can be depicted from the characteristics of instruction and the reasons for practice. Magnusson et al. (1999:100) explain that teachers can be classified as having either "didactic, academic rigor, process, activity-driven, discovery, conceptual change, project-based science, inquiry or guided inquiry orientation." Instead of the nine orientations, Friedrichsen et al. (2010), as well as Sahin et al. (2016), grouped didactic and academic rigor together referring to them as teacher-centred orientations and the other seven as student-centred orientations. Because teachers can display more than one orientation (Campbell et al., 2017), grouping them into teacher-centred and student-centred orientations caters for such cases where teachers display more than one orientation.

Research on teacher orientations focused mainly on their views of science and how they teach it, and not on a particular topic (Campbell et al., 2014; Karal, 2017; Sahin et al., 2016), and most of them explain that teachers display one orientation. Karal (2017) explored the pre-service science teachers' orientations towards lesson planning and found that the majority of them have student-centred orientations. Campbell et al. (2014) explain that, before starting a one-year professional development period, teachers received teacher-centred science teaching orientation about technology-enhanced tools. However, Campbell et al. (2017) indicate that teacher orientations are topic specific and that they depend on the type of students who taught and the teachers' content knowledge.

Melo-Niño et al. (2017) state that the pre-service teachers' views about physics teaching are assimilations of the teachers' explanations; they portray knowledge transmission orientation. When teaching about electric fields, they focus on ideas that students could easily remember, because the purpose was to help them pass the external examination (Melo-Niño et al., 2017). Unlike the concepts of force, which has everyday examples, the teachers highlighted that the concepts of electric field lack everyday examples. Hence, they transmitted information.

Though there are differences in literature on how teacher orientations relate to other components, there is agreement that they determine practice and they can be depicted from the teachers' justification for practice. This literature therefore informed the study regarding how to determine teachers' orientations.

2.2.1.2. Knowledge of science curriculum

Each school and/or education system has its own curriculum with general aims and objectives. However, each course within the school curriculum, such as physical science, has its own specific goals and objectives that are imperative for teachers to know. According to Magnusson et al. (1999), knowledge of the science curriculum includes the teachers' knowledge of the school curriculum as a whole. This comprises knowing the goals and objectives of teaching science and the specific curricular materials and programs as well as the knowledge of the breadth and depth of the curriculum. Knowledge of the breadth of the curriculum refers to knowledge of what students did in previous grades and what they will do in subsequent ones, while knowledge of depth entails having enough subject matter knowledge of the topic in that particular grade. In addition, the knowledge of the science curriculum includes the teachers' understanding of the importance of topics relative to the curriculum as a whole (Park &Oliver, 2008).

The way teachers realise the goals and objectives of science differ. They either cite the goals and objectives as given in curricular documents or infuse those that they wish to attain. In a case study with a chemistry teacher, Barendsen and Henze (2017) captured the teacher's PCK when implementing a context-based science curriculum. When reflecting on the goals and objectives of teaching a context-based module, he pointed to the need for changing students' attitudes towards science by connecting content to their personal life, to show that chemistry has applications and to show students that, with their knowledge of chemistry, they can understand difficult science articles. Karışanet al. (2013) investigated an experienced science and technology teacher's PCK. The teacher expressed the goals and objectives as they appeared in the school curriculum; in order to discover the issue, inferences should be made to teach the subject in an unforgettable way. Henze et al. (2008) indicate that over a three-year professional development stage, the teachers' goals and objectives did not change much. At the beginning of the course, they demonstrated a positivistic epistemological view. The teacher explained that the model of the solar system was not the same as reality; it is meant to describe and explain certain phenomena.

The sources of the knowledge of goals and objectives are national documents that stipulate the framework and standards(Park & Oliver, 2008), such as the syllabi. Accordingly, science teachers are expected to know the school science curriculum, because it describes the goals and objectives for teaching science (Şen & Sarı, 2017). However, it seems that, in addition to the given goals and objectives, teachers have their own goals. The teachers' knowledge of the science curriculum, in this study, refers particularly to the knowledge of goals and objectives as well as the knowledge of the importance of the concepts of force, in the curriculum.

Knowledge of the science curriculum manifests during lesson planning, during instruction, and when teachers articulate the purposes of teaching a particular topic or concept (Carson & Rowlands, 2005; Loughran et al., 2004).The lesson objectives and what both the teacher and students are going to do during the classroom instruction, both communicate what teachers intend their students to achieve. Hence Barendsen and Henze (2017) refer to it as PCK-on-action, the knowledge base that is developed as teachers reflect on knowledge and practice, before and after instruction. Moreover, what happens during the actual teaching, such as how teachers explain concepts and how they relate to other concepts, is indicative of the depth of one' knowledge as well as the goals one wish to advance, thus highlighting knowledge of the science curriculum.

2.2.1.3. Knowledge of students' understanding of science

Magnusson et al. (1999:95) explain that some of the fundamental questions that teachers ask as they think about their work are "What shall I do with my students to help them understand this science concept? What are my students likely to already know and what will be difficult for them to understand? How best shall I evaluate the understanding of what my students have learned?" A critical look at the questions indicate that they enable teachers to reflect on and in their teaching, therefore these are good questions that they can ask as they prepare for teaching and during instruction. Moreover, they provide the aspects of learning that they should pay attention to. As a result, this aspect of teacher knowledge was important for this study, because it provided a guide inanalysing the teachers' documents and classroom teaching in order to ascertain knowledge of how students understand concepts of force.

Sadler and Sonnert (2016) point out that knowledge of students constitutes being aware of their abilities, the difficulties which students are likely to experience when learning a particular topic and the misconceptions they might be having. Moreover, it includes knowing what motivates and discourages students to learn, including how they prefer to learn (Park & Oliver, 2008). Accordingly, Meschede et al. (2017) indicate that knowing these aspects about learning is not enough, as teachers should have the necessary competences to recognise situations during instruction when students experience difficulties or when they display a misconception. During instruction, various events may either enhance or impede learning. Therefore, teachers should know their students so that they canrealise when they experience difficulties and identify classroom events that may provide learning opportunities.

When teaching the concepts of force, it is even imperative for teachers to know how students understand this topic, because students have their own preconceptions, most of which are not scientifically correct (Fadaei & Mora, 2015). Liu and Fang (2016:22-24) highlight some of the misconceptions dominant among students of different grades, from kindergarten to university, as “motion implies force”, “large objects exert more force than small objects” and that “friction hinders motion”. The sources of these misconceptions include real-life experiences, students’ insufficient reading skills and lack of clarity of textbooks (Chrzanowski et al., 2018; Liu & Fang, 2016). The teachers’ awareness of students’ preconceptions and misconceptions and their views about them serve as a filter when teaching.

Teachers who view students’ preconceptions as resources from which students can construct their understanding use them during instruction while those who see them as obstacles that impede learning, do not use them (Fotou & Abrahams, 2016; Hammer, 2000). In a study in which they asked students to make and explain predictions, Fotou and Abrahams (2016) found that the students’ predictions were driven by their experiences, most of which generated scientifically incorrect prediction. For instance, students predicted that when two bulbs hanging from the ceiling are attached to objects of different masses, the bulb attached to a heavier object will light up before the one attached to a lighter object. The subsequent explanations indicated that the students had the misconception that more mass means more force. Fotou and Abrahams (2016) explain that this idea may be because, in their everyday experiences, they observe that heavier objects fall faster than lighter objects.

Barendsen and Henze (2017) explain that it is not easy to observe the teachers' knowledge of how students understand (KSU) science during the lesson. However, Magnusson et al. (1999) highlight that this manifests when teachers use different representations to illustrate one concept and when they engage students in different activities, which help them interact with the subject matter and with each other. Furthermore, it manifests when teachers incorporate students' prior knowledge by referring to what students know, either from previous lessons of from their experience with the environment. This review therefore provided insight into how KSU manifests during instruction.

2.2.1.4. Knowledge of instructional strategies

The teachers' knowledge of instructional strategies constitutes the knowledge of general activities, which both teachers and students do in the science classroom, including those used when teaching a particular topic such as the concepts of force. In this regard, Magnusson et al. (1999) categorised knowledge of instructional strategies (KIS) into subject and topic-specific strategies. Collectively, KIS, which are used to teach science, are called inquiry-based science teaching (Açışlı et al., 2011; Shofiyah et al., 2012).

Inquiry-based science teaching strategies range from open inquiry, in which students take the lead to identify the problem and investigate it, to closed inquiry where the teacher identifies the problem and determines the procedures of the investigation (Crawford, 2007). In inquiry-based teaching, teachers train students to take the lead in identifying the problem, asking questions, designing investigations, recording and interpreting data and developing explanations. In line with the expected strategies to be used when teaching science, particularly the concepts of force, the teachers' classroom practices were analysed and juxtaposed with their perceptual beliefs about teaching in order to determine whether their perceptions influence practice or not.

The learning cycle, as an example of an inquiry-based strategy, constitutes three stages: exploration, term (concept) introduction and concept application (Lawson et al., 1989:4). The model was further modified such that more stages were added; 4E, 5E and 7E models (Sarac, 2018).When using these models, students search and construct knowledge on their own and apply it in real-life contexts. As students search for and formulate explanations, they reveal their conceptions to the teacher while also developing scientific reasoning skills, a goal for science teaching (Shofiyah et al., 2012). However, Magnusson et al. (1999) highlight that, in order to use the learning cycle, the teachers should have a substantive content knowledge.

Instructional strategies, which are topic specific strategies, comprise activities and representations used to make the specific content comprehensible for students (Magnusson et al., 1999).In particular, the concepts of force are abstract for most students, therefore teachers often use analogies, interactive diagrams and free body diagrams to visualise them (Bryce & MacMillan, 2005; Fadaei & Mora, 2016;Savinainen et al., 2013). These are topic specific strategies because they are representations and activities used when teaching force concepts and not any other concept. The teachers' perceptions of KIS were sought and then mapped onto their practices by establishing the activities and representations, which they believed they knew, and whether they do them during instruction or not.

The teachers' choice to use a particular strategy depends on many factors, such as their orientations towards teaching science and their self-efficacy (Park & Oliver, 2008). That is, teachers who hold the view that science is an inquiry and that scientific knowledge is tentative are likely to use instructional strategies that are aligned with those beliefs (Mahmood, 2013). Teachers with high self-efficacy use a variety of strategies as the means to assist all the students to experience learning and to comprehend science (Deemer, 2004). However, as it is indicated that teachers often hold conflicting beliefs, one may acknowledge the tentative nature of scientific knowledge, but, on the other hand, may view teaching as the transmission of knowledge to students, thus using strategies that align with knowledge transmission.

2.2.1.5. Knowledge of assessment strategies

According to Mugimu and Mugisha (2017:22), assessment "…is a form of educational measurement that is used to ascertain whether learning is actually taking place." There are two types of assessment; formative and summative (Acar-Erdol & Yildizli, 2018). Formative assessmentis a process used by teachers and students during instruction in order to provide feedback and adjust instruction (Herman et al., 2015).It involves analysing and interpreting students' responses and using the results to formulate what to do next. This process, however, requires developed PCK. Moreover, teachers should have a clear purpose for every assessment they do in the classroom. In their study to identify classroom assessment practices of teachers, Acar-Erdol and Yildizli (2018) indicate that the teachers' purposes of conducting formative assessments were to give students feedback, increase learning and monitor students' progress. However, they gave explanatory feedback, most of which was abstract. Nonetheless, they highlight challenges brought by the nature of the curriculum, pressures to prepare students for national examinations, and characteristics of students. In addition to the contextual factors that impact implementing formative assessment, Herman et al. (2015) point to the reciprocal relationship between teachers' knowledge base and assessment practices. They indicate that the teachers in their study, which examined the quality of teachers' PCK and its relationship with assessment practices, performed low, before and after two days of professional development, when explaining science concepts, as well as when analysing, interpreting and suggesting subsequent instructional steps.

In order to implement formative assessment, teachers use different strategies. Bulunuz (2019) introduced annotated students' diagrams in science courses. When introducing the topic of reproduction in plants, the teacher asked students to draw the pollination and fertilisation process using a minimum of words. The purpose of the teacher was not only to uncover students' preconceptions, but also to test the strategy. They found that the strategy was effective in revealing what students know, including misconceptions.

Bryce and MacMillan (2005) used interviews and bridging analogies to reveal students' conceptions of action-reaction force at the rest position. They also found interviews, used together with diagrams, as an effective formative assessment strategy.

This study was concerned with the teachers' perceptions of their knowledge base needed to teach the concepts of force. As a result, it was imperative to understand formative assessment strategies, how they are implemented in the classroom as well as the factors that might impede or promote their use so that more understanding of the participants' practices in this study was ascertained.

2.3. Studies on science teachers' knowledge base

Liu (2010:145) defines teacher knowledge as "knowledge exclusively for teaching…" because it is characteristic to teachers. Teaching entails a body of knowledge, not just one aspect of it, hence Verloop et al. (2001)refer to teachers' knowledge base as the total knowledge which teachers have at their disposal at a particular moment. However, teachers' knowledge base is labelled differently by researchers, depending on the purpose of their studies. Nonetheless, they all view it as the knowledge that manifests in the action of teaching and they call it professional or practical knowledge (Kirschner et al., 2016). Common in the literature is that teacher knowledge is considered as an essential factor of effective teaching. Shulman (1987) contributed to the conceptualisation of a knowledge base by enumerating seven domains and citing PCK as the most essential. He clarified PCK as a subject- and topic specific teacher knowledge base for (science) teaching that is both topic- and subject specific (Etkina, 2010). Further research to delineate science teachers' PCK highlighted that content and pedagogical knowledge are central to PCK and that it has different components, as illustrated in Figure 2.1. In pursuit of understanding how it manifests during teaching, different lines of research on science teachers' PCK emanated. These were capturing and portraying teachers' PCK, investigating the integration of components during teaching and ascertaining the relationship between teachers' PCK and their classroom practices.

2.3.1. Capturing and portraying science teachers' PCK

Though different researchers used different methods to capture and portray science teachers' PCK, some of them lacked the details of the classroom incidences and the teachers' thinking (Loughran et al., 2000; Mulhall et al., 2003). As a result, the researchers devoted their research to developing tools to capture and thus portray samples of experienced science teachers' PCK of different topics. They named their tools Content Representations (CoRes) and Pedagogical and Professional-experiences repertoires (PaP-eRs).

CoRe is a tool that is used to capture science teachers' PCK and comprises a table that teachers fill as they respond to the pedagogical questions. It constitutes a vertical column, which requires teachers to fill the big ideas they intend to teach under a particular topic, such as the concepts of force. The horizontal rows comprise the prompts that teachers answer per big idea (Mulhall et al., 2003; Bertram, 2012). PaP-eR is a representation of the teachers' pedagogical reasoning of a particular topic developed through an interview (Mulhall et al., 2003).

Bertram (2012) explored whether CoRes could indeed capture and reveal aspects of teachers' PCK and the impact the process had on their long-term knowledge of teaching and learning. Bertram (2012) found CoRe useful for capturing teachers' PCK that influences their long-term professional practice. Moreover, he found that it was a framework which enabled teachers to engage more meaningfully with planning and lesson preparation and that it offered rich ways of thinking about their practice. Furthermore, Bertram (2014) explored how an understanding of PCK, as conceptualised through CoRe and PaP-eR, might develop science teachers' knowledge of their professional practice and develop the start of the primary teachers' PCK. The author found that, though the teachers' science content knowledge was limited, CoRe and PaP-eR portrayed aspects of the teachers' developing PCK and enabled them to connect the little content knowledge they have with pedagogical knowledge.

Content representation (CoRe) was used differently by science education researchers to capture the teachers' PCK. While Bertram (2014) and Mazibe et al. (2018) asked teachers to complete the CoRe in order to capture their articulated PCK, Barendsen and Henze (2017) as well as Mazibe et al. (2018) used CoRe prompts as interview questions for the same purpose. Common about these two groups of researchers is the fact that they collected PCK using CoRes as a data collection tool together with classroom observations.

Differently from the use of CoRes and PaP-eRs, other researchers use classroom observations, teacher interviews, pre- and post-observation interviews as well as artefacts such as curriculum materials and lesson plans (Park & Oliver, 2008; Park & Chen, 2012). In contrast to researchers who use CoRes as data collection tool, teachers are observed while teaching a particular topic (Barendsen & Henze, 2017). Similarly, the teachers were interviewed after a series of classroom observations with the purpose of capturing their thinking as it transpired during the lesson. Other researchers, such as Park and Oliver (2008), asked teachers to write reflective journals so that their pedagogical reasoning may be discerned.

Though it is time consuming, CoRe has proved to be a useful instrument in helping teachers to be in touch with their PCK (Bertram, 2012). As a result, research should focus on how to make it part of regular teaching practices. Moreover, no single instrument can capture teachers' PCK, hence CoRes are coupled with PaP-eRs so that they complement each another.

2.3.2. Relationship between PCK and classroom practice

Alonzo et al. (2019) suggest that teachers with coherent and established knowledge are not only able to articulate PCK, but also use it to shape their classroom practices, what they do together with their students during the classroom instruction. However, different scholars use different approaches to probe the relationship between teacher knowledge and practice. For instance, some investigated only one domain of teacher knowledge and its relation with classroom practice (Campbell et al., 2017; Hill & Chin, 2018; Lucero et al., 2017; Rahman, 2018), while others explored more than one domain (Aydin et al., 2017; Mazibe, 2018; Park & Chen, 2012).

Rahman (2018) investigated classroom assessment practices of secondary school science teachers and highlighted that teachers had limited knowledge of assessment methods to assess students' learning. Campbell et al. (2017) explored the impact of science teachers' orientation on instructional practice. They pointed out that teachers' orientations towards science teaching are not generic; they are topic-specific. As a result, instructional practices when teaching different topics differ depending on the teachers' orientation to teaching that particular topic. Lucero et al. (2017) probed the relationship between the subject matter knowledge and the knowledge of students' conceptions of evolution. In both cases the teachers demonstrated a strong knowledge of students' conceptions. Hill and Chin (2018) investigated whether there is a relationship between teachers' accuracy in predicting students' performance in cognitive assessment and their knowledge of students' misconceptions and instructional practices. Lucero et al. explained that the teachers were able to predict students' responses to particular questions about evolution. However, they were not able to structure their instructional practices so that students' alternative conceptions could be used productively. Hill and Chin (2018) observed that the teachers' accuracy to predict students' performance had a limited relationship to practice, though knowledge of misconceptions is difficult to measure. Alonzo et al. (2019) describe the fact that the researchers find different results as indicating that the uniqueness of teachers' classroom practice is a result of different knowledge resources they bring to the classroom. They characterise these knowledge resources to comprise what they call personal PCK (pPCK).

In studies that focused on more than one domain of teacher knowledge and their relationship to instructional practice, researchers observed variations between the teachers' reported PCK and the enacted PCK. Mazibe et al. (2018) observed that the teachers' enacted PCK was predominantly lower than the reported PCK in the following aspects of science teachers' topic specific PCK: students' prior knowledge, curriculum saliency, what is difficult to teach, representations, and analogies and conceptual teaching strategies. Teachers applied their knowledge about teaching graphs of motion to some of the components. Park and Chen (2012) investigated the nature of the integration of the five components of science teachers' PCK. They recognised a strong integration between knowledge of how students understand science and instructional strategies, and a weak relationship between practice and knowledge of assessment and students' understanding. Suh and Park (2017) also observed a strong connection between orientations towards teaching, knowledge of students' understanding and knowledge of the curriculum. The integration was observed when teachers recognised students' misconceptions during teaching and thus restructured instruction to address their needs. Barendsen and Henze (2017) compared PCK-on-action to teachers' classroom practices by unravelling each in terms of its pedagogical elements and interrelatedness. Unlike Park and Chen, who investigated how the elements relate during practice, Barendsen and Henze (2017) compared the connection of the articulated pedagogical elements and their interconnection during practice. In both studies, a connection was found between science teachers' knowledge of how students understand physics, and the knowledge of instructional strategies and representations. However, the connections were idiosyncratic (Park & Chen, 2012). The idiosyncratic nature of science teachers' PCK is explained by Carpendale and Hume (2019) who highlight that during teaching, teachers transform their personal PCK (pPCK) into enacted PCK (ePCK), both of which are context dependent. Consequently, classroom practices of two different teachers can only have similar features, although differences are always observed. This is because science teaching is complex; it requires continuous in-the-moment responses to students' needs. Responses may not be the same for different sets of students (Alonzo et al., 2019). Nonetheless, the teachers' knowledge of how students understand science seems to relate more to classroom practices. The relationships become evident when teachers notice the students' display of alternative conceptions (Lucero et al., 2017) and restructure their practices.

2.3.3. Studies on physics teachers' PCK

The literature is replete with studies on physics teachers' knowledge base. However, most of them study one component of physics teachers' professional knowledge (Haagen-Schützenhöfer & Joham, 2018; Karal, 2017) and they probe the teachers' knowledge of physics in general (Qhobela & Moru, 2014). These studies sought to understand physics teachers' views about their professional practice through open-ended surveys followed-up with teacher interviews. This approach is challenging. As Shulman (1986) posit that PCK is the knowledge to teach particular content to particular groups of students, it is imperative for teachers to develop knowledge and skills to teach each topic within the school curriculum.

In other studies, the focus was on physics teachers' knowledge of specific topics, such as force and motion (Alonzo & Kim, 2016; Mazibe et al., 2018; Liepertz & Borowski, 2018; Loughran et al., 2012). Mazibe et al. (2018) used content representations (CoRes), interviews and classroom observations to investigate physics teachers' topic specific PCK to teach graphs of motion. Alonzo and Kim (2016) used two video stimulated interviews to elicit high-school physics teachers' PCK the topic of force and motion. Similarly, Karışan et al. (2013) investigated physics teacher's PCK on the topic of fluid pressure. They collected qualitative data through a pre-instructional interview, classroom observations and post-observation interviews. Dissimilar from the two studies, Liepertz and Borowski (2018) studied physics teachers using both quantitative and qualitative methods. They investigated the relationship among the aspects of teachers' knowledge and skills as suggested by the Consensus Model. That is, they tested both the students' and teachers' knowledge through a paper-and-pencil test followed by video-recorded classroom observations while teaching the concepts of force. The teachers' tests measured PK, CK and PCK.

Some studies investigated physics teachers' knowledge in the context of professional development (Mualem & Eylon, 2009; Sorge et al., 2019). Mualem and Eylon (2009) explored physics teachers' qualitative understanding (content knowledge) of force concepts, their views towards physics teaching and the effectiveness of professional development in changing their views and practice. Sorge et al. (2019) investigated the structure of the pre-service physics teachers' professional knowledge (CK, PK and PCK) in the context of force and motion. They investigated it at different levels of training in order to determine the effectiveness of the programme in developing pre-service teachers' professional knowledge. Both studies found a close relationship between PCK, content and pedagogical knowledge. In particular, Maulem and Eylon (2009) explain that physics teachers who did not major in physics expressed more confidence, skills and knowledge to teach it after they had participated in professional development (PD) activities, as demonstrated by the pre- and post-questionnaire results. Sorge et al. (2019) found that pre-service science teachers' PCK was closely related to pedagogical knowledge before participating in professional development (PD) whereas at the end of the PD course, their PCK was more related with content knowledge.

As already highlighted, researchers used different methods of data collection to study physics teachers' professional knowledge. They used a quantitative paper-and-pencil test, video-recorded lesson observations and video-based interviews. It is observed that most studies investigated physics teachers' professional knowledge through qualitative methods, which makes generalisation of the results difficult because of the limited number of participants.

Furthermore, I have observed variations in the number of PCK components that were investigated as well as the frameworks that they used. Mazibe et al. (2018) investigated five topic specific PCK TSPCK components that they framed through the topic specific PCK (TSPCK) introduced by Mavhunga and Rollnick (2013) whereas Liepertz and Borowski (2018) investigated the relationship among the five knowledge bases, as framed by the Consensus Model. Conversely, Alonzo and Kim (2016) used Shulman's (1987) PCK framework and studied the teachers' declarative and dynamic PCK by unpacking their knowledge of students' difficulties and instructional representations.

2.4. Teachers' beliefs, perceptions and classroom practice

Beliefs and perceptions are integral to the teaching practice because they serve as filters between teachers' knowledge and practice (Liepertz & Borowski, 2018; Şen &Sarı, 2017). According to Savasci-Acikalin (2009:2), beliefs are "dispositions to actions and major determinants of behaviour." Meschede et al. (2017:159) refer to beliefs as "…understandings or premises that are personally felt to be true." Perceptions, on the other hand, are the personal understandings about a phenomenon (Cheng et al., 2016). That is, following an observation of a natural phenomenon, it is common for people to frame their own intuitive understanding, hence their perceptions of reality. From the definitions, it can be concluded that a belief is what one accepts to be true without necessarily having data or facts about it. However, perception, as put by Kurki-Suonio (2010), is an intuitive understanding, which is a result of identifying, organising and interpreting what one has observed. Unlike beliefs, which are not based on prior knowledge, perceptions emanate from what one experienced or observed happening. However, both beliefs and perceptions determine how teachers understand teaching. In this study, perceptions and beliefs are used interchangeably. For instance, teachers who view teaching as knowledge transmission tend to teach accordingly. This argument is supported by Şen and Sarı's (2017) observation that beliefs and perceptions are related. In their study to investigate the relationship between pre-service teachers' beliefs about teaching and learning and perceptions of the nature of science, Şen and Sari (2017) indicate that pre-service teachers who have traditional beliefs are more likely to have naïve perceptions of the nature of science. Those with reform-based beliefs tend to have realistic perceptions of the nature of science, thus they teach accordingly when they begin their teaching careers.

2.4.1. Relationship between teachers' perceptions and classroom practice

Knowing science teachers' beliefs and perceptions about different aspects of science teaching is critical for understanding their instructional practices. Cheng et al. (2016) point out that perceptions are precious and invaluable in the teaching and learning process, because they affect the teachers' attitudes and instructional practices. A review of the literature revealed inconsistencies in the findings of studies, which explored pre-service teachers' perceptions and the relationship between knowledge base and practice (Savasci-Acikalin, 2009). For instance, Du Plessis (2020) and Yaşar (2017) note that, pre-service teachers had negative perceptions of formative assessment and student-centred teaching. In other studies, pre-service teachers were found to have positive views about the knowledge base. However, their perceptions did not match their practices (Azam, 2018). For instance, pre-service teachers, who were doing the final year of postgraduate teacher education, whose undergraduate majors were physics and/or general science, report positive perceptions about the relevance of the physics courses, whereas those who did engineering reported negative perceptions (Azam, 2018). However, both groups explained that during teaching practice, they had more factual than conceptual knowledge. Hence, they struggled when planning and teaching during teaching practice. Feyzioğlu (2019) also explored laboratory perceptions and practice of pre-service teachers and found that their participation in laboratory activities was in accordance with their perceptions. Those with avoidance perceptions avoided to do investigations while those with mastery-goal perceptions strove for mastery. As they did not want to be wrong, they did laboratory activities to confirm what they already knew. After a PD experience there was a shift in the perceptions of teachers, except for those who held avoidance perceptions. This could mean that the teachers' undergraduate physics study did not equip them with the necessary conceptual understanding of physics. Yaşar (2017) who found that pre-service teachers with a low level of perceptions of formative assessment lacked knowledge of the purpose, preparation, interpreting and scoring of formative assessment results, supports this view. The findings that the pre-service teachers have under-developed beliefs and low-level perceptions have implications. That is, they have inadequate CK and that the knowledge of assessment strategies indicates a lack of PCK. Consequently, pre-service teachers may have challenges when they become in-service teachers. Therefore, while still at training, they should be helped to develop PCK by providing specific professional development activities (Qian et al., 2019). To address pre-service science teachers' negative perceptions about different aspects of science teaching and learning, while still at teacher training, professional development (PD) courses that are intended to boost their PCK are put in place. Studies aimed at investigating and addressing pre-service science teachers' perceptions about inquiry, report that after the PD courses, some of the teachers' perceptions changed.

Studies exploring the relationship between in-service science teachers' perceptions and classroom practices are limited and found that perceptions do not influence practice (Barendsen & Henze, 2017; Qhobela & Moru, 2014; Savasci & Berlin, 2012). In the study to examine science teachers' beliefs and classroom practices related to constructivism, Savasci and Berlin (2012) observed that the teachers' expressed beliefs did not match their classroom practices. Most of the participating teachers experienced difficulties with incorporating their beliefs into practice. That is, classroom practices of those teachers who reported expert constructivists were classified as emerging constructivists. Similarly, in their study to identify areas where physics teachers in Lesotho may need professional support, Qhobela and Moru (2014) examined how the teachers describe the teaching of science and their actual practice. They pointed out that there was a mismatch between what teachers believe is the effective way of teaching science and their actual practice. Barendsen and Henze (2017) explored whether and how a chemistry teachers' PCK-on-action, as captured by content representations (CoRes), informed practice in the context of an educational innovation. The study found that though the teachers' PCK-on-action was largely conceptual, the practice was more traditional and teacher-centred. Meschede et al. (2017) observed a substantive and different relationship between beliefs, professional vision and PCK. They explain that beliefs serve as filters for how teachers observe classroom situations and what they notice during instruction. That is, teachers with high professional vision and PCK tend to have less knowledge transmission beliefs whereas those with constructivist beliefs and PCK displayed moderate positive correlation. This means that, teachers who hold knowledge transmission beliefs struggle to notice, describe and interpret classroom situations, while those who hold constructivist beliefs are better able to recognise and describe them. From this review, it seems that although teachers' perceptions of their knowledge base are said to determine practice, it becomes apparent that this is not always the case. Some teachers may hold constructivist beliefs, but lack the knowledge and skills to enact them, thus implying undeveloped PCK.

In-service teachers displayed both positive and negative perceptions about different aspects of science teaching and learning, such as experimental work (Sadoglu & Durukan, 2018; Wei & Li, 2017) and teaching electric circuits (Moodley & Gaigher, 2019). Teachers seemed to understand experimentations as a way in which students develop new knowledge and as a way of motivating students and concretising abstract concepts (Wei & Li, 2017). Those with negative views about experimentation believed that it is done mainly to confirm what students have already learned and that they follow a given procedure as opposed to designing their own. Furthermore, the teachers' perceptions were found to be dependent on their content knowledge (CK) (Moodley & Gaigher, 2019). Teachers with adequate CK displayed conceptual perceptions of students' misconceptions. They included using analogies, constructivism and conceptual explanations during instruction. However, those with inadequate CK held the perception that teaching electric circuits entails transmission of factual information, demonstrations and calculations as opposed to developing students' conceptual understanding. Similarly, Qian et al. (2019) report that computer science teachers whose undergraduate major was computer science and those who had additional computer training reported high perceived importance of students' misconceptions and confidence to address them. That is, teachers with high CK have high perceptions about their ability to help students understand science.

This study aspires to understand the interplay between the teachers' perceptions of their knowledge to teach the concepts of force and their classroom practices. As a result, understanding that it is not only teacher knowledge that determines classroom action enables more understanding of teachers' practices.

Magnusson et al. (1999) coined the knowledge and beliefs about the purposes and goals of teaching science at a particular grade level as teacher orientation towards teaching. This implies that beliefs are an integral part of teacher knowledge. In science education literature, teacher beliefs and orientations are investigated differently. As highlighted in the preceding paragraphs, the approach was that teachers were probed for their beliefs through either interviews or surveys, followed by classroom observations and analyses of documents in order to ascertain whether there is a relationship between them or not (Savasci & Berlin, 2012; Şen & Sarı, 2017). However, investigations of science teachers' orientations took the form in which researchers observed teachers' classroom teaching followed by an interview to understand the reasons for their practice (Boesdorfer & Lorsbarch, 2014; Campbell et al., 2017). These researchers observed that the teacher's orientations aligned with their practice. However, Campbell et al.'s (2017) purpose was to explore the interplay between a science teacher's orientations and the topic specificity of PCK across two science topics within a grade 9 earth science course. They found that teacher orientations are not consistent across topics; rather, they are topic specific. Another angle of research on science teachers' orientation done by Demirdöğen (2016) investigated how pre-service science teachers' teaching orientations interact with other components of PCK. They observed that a teacher's purpose for teaching science determines the PCK component with which to interact, teachers' beliefs about the nature of science do not directly interact with their PCK and beliefs about science teaching and learning interact with knowledge of instructional strategies. It is therefore imperative to know the science teachers' beliefs and orientations about physics teaching and learning in order to discern whether they are likely to advance the purposes of science teaching or not and to understand their classroom practices.

The literature on science teacher orientations yields opposing results. In their study to examine how science teaching orientations and beliefs about technology-enhanced tools change over time in a PD process, Campbell et al. (2014) explain that the orientations of some of the teachers changed from information transmission to sophisticated orientations. The conclusion made was that the teachers had one orientation about technology-enhanced tools. However, Campbell et al. (2017) found that teachers do not have unitary orientations. Their orientations are topic-specific. The authors explain that one teacher displayed two different orientations, reform-based and traditional, when teaching two topics, oceanography and pollution. Similarly, Feyzioğlu

(2015) found that pre-service science teachers exhibited different pedagogic orientations of inquiry characteristics. That is, the teachers displayed a teacher-centred orientation about the problem or question posing part of the investigation. Instead of having students devise their own problems, the teachers believed that students will learn better when they were told about the problem before the investigation. However, the same teachers exhibited a student-centred orientation about the results analyses. These results seem to align with those of Campbell et al. (2017). They show that teachers do not have unitary orientations. With topics or aspects of science teaching where they feel confident and knowledgeable, they seem to have a student-centred orientation. This is because they seem to engage students into knowledge construction and a high level of student-student interaction.

2.5. Importance of perceptions of knowledge

It is important to know teachers' perceptions of knowledge bases, because they inform how they participate in the teaching and learning environment. For instance, Feyzioğlu (2019) explain that pre-service teachers with an avoidance of performance approach do not want to make mistakes when participating in science learning activities such as experiments, whereas those with a performance approach engage in all the steps involved in chemistry laboratory work. Even during chemistry laboratory work, the teachers' participation aligned with their perceptions and orientation. That the pre-service teachers' participation in the chemistry laboratory aligned with their perception could make one believe that perceptions inform practice. However, this does not seem to be the case.

Abergaria (2010) explored the teachers' perceptions of questioning; the teachers believed that they asked open-ended questions and their students asked more in the classroom. However, the actual practice revealed that the opposite was true in both cases. The teachers were the ones who asked more questions and they asked low-order questions. Similarly, Mazibe et al. (2018) points out that the teachers' reported or perceived PCK was not necessarily a reflection of enacted PCK. The teachers' reported PCK was either lower or more than the enacted PCK. Nonetheless, Park et al. (2016)

report a match between perceptions and practice. They indicate that Korean primary science teachers' views about science, technology, engineering, arts and mathematics (STEAM) education matched their practices more than that of secondary science teachers.

This review shed some light on the fact that knowing teachers' perceptions of knowledge bases do not necessarily mean knowing their practices. They may have positive views about their knowledge but fail to translate that into practice. However, a mismatch between them does not necessarily mean that teachers lack the appropriate knowledge; rather, they are confronted with issues, such as finding time to enact their perceptions and added workload (Cheng et al., 2016).

2.6. Understanding concepts of force and momentum

One of the goals of including science in the school curriculum is to assist students to develop scientific skills, which are necessary for effective functioning and contribution in their society (Şen& Sarı, 2017). Physics is believed to provide the tools that are most essential in understanding the natural phenomena. Mechanics, of which the concepts of force and momentum are part, is the foundation for all sciences. It provides those essential tools necessary to understand the natural environment (Carson & Rowlands, 2005). This is because it explains why things in nature happen the way that they do. Therefore, in order to understand some of the scientific concepts, they should understand mechanics. One of the purposes of teaching the concepts of force is to set the foundation to understand the scientific and natural phenomena (Akçay & Doymuş, 2012) and thus be able to make informed decisions when confronted with issues in their everyday lives.

Fadaei and Mora, (2015) explain that it is challenging to understand force concepts because people do not observe or experience them in their everyday lives; they experience the actions and effects of the force concepts. Unlike other scientific concepts that are defined as relations between two objects, force is not. A comprehensive understanding of force requires one to know all three laws of motion.

For instance, Carson and Rowlands (2005:475) explain that when one is confronted with the situation; "…what would be required to set in uniform motion a puck at rest on a frictionless horizontal surface," One should first understand the first law before applying the second law (F=ma). That is, one needs to understand that if a puck is not pushed, it will stay at rest and that once it moves, on the frictionless surface, it will continue moving. Without this understanding, it is likely to develop misconceptions similar to those exhibited by famous scientists such as Galileo (Fadaei & Mora, 2015).

2.7. Knowledge base to teach force and momentum

Most students perceive Physics to be difficult for because of its abstract nature (Ergül, 2013). The concepts of force are among the physics concepts that students experience in their everyday life. As they grapple with them, students develop their own understanding, which sometimes refutes the accepted science knowledge (Liu & Fang, 2016). That students have alternative views about force concepts makes it problematic for teachers. This has resulted in the literature being replete with research that probed into the teachers' knowledge base that is essential for teaching the concepts of force effectively (Fadaei & Mora, 2015; Gupta et al., 2014; Hammer,2000).

2.7.1. Lesson planning

Süral (2019:1) defines a lesson plan as a "…template with diagrams or steps used to achieve a goal." Ballet al. (2007:56) explain that teachers are "reflective practitioners". That is, they engage in lesson planning as a means to reflect on their practice. Ball et al. (2007:57) further explain that a lesson plan provides a teacher with "concrete representations of the day's events that guide teacher-students' interactions and instructional outcomes."

During the lesson planning stage, teachers reflect on a number of issues, including what content to teach, what prior knowledge of a particular content students have, what they would like to learn, what interests them, as well as the available resources and materials that they will need to use (Ball et al., 2007; Loughran et al., 2012; Süral,2019).

Important for teachers to consider when developing lesson plans are the objectives students are expected to achieve in that lesson, the in-class activities and the assessment, all of which should align with the lesson objectives (Ball et al., 2007; Süral, 2019). However, Krajcik et al. (2014) advise teachers to plan their lessons based on the performance expectations, as stipulated in curriculum documents such as syllabuses. This is because students are assessed based on those standards.

As a means to facilitate lesson planning and for teachers to integrate different dimensions of teaching and learning, Loughran et al. (2012) highlight that content representation (CoRe) can act as a template to engender teachers to think about what to teach, why and how. As they plan, using CoRe, teachers answer questions such as:What do I want my students to know about this content? Why is it important for my students to know this content? What difficulties are students likely to have when learning this content? And How am I going to help them to use what they know to construct a new understanding? Loughran et al. (2012) explain that teachers who engage in this kind of pedagogical thinking during planning demonstrate an integrated knowledge necessary during teaching. Moreover, lesson planning enables teachers to organise elements of instruction, to monitor and evaluate their activities and thus improve their teaching (Ball et al., 2007; Ceylan & Ozdilek, 2014; Süral, 2019).

Despite the benefits of lesson planning, Ball et al. (2007) explain that teachers do not usually go through all the steps when planning the lessons. They consider lesson planning as a mental process, which entails thinking about what they want to accomplish. Consequently, they do not develop detailed lesson plans. Süral (2019:1) highlights the fact that “preparing a lesson plan is a duty of teachers in terms of professional responsibility and legislations”, and that it serves as a basis for effective teaching. The present study was intended to establish whether science teachers in this study compile lesson plans or not and to determine how they do it and what it constitutes.

2.7.2. Content knowledge

Hançer and Durkan (2008:45) observe that “[o]ne of the main purposes of science education is to bring up the students’ scientific literacy level.” They explain that scientific literacy constitutes, among others, knowing the basic concepts and theories and to be able to differentiate between academic proof and personal opinion, both of which symbolise content knowledge (CK). The teachers’ knowledge of the science content, including the concepts of force, is realised in how they explain science concepts (Geelan, 2020). Science teaching explanations primarily aim at developing an understanding on the part of students. In order for teachers to achieve this aim, they draw on their CK and knowledge of students. Hence, Geelan explains that science teaching explanations require teachers to draw on students’ existing understanding and to include visualization. This is in line with the argument, made by Ball et al. (2008), that CK entails knowing not only how to state facts but also how to explain why they are the way they are. Knowledge of the content of force concepts constitutes teachers’ ability to explain the concepts accurately by also focusing on the underlying principle (Carpendale & Hume, 2019), thus linking concepts and providing students with clear explanations about how they link.

Nieminen et al. (2010) further clarify that CK is evidenced when teachers represent the same concept differently, given similar and/or different contexts. Teachers usually create representations as the ways to visualize what they explain and as a mechanism to promote understanding (Cabello et al., 2019). Moreover, they try to link phenomena with their underlying causes. Savinainen and Viiri (2008) call this aspect of scientific knowledge conceptual coherence and warn that if teachers do not link concepts, they may end up with fragmented knowledge, as opposed to conceptual understanding as one of the goals of science teaching. Since this study sought to understand science teachers’ classroom practices, the literature reviewed here enabled the deconstruction of the teachers’ CK by analysing the teachers’ explanations.

2.7.3. Students' preconceptions

Students do not enter classrooms as empty vessels (Chrzanowski et al., 2018; Fotou & Abrahams, 2016; Morrison & Lederman, 2003). Rather, they bring along some understanding of most of the science concepts taught at schools. The knowledge that students have before they are taught is referred to as either prior knowledge or preconception. It is referred to as preconception this study. Binder et al. (2019) define prior knowledge as different types of knowledge, skills and competences that form the knowledge of facts, meaning, knowledge integration and application. The knowledge of facts needs simple recall, recognition and reproduction, while knowledge of meaning is the ability to understand the meaning of concepts, which they referred to as declarative knowledge. However, the knowledge of integration and problem solving refer to a high level of abstraction, which entails the ability to link concepts and to apply and solve problems. This is referred to as procedural knowledge.

Students' preconceptions of school science, either develop formally while at school or informally when they interact with other students and the environment. Within science, and physics in particular, the concepts of force are among those that students have more prior knowledge of (Hestenes et al., 1992). As students encounter the concepts of force in their everyday lives, they rationalise their experiences, based on their prior knowledge, and subsequently come up with knowledge structures that appear locally acceptable although they may not be consistent with the accepted scientific knowledge (Singh & Schunn, 2016). Fadaei and Mora (2015) indicate that the students' locally acceptable knowledge is sometimes called common-sense knowledge. Though researchers agree that some students' preconceptions are not scientifically correct, they hold contrasting views about how to use and refer to them during teaching (Fadaei & Mora, 2015; Gupta et al., 2014). Hammer (2000) refers to them as building blocks from which new knowledge can be constructed; he calls them anchoring conceptions or productive resources. Rowlands et al. (1998) consider them as obstacles to effective learning, thus they call them stumbling blocks. Fotou and Abrahams (2016) call them phenomenological primitives. Nonetheless, in most studies they are referred to as misconceptions.

What is common in literature is that, knowledge of students' thinking is important for effective teaching and learning therefore it is imperative to investigate whether teachers know what students know about concepts they teach (Çelik & Güzel, 2017; Hill & Chin, 2018). Consequently, literature identified different lines of research on teachers' knowledge of what students know. These include investigating teachers' knowledge of students' misconceptions of particular concepts such as force (Gomez-Zwiep, 2008; Gupta et al., 2014; Sadler & Sonnert, 2016) and knowledge of students' thinking (Çelik & Güzel, 2017; Olfos et al., 2014).

Gupta et al. (2014), Gomez-Zwiep (2008), and Sadler and Sonnert (2016) probed science teachers' knowledge of students' misconceptions. Gomez-Zwiep, (2008) examined elementary teachers' knowledge of students' misconceptions and how they address them during classroom instruction, while Gupta et al. (2014) investigated the teachers' reasoning about why objects of different masses fall with the same acceleration. Common among these studies is that the teachers displayed some misconceptions. Moreover, Gomez-Zwiep (2008) highlights that the teacher shared a limited understanding of misconception, such that they referred to them as confusion that needs more information to dispel. In their attempt to reason about the falling objects, the teachers displayed some misunderstandings. Interestingly, Sadler and Sonnert (2016) explain that some of the teachers in their study selected dominant students' misconceptions as their own correct answer. This is detrimental to effective teaching, because students who are taught by teachers with limited content knowledge and who have some misconceptions run the danger of passing those beliefs on to their students. As a result, science teachers should know possible students' misconceptions so that they can use them as either productive resource from which to construct new knowledge (Hammer, 2000) or to help their students to restructure their understanding.

In their study to investigate mathematics knowledge of students' thinking and its evidence in their teaching, Çelik and Güzel (2017) observed that the teachers' knowledge of students' thinking was limited. During instruction, they focused on students' prior knowledge as opposed to other components, such as ideas that students have about a particular concept, the mistakes they make and misconceptions they might have. Rice and Kitchel (2016) explored how the beginning agriculture teachers' knowledge of content and students influence how they broke down the content for students' understanding. The study revealed that the teachers recognised the importance of the students' prior knowledge in learning new content. This constitutes the subject matter students learned in either previous classes or subjects. There was no evidence of finding the difficulties and/or alternative ideas students might have about their prior knowledge. Moreover, the teachers struggled to use that knowledge to facilitate further learning. That the teachers mainly recognised students' prior knowledge as opposed to other components of students' knowledge, is problematic and it indicates that their knowledge of students' knowledge is limited, so is their PCK. As a result, both pre-service and in-service teachers should be provided opportunities to develop diverse knowledge of students' preconceptions and how to use it to advance students' understanding.

Fadaei and Mora (2015) examined students' misconceptions of force and motion before and after formal instruction, while Canu et al. (2016) investigated university students' conceptions and misconceptions about equilibrium and stability. Both studies observed that students displayed some misconceptions of certain subjects. Similarly, Zhou et al. (2015) highlight that students have difficulties identifying Newton's Third Law(NTL) force pair in gravity interaction and they experienced difficulties differentiating between the concepts of interaction and force. It is therefore necessary for teachers to know common students' misconceptions for all the topics in the school curriculum, including the concepts of force and their sources, so that they may use the strategies aimed at helping students to restructure their conceptions. The reviewed literature afforded this study the opportunity to understand how science teachers view and use students' preconceptions while teaching. Moreover, it provided a lens through which to understand how the teachers in this study tapped and used students' preconceptions.

2.7.4. Students' common misconceptions of force concepts

Literature reports that students hold unscientific understanding of most of the physical science concepts, including force and motion. Since misconceptions are said to play a critical role in the teaching and learning process, understanding students' common misconceptions of force and how teachers tap and use them during instruction are critical in this study. Hestenes et al. (1992:144) probed students' misconceptions using the force concept inventory (FCI) after which he classified them into six major categories: "Kinematics, Impetus, Active force, Action/Reaction pairs, Concatenation of influence and Other Influences on Motion." Following this research-based assessment tool, researchers probed students' misconceptions using either the complete tool or part of it.

Fadaei and Mora (2015) used the FCI to investigate high school (grade 10) students' misconceptions before and after the traditional teaching of force and motion. They found similar misconceptions to those given in the FCI and most of them persisted even after the instruction. Handhika et al. (2016) used some of the items from the FCI to probe the students' misconceptions of Newton's laws and found that students indeed have misconceptions about them. Students believed that there are no forces acting on stationary objects; net force equals zero when acceleration and mass equal zero; net force is proportional to velocity and Newton's Third Law (NTL) occurs on one object instead of two. Similarly, Khandagale and Chavan (2017) found that students believe that a continuous force is needed for continuous motion to take place; motion of object is in the direction of net force applied to the object; gravity is stronger between objects very far apart; there is no gravity when moving; and that gravitational force acts only on heavy objects. Zhou et al. (2015) investigated students' performance in identifying reaction force in gravity interaction. They found that students experience difficulties identifying reaction force of the gravitational force acting on an object. The majority of them believed that the normal force acting on the table is the reaction force of the gravitational force on the table.

2.7.5. Assessing students' prior knowledge and understanding

Assessment is an integral part of teaching as is the teachers' knowledge of how to assess. Through different assessment methods, teachers can gather information about what and how much students know as well as what their needs and strengths are (Acar-Erdol & Yildizli, 2018). The researchers further explain that, in order to obtain the necessary information, teachers should know different assessment techniques, including the purpose of using formative and summative assessments. Since there are different assessment methods, each meant to give and/or address a particular situation, ascertaining what and how teachers engage in assessment practices provided a framework to engage and understand the teachers' practices.

Formative assessment, which is also referred to as assessment for learning and assessment as learning (Acar-Erdol & Yildizli, 2018), is regarded as the most essential assessment, because it provides both teachers and students with the necessary information to advance the teaching and learning process. Bulunuz (2019) explains formative assessment as a teaching method that helps teachers to determine students' prior knowledge, plan and shape instruction based on students' feedback. Feedback enables students to have a conceptual understanding of the subject matter that is taught. Moreover, Herman et al. (2015) consider it a powerful classroom intervention particularly for low-achieving students. However, most classroom assessment practices still use traditional assessment techniques (Anteneh & Silesh, 2018; Rahman, 2018), which focus on measuring how much students know.

Assessment of students' prior knowledge entails determining, before instruction, what students know about what they are going to learn. In their study, Hailikari et al. (2007) used a questionnaire to measure university students' declarative and procedural knowledge of mathematics concepts before teaching them. In the science education literature, the force concept inventory (FCI), first introduced by Hestenes et al. (1992), is a commonly used assessment tool to unravel what students know about force concepts. However, other scholars used other formative assessment strategies, such as annotated students' drawings (Bulunuz, 2019) and student interviews through the aid of bridging analogies (Bryce & MacMillan, 2005).

In the study to investigate secondary school science teachers' classroom assessment practices, Rahman (2018) found that the teachers use oral questioning as the main form of assessment. They asked oral questions prior and during the instruction. Then teachers give students some individual written class work. However, the teachers' feedback was not explanatory enough to support learning. Acar-Erdol and Yildizli (2018) elaborate that assessment warrants to be called formative when feedback is used to adjust instruction. Izci and Caliskan (2017) indicate that teachers spend most of their classroom time on assessment related activities. However, they do not use the information that they get to adjust their teaching. Consequently, this does not qualify their activities as formative assessment.

It is well posited that assessment can be done at any point during the teaching and learning process and for a particular reason (Izci & Caliskan, 2017). A common assessment practice used when teaching force concepts is administrating FCI before instruction, with the purpose of establishing students' prior knowledge and misconceptions (Fadaei & Mora, 2015; Fulmer et al., 2014). Savinainen and Viiri (2008) investigated how FCI can be used to characterise students' conceptual coherence, while Fulmer et al. (2014) validated the FCI in order for it to be used in conjunction with the Learning Progression (LP). Zhou et al. (2015) used a self-designed multiple-choice test to investigate students' performance in identifying the reaction of force to gravity. Similar among these studies is the fact that the studies reported that FCI was successful in measuring students' understanding of force concepts. In particular, Savinainen and Viiri (2008) highlighted that FCI enabled them to measure contextual as opposed to representational coherence. This suggests that science teachers should be knowledgeable about research-based assessment tools so that they may use them in their classrooms. These assessment tools proved to be reliable because studies that used them were able to reveal students' understanding.

In addition to FCI, other tools that researchers used to assess students' prior knowledge are concept maps. Concept maps assess the organisation and structure of students' conceptual knowledge (Stoddart et al., 2000). Subramaniam et al. (2017) used concept maps to assess pre-service elementary teachers' conceptual understanding of buoyancy. Before and after instruction, the teachers constructed concept maps and this enabled the researchers to determine the teachers' understanding and misconceptions, if any, of buoyancy and whether the intervention had an effect or not. However, Martinez et al. (2013) used concept maps as an instructional strategy in order to assess its effectiveness as compared to traditional strategies. In both studies, concept maps were found to be effective when used as assessment and instructional tools. This suggests that physics teachers have to learn how to use concept mapping as it has proved to be an effective strategy for teaching physics in general. Martinez et al. (2013) explain that concept maps proved effective regardless of the topic under investigation.

Magnusson et al. (1999) refer to teachers' knowledge of assessment as knowing the dimensions of science learning in order to assess as well as to differentiate among the assessment strategies suitable for each dimension. Among the dimensions of science learning, the authors refer to conceptual understanding as the nature of science and scientific investigations. Assessment strategies refer to the methods, such as written tests, laboratory practical examinations, activities that can be used when teaching a unit, performance based assessment, and portfolios.

2.7.6. Instructional strategies when teaching concepts of force and momentum

In order to make force concepts more comprehensible to students, research on instructional strategies to teach the concepts escalated. Inquiry-based teaching and learning strategies, such as analogical reasoning (Badeau et al., 2017), conceptual mapping (Martinez et al., 2013) and argumentations (Pimvichai & Buaraphan, 2019; Qhobela, 2012) are among the most researched strategies. The prime aim of science teaching is to help students restructure their conceptions so that they develop scientific understanding. Though there are contrasting views regarding how to achieve this, there is agreement among researchers that teachers should have a repertoire of instructional strategies that engage students in knowledge construction. As a result, literature report different instructional strategies, including activities and representations of force concepts (Hubber et al., 2010; Martinez et al., 2013; Savinainen et al., 2013). What follows are the different classroom activities and representations that teachers use to teach science, particularly force and motion, which provided a frame on which to determine the types of activities the teachers in this study used.

2.7.6.1. Analogies/activities

An analogy is a teaching strategy that uses a familiar model, concept or situation to explain an unfamiliar concept in order to enable transfer of familiar concepts (analogous) to unfamiliar concepts (target) (Nashon, 2003;Richey & Nokes-Malach, 2014). Two lines of research about analogies as instructional strategies emerged from the literature. On the one hand, the focus was on the teachers' knowledge and nature of analogies and how these are used during the classroom teaching (Maharaj-Sharma& Sharma, 2017). On the other hand, it focused on the effectiveness of analogies when teaching physics, especially when teaching force concepts (Bryce & MacMillan, 2005). Maharaj-Sharma and Sharma (2017) explored the experiences of Trinidadian physics teachers on the importance of analogies as an instructional tool and the extent of its use in physics teaching and learning. Nashon (2003) provided an insight into the nature of analogies that physics teachers use and students generate. Maharaj-Sharma and Sharma (2017), highlight that some teachers made deliberate use of analogies. Nashon (2003) indicates that the teachers mostly used environmental analogies, which they derived from textbooks. Nonetheless, physics teachers use analogies when teaching.

Other studies investigated whether the use of analogies has any effect or not in changing students' conceptions and whether they facilitate students' abilities to solve problems or not (Bryce & MacMillan, 2005; Richey & Nokes-Malach, 2014). Bryce and Macmillan (2005) worked with secondary school students and used the bridging analogies when interviewing them for their understanding of Newton's Third Law (NTL). They used bridging analogies in order to encourage students to reflect on their ideas regarding the existence of upward reaction force. Similarly, Richey and Nokes-Malach (2014) investigated how analogical comparison and other strategies, such as self-explanation, can promote features of robust knowledge (depth, connectedness and coherence). In both cases, the use of analogies was successful in effecting conceptual change and acquisition of deep knowledge. Importantly, teachers' competence is pivotal as it has a significant impact on the nature and extent of analogical reasoning (Maharaj-Sharma& Sharma, 2017).

Badeau et al. (2017) trained students to solve synthesis problems through an analogical comparison. They compared two examples and used the information that they acquired to solve new problems. Bryce and MacMillan (2005) provided students with different contexts of NTL and engaged them in a think aloud interview. In both cases, the authors explained that the use of bridging analogies and analogical comparison seemed plausible in effecting conceptual change and concept identification when solving problems that needed applying more than one concept. Nonetheless, the effectiveness of analogies in effecting students' understanding requires thorough planning so that students are systematically taken through the comparison process. Moreover, using analogies as a teaching strategy requires certain teacher competences with regard to planning and guiding students to compare analogue and target (Richey & Nokes-Malach, 2014). The improper use of analogies may lead to counter effective learning and thus result in students developing misconceptions (Nashon, 2003).

Further research used an instructional tool, which seems like a modification of analogical comparison and self-diagnosis to facilitate conceptual understanding and achievement. As an example, Safadi and Yerushalmi (2013) examined how students' self-diagnose (SD) their solutions when aided with worked examples. The process of SD constitutes a comparison of students' solutions (target) to the worked examples (analogue) in order to identify the similarities and differences. They compared the steps taken and the concepts used in both solutions. The authors explain that, as students identify a conflict between the solutions, they should acknowledge it and resolve it. However, Safadi and Yerushalmi (2013) explain that almost all the students were able to identify at least one major difference between their solutions and the worked example, but did not acknowledge the conflict. This could mean that students did not engage with the worked example; rather, they skimmed through and missed important points.

Contrary to Safadi and Yerushalmi (2013), Safadi (2017) investigated the impact of self-diagnosis and whole class discussions on students' conceptual understanding and achievement. Similar about the studies is the fact that the problems concerned force and motion concepts; students compared their solutions to the worked examples without assistance of the teacher. However, Safadi (2017) had two groups: one diagnosing their solutions without teacher intervention and the other engaging in a whole class discussion in which the teacher did most of the talking and justifications. After the discussion and SD, students scored their own solutions and then wrote a final test. The author points out that, contrary to classroom discussions, SD promoted students' conceptual understanding. However, the effectiveness of all strategies rests on the teachers' knowledge, about and how to implement them during the instruction.

2.7.6.2. Classroom discussion (Argumentation)

The view that learning is a social and cultural process places more emphasis on language, hence classroom discussions become the key feature of classroom teaching (Zhang et al., 2010). During classroom discussions, one of the main activities of teachers is questioning, while the students' role is to respond mainly by explaining (Döş et al., 2016). Effective classroom discussions require effective questioning; clarity and coherence of the subject of discussion; adequate representation of content; and equitable participation (Kulgemeyer & Riese, 2018; O'Connor et al., 2017).The authors explain that maintaining the balance between these requirements is daunting for most teachers because the level of students' participation is not the same and some give clearer explanations than others. This eventually tempts teachers to rely on them, thus resulting in unbalanced participation. Moreover, teachers worry that when they try to balance students' participation during discussions, they find that it takes more time, thus running against time constraints. Consequently, even teachers who try to engage in whole class dialogic discussion, revert to the dominant "default pattern of classroom talk”, recitation (O’Connor et al., 2017:5) due to these challenges. In recitation, a teacher initiates a question; students respond; then the teacher evaluates the response (IRE). However, the IRE model is not effective in promoting the thinking and sharing of ideas among the students and teacher; it does not yield an effective discussion (Sherry, 2019; Zhang et al., 2010). It focuses on vocabulary and memorisation rather than scientific reasoning (Ford, 2012). Since one of the purposes of science teaching is to help students to be able to participate in debates about scientific issues that affect them in their daily lives (Zhang et al., 2010), teachers should engage students in argumentative classroom activities. That is, they should encourage students to express their thinking about an issue, and evaluate and support it with evidence or modify it if it is not suitable in that context (Büber & Coban, 2017).

Introduction of argumentation in science, especially physics classrooms, has gained popularity among the science education researchers (Büber &Coban, 2017;Ford, 2012; Katchevich, et al.,2011;Qhobela, 2012). Popular among the researchers is the investigation of the effectiveness of argumentation in students’ gains. Büber and Coban (2017) investigated the effects of the learning activities, based on argumentation about the force and motion unit, on the conceptual understanding and views about establishing a thinking friendly environment of grade 7 students. Qhobela (2012) established the feasibility of success when argumentation is introduced as part of learning physics and whether it can increase their performance. Although done with students at different levels of education–primary and high school–both studies highlighted that, teaching the force concepts through argumentation has the potential of increasing students’ academic performance. Moreover, Qhobela (2012) explains that it is feasible to teach physics through argumentation. However, Büber and Coban (2017) indicates that teaching through argumentation did not seem to increase students’ conceptual understanding. However, it promoted thinking and friendly classrooms, because students were free and more willing to participate in argumentative discussions. Increasing students’ gains is not the only goal for science teaching; even developing students’ thinking capabilities is important. As a result, it seems important for teachers to be competent in teaching through argumentation.

Ford (2012) identified the aspects of argumentation in scientific practice that are essential for scientific sense making. He highlighted that the students' ability to critique and to identify their errors is important for students. Katchevich et al. (2011) explored the high school chemistry laboratory as a platform for developing and enhancing argumentation. In particular, the study investigated how the skills of constructing arguments, such as questioning, claiming, providing evidence and scientific explanations, are expressed in different types of experiments. In both studies, it was observed that students who participated in open-ended experiments or inquiry-based learning developed argumentative skills. In particular, the studies concluded that inquiry-based students were better able to critique the results of the experiment as opposed to students whose experiments were confirmatory. Nonetheless, the ability to teach through argumentation has some implications for teacher knowledge. Since argumentation is a form of classroom discussion in which students as well as teachers engage in the act of explaining their viewpoints and supporting them in order to convince others, teachers are expected to have good listening and questioning skills. Zhang et al. (2010) expound that teacher questioning is the main component of a classroom discussion. They also highlight that not all the questions are effective; therefore, teachers should ask open-ended and/or authentic questions that focus on eliciting or extending students' thinking and ideas. Furthermore, teaching through argumentation requires teachers to have an integrated knowledge base. For instance, teachers who have continually implemented an argument-based inquiry approach demonstrated integrated knowledge of the students' understanding, instructional strategies and orientations towards argument-based teaching (Suh & Park (2017). The implication here is that, for teachers to enact argumentations in their teaching, their beliefs about how students learn and about science and learning should support the socio-cultural view of learning.

2.7.6.3. Representations of force

In order to understand the teachers' practices, it is imperative to know the types of representations of the concepts of force that teachers use. This is because the teachers' knowledge of how to represent the subject matter differently is characteristic of teacher PCK (Janík et al., 2009). Mešić et al. (2017) argue that students learn by putting mental efforts into the process of knowledge construction and they use different representations, verbal, diagrams, gestures and mathematical, to communicate their understanding. Using multiple representations is pedagogically helpful, because one representation may also lack some of the information (Nieminen et al., 2010). However, it is even more important to use multiple representations, which are developed by both the teacher and students, as one representation might not be making sense to some of the students (Furwati et al., 2017).

In addition to the verbal and mathematical representations commonly used when teaching science, there are research-based representations. These constitute the concept maps (CM), free body diagrams (FBD) and interaction diagrams (ID) (Martinez et al., 2013). An ID is a diagram which shows the target object and the objects interacting with it while an FBD is a diagrammatic representation which focuses on the target object and the forces exerted on it by other objects (Mešić et al., 2017; Savinainen et al., 2013).

In their study intended to investigate whether using ID can help students to identify the forces acting on an object and thus draw a correct FBD, Savinainen et al. (2013) indicated that the use of ID was helpful in identifying forces and thus drawing FBD. Similarly, Mešić et al. (2017) explain that students perform best in problem-solving activities when they construct their own FBD, as opposed to using ready-made diagrams. Student-constructed representations are powerful tools that teachers can use to assess students' understanding and to engage them inactive learning. Hubber et al. (2010) explain that, because of the benefits observed on the part of students and teachers, teachers should change the traditional practice of transmitting content to a more active view of knowledge and learning.

In literature, the use of multiple representations during instructions is advocated for (Furwati et al., 2017; Hubber et al., 2010). In their study to investigate the improvement of junior high school students' understanding of the concepts of Newton's laws and the quality of representations used in solving problems pertaining to Newton's laws of motion, Furwati et al. (2017) applied multi-representation learning, that is, a verbal, mathematical and force diagram, to 25 eighth grade students. They found that the multi-representation learning approach improved students' understanding of Newton's laws and the quality of representations, whereas there was no change in the quality of force diagrams. However, teaching science through representations is even more effective when students construct and negotiate their own representations. In their study to explore what it means to teach science with a representational focus, Hubber et al. (2010) worked with teachers to assist them to plan and enact instruction that focuses on helping students develop their own representations of force. The teachers were successful in assisting students to develop and negotiate their own representations. This was found to enhance students' understanding and the teachers' pedagogical competences. Thus, this could also be taken to indicate that learning is primarily a representational issue, whether developed by the teacher or students.

However, there are contrasting views regarding the effectiveness of representations given by the teacher. Mešić et al. (2017) argue that it is a theoretical belief that including diagrams to a problem decreases its difficulty but increases students' understanding. Mešić et al. (2017) investigated how the inclusion of free-body diagrams into problems influences students' performance in solving mechanics problems. They administered two versions of five-point assessment problems. One group was given problems with free-body diagrams while the other group was given the same problems, but with no free-body diagrams. They found that the group whose problems did not have free-body diagrams outperformed their counterparts, indicating that those with verbal and pictorial representation had to interpret both representations, which was daunting for some of them.

These findings indicate that teachers often believe that providing students with multiple representations help them understand the subject matter better. Nonetheless, these results indicate that solving problems with externally made representations is problematic for most students, because they have to interpret both forms of representations that then increase the cognitive overload (Nieminen et al., 2010). Consequently, students should be helped to develop their own representations (Hubber et al., 2010). Though having students develop their own representations is pedagogically effective, avoiding exposing students to externally developed representations is not encouraged. Rather, students should be taught how to interpret them.

In their study to investigate the nature of teachers' PCK, Janík et al. (2009) made video recordings of classroom teaching in order to identify the representations which the teachers use when teaching composition of force. The teachers made different representations, such as experimental, pictorial, schematic, symbolic and verbal representations, at different levels of instruction. They started with those that do not require high cognitive skills such as observation of a demonstration and transcended to schematic and symbolic representations, which are more cognitively demanding (Janík et al., 2009).They explain that moving from one representation of the same concept to the other supports learning. Nieminen (2013) refers to the ability to represent and interpret different representations of the same concept as representational consistency. Nesbit and Adesope (2006) explain that low-ability students, especially those with low verbal ability, benefit more from instructional diagrams than high-ability students. Moreover, engaging students in concept mapping activities is effective in enabling knowledge retention, as students actively constructed knowledge. Consequently, teachers' knowledge of different representations of force is an essential competence for effective teaching.

The teachers' knowledge of how to use research-based representations is also imperative, because their effectiveness has been tested. According to Nesbit and Adesope (2006), concept maps can be used at different stages and for different purposes within the teaching sequence. Some teachers use it to introduce a topic or unit, then scaffold the discussions, based on CM, while others use it to summarise a topic (Nesbit & Adesope, 2006). Hubber et al. (2010) further explains that concept maps can be used as an instructional strategy in which students make their own representations and present them to each other. The teachers facilitate and scaffold discussions so that they may identify students' conceptions and to restructure and refine them to yield accepted knowledge.

Martinez et al. (2013) examined the effectiveness of CM in the teaching and learning of physics in engineering. Increased learning was observed with students taught using concept maps compared to those who were taught through traditional lecture methods. High learning gain was attributed to students' involvement in constructing the maps. This activity helped students to confront their own preconceptions and thus restructure their understanding. However, the use of this strategy requires teachers to be able to give students tasks that are at their level of cognition. This is because, constructing concept maps can be challenging for some students, as it requires high order cognitive thinking, thus resulting in cognitive overload.

2.8. Classroom practices when teaching force concepts

Classroom practices are connected to both the teachers' and students' behaviours during instruction (Tay & Saleh, 2019). These practices relate to the teachers' beliefs about the purposes of teaching, the nature of the subject/topic, the students, and learning (Magnusson et al., 1999; Suh & Park, 2017).Science teachers hold different beliefs and conceptions about science, students and instruction. Consequently, this has an influence on their practice (Campbell et al., 2017;Mahmood, 2013). Teachers' classroom practices are depicted in the type of representations that they make, the type of activities that they engage in and give to students, how they assess learning, as well as the feedback that they give to students. Dancy and Henderson (2007:3) frame classroom practice around ten categories: "interactivity, instructional decisions, knowledge source and students' success, learning mode, motivation, assessment, content instructional design and problem solving." Depending on what teachers and students do during instruction, they classify them as either traditional or alternative practices. Common in literature is that practices are classified into two categories, although different names are used. These are either reform-based or constructivist and conventional teacher-centred practices (Boesdorfer & Lorsbach 2014; Campbell et al., 2017). In this study, they are referred to as traditional teacher-centred and reform-based classroom practices.

What teachers do during instruction depends on a myriad of factors, among which teachers' perceptions. This study sought to understand the science teachers' perceptions of their knowledge bases and how they relate to their classroom practices. Therefore, knowing whether their classroom practices are traditional or reform-based can be related to their perceptions of students' involvement and the nature of the subject matter.

2.8.1. Traditional teacher-centred practices

Science teaching, including physics teaching, is dominantly taught through traditional practices where teachers take the leading role in classroom discourse (Fadaei & Mora, 2015; Mariappan et al., 2004; Prince& Felder, 2006; Verloop et al., 2001). Dancy and Henderson (2007) explain that teacher-centred practice is characterised by minimal interactivity, knowledge transmission, knowledge-based assessment and a competitive individualised learning mode. Madu and Orji (2015) elaborate that the lecture method, note giving and encouraging students to study their textbooks on their own before class are the dominant activities in teacher-centred classrooms.

Though some researchers view teaching through traditional strategies as not good science teaching, others believe that it is the best approach to learn content and skills, because teachers provide step-by-step guidance for students to acquire content (Shamsudin et al., 2013). Moreover, it reduces the pressure of dealing with disciplinary and/or behavioural issues during the classroom instruction. Nonetheless, its critiques argue that it is the cause of the high number of students who dislike science, because they get bored and thus lose interest (Madu & Orji, 2015). Furthermore, teaching through traditional approaches is not effective in promoting conceptual change, because it offers minimal social interactivity, thus neglecting students' preconceptions when teaching (Zhang et al., 2010).

In their study to examine the secondary school physics teachers' beliefs about teaching and classroom practices, Qhobela and Moru (2013) explain that in most classrooms, students' talking and participating is confined mostly to writing notes, asking questions or responding to the teacher's questions. This practice supports the literature, which indicates that the lecture method dominates all the levels of education, primary to university (Mariappan et al., 2004). On a few occasions, students participate in group activities in which they perform experiments to verify the theories and laws such as Hooke's law. These practices dominate most classrooms, because they are appealing to most teachers as they minimise chaos during the instruction (Shamsudin et al., 2013), hence disciplinary issues are minimal as students are mostly quiet and seated. Moreover, they are driven by different goals such as covering all the content in the syllabus so that students are ready to sit for examinations; others do so in order to keep order and discipline. However, these practices make science content unintelligible and lower students' motivation (Changeiywo et al., 2011).

Students who receive science instruction through teacher-centred practices are not informed about the importance of learning particular content and how it will help them to solve the problems in their everyday lives. Subsequently, they do not see the value of learning physics and thus they do not expend enough effort to understand it. This results in a low achievement in science and/or physics culminating in a few students choosing careers that need a strong physics background (Changeiywo et al., 2011).

The nature of teacher-centred practice does not seem to be in alignment with the nature of the force concepts as well as the purpose of including this topic in the school science curriculum. This is so, because students have some preconceptions about the concepts of force, which need to be interrogated in order to establish whether they deserve to be accepted as they are or should be modified. In order to teach science meaningfully, science scholars advocate for inductive teaching and learning strategies, which manifest in student-centred or reform-based classroom practices (Narjaikaew et al., 2016).

The literature reviewed here shed some light on the characteristics of traditional teacher-centred strategies. This is important for this study because it provided guidance when the teachers' practices were analysed and categorised.

2.8.2. Reform-based classroom practices

Given the myriad of issues facing the global community, science education is yet to be transformed as the imperative subject to assist students to develop the skills and attitudes deemed necessary for their sustainability (Tsakeni, 2018; Zoller, 2012).This is because education for sustainability calls for classroom practices that help students to develop high order cognitive skills (HOCS), such as critical thinking, question-asking, decision making and problem solving. These HOCS cannot be realised through algorithmic and imparting knowledge types of instruction. They call for classroom practice that assist students to develop evaluative systems thinking and transfer (Zoller, 2012). Classroom practices, which are believed to develop these skills, are reform-based student-centred practices (Anney & Bulayi, 2020).

According to Verloop et al. (2001), reform-based classroom practices involve classroom activities that afford students the opportunity to learn in an active manner, thus making science appealing even to those students who are not highly motivated. It also includes a shift from traditional training of practical skills to inquiry skills such as engaging students in information searching activities where they make predictions and decide on how to test them (Campbell et al., 2017).These practices seem to transcend all science domains as they are researched in the domains of chemistry (Boesdorfer & Lorsbach, 2014) and physics (Savinainen et al., 2013; Bryce & MacMillan, 2005). The following are strategies used in reform-based classroom practices.

2.8.2.1. Inquiry-based teaching and learning practices

Inquiry-based learning is an approach that puts the responsibility on students as they engage in knowledge construction by solving real world problems (Crawford, 2000). Hussain et al. (2011:269) define inquiry as “a seeking for truth, information, or knowledge…by questioning.” They show that an inquiry-based practice involves students’ engagement in knowledge construction. It involves working with authentic problems in which students make observations, collect data, grapple with data, pose questions, and work collaboratively; both the teacher and students model the behaviourof scientists (Crawford, 2000; Hussain, et al., 2011; Shamsudin et al., 2013). Inquiry-based teaching and learning is therefore composed of a myriad of strategies that are characterised by high student involvement in knowledge-seeking activities. In science classrooms, one way of achieving this is by engaging students into experimentation (Trna, 2012). Katchevich et al. (2011) explain that when students learn science in a laboratory, they are likely to develop high order scientific skills, such as constructing arguments, reasoning and thinking critically. However, these goals can only be achieved when experiments are inquiry based rather than confirmatory.

Anney and Bulayi (2020) investigated mathematics teachers' PCK in the use of student-centred approaches. In particular, they assessed the teachers' orientations to teaching mathematics, knowledge of students' understanding of mathematics and knowledge of instructional strategies applied in the teaching and learning of mathematics. However, the authors observed that the mathematics teachers' PCK in the use of student-centred approaches was under-developed, mainly because their classroom practices and explanations thereof revealed limited knowledge of student-centred approaches.

The learning cycle is an example of inquiry-based instruction, which is mainly used in science classrooms (Lawson et al., 1989; Tuna &Kaçar, 2013; Sarac, 2018). The basic 3-stage model involves discovery, terminology recognition and concept implementation and this has even evolved into more stages, such as five and seven stage models. Other than the learning cycle, Margunayasa et al. (2019) used a 6-stage inquiry model. These stages are inquisition, acquisition, supposition, implementation, summation and exhibition. The learning cycle, in its different forms, is engaging, because teachers give students the opportunity to explore authentic problems before introducing scientific terminology.

Science education scholars therefore recommend and advocate for the application of inquiry-based learning, because it resembles the way scientific knowledge is developed (Hussain, et al., 2011; Shamsudin et al., 2013). However, inquiry is not straightforward, meaning that's students should be well motivated so that they engage meaningfully in inquiry activities (Edelson et al., 1999). In their study of primary school students' learning, Margunayasa et al. (2019) found that there is an interaction between students' cognitive learning styles and science achievements when taught through inquiry and conventional teacher-centred strategies. They found that when students with a reflective cognitive style are taught through inquiry strategies, they achieve more than those with impulsive cognitive style. Reflective students do not rush to give a solution when confronted with a problem. They take time to think about it looking for alternatives and checking for the accuracy of their responses. This is not the case with impulsive students (Margunayasa et al., 2019). These findings imply that teachers should know the learning styles of their students so that they structure classroom practices in such a way that it caters for all types of students.

The process of inquiry takes time and effort to enact because students have to undergo repeated trials and testing, and continuously search for information in order to see patterns or connections (Margunayasa et al., 2019; Shamsudin et al., 2013). If students are not motivated, it becomes challenging for them to engage in inquiry learning. Holubova (2015) highlights that one of the aspects that de-motivates students to study physics is the use of passive instructional strategies. Students expend less time studying and their achievement becomes low. However, Margunayasa et al. (2019) explain that exposing students to inquiry-based learning can change their tendency in the cognitive style from impulsive to reflective. Consequently, even those students with an impulsive style may develop the habits and skills to engage in analytical thinking when engaged in any activity. Discussed below are some of the inquiry-based strategies that are used to teach force.

2.8.2.3. Contextual-based instruction

Students experience force concepts in their daily activities and they consequently develop their own understanding, which some teachers use as the starting point for instruction. In line with this contention, literature reviewed about context-based instruction helped in understanding how teachers use students' environmental issues during instruction. Context-based instruction uses particular situations or events that occur outside a science classroom to guide the presentation of science concepts

(Ngman-Wara, 2015). Contextualising science instruction can be done by using students' prior knowledge as building blocks to the active process of linking, connecting, distinguishing, organising and structuring the understanding of scientific phenomena. However, the particular situations or events should be known and relevant to students in order for meaningful learning to take place (Prins et al., 2018).

Classroom practices that make use of contextual issues can take the form of both traditional and reform-based practices(Ng & Nguyen, 2006). In the traditional classroom setting, teachers start by teaching scientific ideas, followed by their application, whereas in reform-based classrooms, teachers give students familiar contexts as the starting point for the development of scientific ideas (Bennett et al., 2007; Ng & Nguyen, 2006). Contextual teaching is based on the premise that students are able to process new information if it is placed in the context that they can relate to (Ozdemir, 2017; Tural, 2013). This is because using students' context to teach physics makes new information comprehensible, meaningful and plausible (Bennett et al., 2007; Ng & Nguyen, 2006; Tural, 2013) and it reduces the struggle to understand the subject matter and the problem. On teacher knowledge, Ngman-Wara (2015) explains that junior high school teachers in Ghana lacked competencies in both content and context-based science instructional strategies and that their knowledge correlated positively with their professional qualifications. This indicates that the teachers' background data, such as qualifications, can serve as a limiting or promoting factor towards the use of context-based instruction.

When teaching NTL, Bryce and MacMillan (2005) used contexts familiar to students such as a block resting on a spring and a book resting on a table. Since the situation is familiar, students did not struggle to understand it. They grappled with the object of study, the NTL pair. Studying the effect of context-based instruction on the achievement of university students, Tural (2013) found that it has no effect on their achievement. An effect was found on their motivation and attitudes. Though motivating students is one goal for science instruction, understanding the science concepts is mandatory. The students became motivated and interested in physics as they found it more meaningful than when taught using traditional methods. These findings are also reported by

Bennett et al. (2007) in their meta-analysis of research on the effect of context-based instruction. As a result, to complement the benefits of context-based instruction, teachers could use this strategy as it was the case in Bryce and MacMillan's (2005) study.

Contrary to Tural's findings, Bennett et al. (2007) report that some studies found that context-based teaching has an effect on students' achievement. Students who are motivated to learn physics tend to spend more time learning, which may result in improved achievement (Ng & Nguyen, 2006). The difference in the findings may also be due to the nature of the assessment items used to compare students who were instructed through conventional approaches and context-based approaches (Bennett, et al. 2007). In order to assess the effectiveness of context-based instruction, the type of assessment should resemble the type of instruction used (Bennett et al., 2007; Tural, 2013). However, this is not the case in national examinations and as a result, teachers mainly focus on factual knowledge.

An intriguing finding by Ng and Nguyen (2006), as they investigated the Vietnamese high school physics teachers' integration of practical work and contexts, is that teachers are perceived to understand the integration of real-life context to physics teaching. Nonetheless, the examples of real-life contexts that they gave showed a limited understanding of the phenomena. For example, when teaching about gravity and free falling bodies, the teachers referred to the following as a context problem, 'two bodies with different masses falling at the same acceleration…' (Ng & Nguyen, 2006:44). There is no explicit naming of the objects so that students can associate with them. The contradiction indicated that the teachers' understanding of context-based instruction is limited.

Even though context-based instruction have some benefits to teaching and learning, Bennett et al. (2007) indicate that, because science ideas are introduced as they arise, this may result in students not fully developing the concepts taught through context-based instruction. This finding is not surprising, because research about teaching and learning advocates the use of multiple approaches to science teaching, such as lecturing, problem solving, cooperation and analogical reasoning (DeWitt, et al., 2014; Fadaei & Mora, 2015; Maharaj-Sharma & Sharma, 2017; Safadi, 2017; Suh & Park, 2017; Nashon, 2003). As such, context-based approaches should be complemented by other approaches so that the limitations of one approach can be supplemented by the strengths of the other.

2.8.2.4. Conceptual change approaches

As highlighted earlier, students enter the teaching and learning environment with some preconceptions or conceptual frameworks (Duit & Treagust, 2003; Sarıoğlan & Küçüközer, 2014; Zakaria & Iksan, 2007), which are mostly inconsistent with established scientific conceptions such as Newton's laws. Physics teaching is therefore meant to assist students to change these naive concepts as they hinder scientific understanding, thus the development of conceptual change strategies. Conceptual change approaches immerse students in activities that help them to restructure their existing understanding in order to align with scientific knowledge (Duit & Treagust, 2003). Conceptual change is a personal active learning process (Duit & Treagust, 2003; Sarıoğlan & Küçüközer, 2014), which require teachers to make students' preconceptions explicit. The use of conceptual change strategies is reported for different force concepts, such as moments of force, NTL and torque (Bryce & Macmillan, 2005; Rowlands, et al., 1998; Sarıoğlan & Küçüközer, 2014).

Rowlands et al. (1998) indicate that teachers represent moments of force mostly by horizontal beams, a variety of examples and calculations. As a result, students do not develop conceptual understanding of moments such that they associate equilibrium to horizontal orientation. This finding indicates that students' misconceptions do not only result from their interaction with the environment but also from instruction (Nashon, 2003).

In their study to promote conceptual change in understanding NTL, the presence of the action-reaction force in the at rest position, Bryce and Macmillan (2005) used bridging analogies so that students can undergo analogical reasoning. Analogical reasoning is a process of making comparisons in search of similarities between familiar and unfamiliar novel situations, or the known and unknown (Fotou & Abrahams, 2016). Analogical reasoning is a conceptual change strategy because students engage with the subject matter cognitively as they search for similarities. Bryce and Macmillan (2005) asked students to explain force diagrams, thus revealing what they know. Through continuous questioning, students eventually came up with acceptable causes of reaction force, indicating that bridging analogies were effective in helping students to construct and understand the cause of the reaction force in Newton’s Third Law. However, there is no conclusive evidence that bridging analogies alone have resulted in conceptual change. Students’ engagement with the analogies and thinking through their meaning by themselves could be attributed to the change in understanding. This finding seems to be complemented by that of Bennett et al. (2007) that engaging students in activities, which are context based, increases their motivation and time on task and, hence, increases their understanding and performance. Nashon (2003) warns teachers that if analogies are not well planned before the instruction, conceptual change might not be attained and serious misconceptions can be developed. This is because the analogue structural information of concern should be organised before applying it to the target. This means that teachers should thoroughly think through the intended instructional approach in order to evaluate its worth and the load that it will impose on students.

In their study on the effects of instruction on students’ ideas about torque Sarıoğlan and Küçüközer (2014) administered a pre-test, followed by an instruction, where students constructed meaning of torque through discussions with their peers. Sarıoğlan and Küçüközer (2014)explain that, before instruction, some students did not show any understanding of the concept while others had some alternative ideas. However, none of them demonstrated a scientific understanding of the concept before instruction. When administering a post-test immediately after the instruction and again fifteen weeks later, some students demonstrated scientific understanding. This finding revealed that concept permanence can be attained when students are helped to formulate their own meaning of the concept, because the new scientific understanding makes sense to the students.

Nieminen (2013) also explains that, in order to assist students to have conceptual understanding and scientific reasoning, multiple representations of a concept should be used when teaching them. In a study to determine the relationship between representational consistency, conceptual understanding of force and scientific reasoning, they found that after instruction, students were able to interpret different representations and their performance in a post-test was better than in a pre-test. The implication for this finding is that teachers should know how to represent the concepts in different ways and be able to facilitate students' construction of their own representations. One representation may not provide the full set of information essential to understand particular concepts such as moments. Thus, integrating information from different representations may be beneficial as they complement each other (Nieminen et al., 2013).

The reviewed literature highlighted the types of conceptual change strategies and how they are applied when teaching the concepts of force. For this study, it provided some guidelines which facilitated the classification of classroom activities.

2.9. Challenges of teaching force concepts

The reviewed literature showed that teachers' knowledge base for teaching, PCK in particular, including teachers' perceptions of knowledge inform instruction (Magnusson et al., 1999; Shulman, 1987). Of particular importance is the teachers' subject matter knowledge. However, in some countries, there is a lack of physics and other science teachers (Meschede, et al., 2017; Qhobela, 2012). As a result, teachers are compelled to teach the subjects that they are not qualified to teach. This situation is challenging, because unqualified physics teachers lack the essential knowledge such as the common content knowledge (CCK) and specialised content knowledge (SCK) (Ball et al., 2008). According to Ward et al. (2015), enacted PCK is demonstrated as teachers plan and give developmental and principle appropriate tasks. In their quasi-experimental study, Ward et al. (2015) exposed one group of physical education teachers to a content workshop. The experimental group demonstrated developed PCK. They planned and assigned appropriate tasks and adapted them according to students' needs. According to Ball et al. (2008), this indicates that the teachers have specialised and common content knowledge, which is symbolic of the developed PCK. Teachers with weak content knowledge often struggle to select and sequence the tasks so that they can culminate in a meaningful understanding, consequently their teaching becomes compartmentalised and out of context (Ward, et al., 2015).Moreover, they struggle to provide qualitative explanations, using simple language that students can understand (Etkina et al., 2015). Instead, they use mathematical language, which is challenging to most students.

Although students experience most of the physics concepts daily, they are abstract and when they are taught in school, students find them boring and do not expend enough time and effort to understand them (Ho & Boo, 2007; Maharaj-Sharma & Sharma, 2017; Mualem & Eylon, 2009), because they believe they already know them. Consequently, such concepts should be taught through constructive or student-centred strategies. The subject-specific strategies such as representations of concepts and appropriate activities are content dependent and they could be used to reveal students preconceptions and misconceptions (Mahmood, 2013). As pointed out, some teachers lack the necessary knowledge and skills to do so (Mahmood, 2013). Hence, it becomes a challenge for them to teach in ways that demonstrate students' understanding and thus facilitate transfer of what is learned to different contexts.

Literature has also indicated that teachers face the challenges of having underdeveloped PCK, because they demonstrate limited knowledge and skills of some aspects of teaching such as questioning (Albergaria-Almeida, 2010; Döş et al., 2016), and recognisingand using some of the physics laboratory materials. Gülçiçek and Kanli (2018) investigated the physics pre-service teachers' recognition of laboratory material. They indicated that some of the teachers did not realiseusing some of the apparatus.

Another challenge regards the teachers' questioning skills. Questions are tools that teachers use to activate students' cognitive resources. When used appropriately, they motivate students, make them think, ensure active participation and improve achievement (Döş et al., 2016). However, the teachers do not fully understand different types of questions, convergent and divergent, such that their purposes for asking each of them revealed that they hold misconceptions about them. Teachers mostly asked low-level questions and did not give students enough time to think about the questions (Albergaria-Almeida, 2010). The teachers' competences to ask meaningful and thought-provoking questions are critical, especially when teaching the concepts of force, because students know more about them, even though their knowledge is sometimes not congruent to scientific knowledge. Teachers should develop questioning skills to reveal students' preconceptions, including misconceptions, evoke thinking and facilitate conceptual gain.

Experimentation facilitates the development of scientific knowledge as a result, students should be helped to master. Furthermore, experimental skills play a crucial role in developing teachers' PCK (Katchevich, et al., 2011; Trna, 2012). However, most science teachers, particularly physics teachers, seem to lack experimental skills such that the experiments they use when teaching do not seem appropriate and suitable to develop students' physics knowledge and skills (Trna, 2012). Dominantly, they use experiments to verify or refute knowledge as opposed to generating it (Koponen & Mäntylä, 2006).Trna (2012:2) highlights that physics teachers do not use experimentation because of "... the poorly developed skills to use science experiments." This insufficient knowledge and skills to use experiments in teaching and learning is challenging for teachers, because they perform only a few experiments that they feel are easy to do.

It is explained in the preceding sections that, knowing students' misconceptions of force and being able to assess them is crucial as it measures the level of conceptual understanding (Sadler & Sonnert, 2016; Sands et al., 2018).Being able to reveal students' misconceptions before and after instruction helps the teachers to make informed decisions about instruction. However, Gomez-Zwiep (2008) explains that some teachers find it challenging to design activities that reveal students' misconceptions.

In contrast to the teachers whose nature of science (NOS) is not well developed, those with developed NOS are able to structure inquiry activities that are based on students' experiences and interests. Consequently, students are able to work together to construct their own understanding of scientific concepts (Abd-El-Khalick, 2013).

In order to teach physics effectively, most scholars advocate for the use of student-centred or constructivist strategies (Fadaei & Mora, 2015; Mahmood, 2013), such as inquiry, collaboration and problem-solving, as explained above. For their effective implementation, a number of factors are essential. With insufficient knowledge of the necessary elements of PCK, it becomes a challenge to teach physics.

In conclusion, the challenges that teachers have when teaching the concepts of force are:

1. Some of the teachers have insufficient physics content knowledge.
2. Teachers have insufficient knowledge of asking questions that promote and facilitate knowledge construction.
3. Some of the teachers' PCK is not fully developed.
4. Teachers have insufficient knowledge to help students generate scientific knowledge through experimentation.
5. Some of the teachers are unable to assess students' preconceptions and misconceptions.

2.10. Overcoming the challenges of teaching physics

From the literature, it is clear that most challenges experienced by physics teachers are rooted in underdeveloped PCK (Henze & Van Driel, 2015; Mavhunga & Rollnick, 2013; Shamsudin et al., 2013). The authors suggest that both prospective and in-service teachers should be engaged in well-planned continuing professional development in all aspects of teacher knowledge.

After Mulhall et al.'s, (2003) five year project of representing and documenting the PCK of successful science teachers, researchers used their framework to help science teachers to develop their PCK (Bertram, 2014; Bertram & Loughran, 2012; William &

Lockley, 2012). Though the main purpose of CoRe is to portray science teachers' PCK, Loughran et al. (2012) indicate that most of the science education researchers use it as a professional development (PD) tool aimed at developing science teachers' PCK. As a result, Bertram (2014) explored whether CoRes and PaP-eRs can offer the means of articulating and portraying the beginning primary school science teachers' PCK and how teachers may be assisted to develop it. Bertram and Loughran (2012) examined how the two tools can affect practice. In both studies, the tools were found useful in developing science teachers' PCK, hence affecting their practice positively.

When teachers develop CoRes, they engage in conceptual understanding of different knowledge domains, the understanding of which can be facilitated through collaboration. Through these encounters, teachers restructure their content and develop better knowledge structures. Lehane and Bertram (2016) report on a number of studies which used CoRe as a PD tool. Eames et al., in Lehane and Bertram (2016), report that CoRe has the potential to help novice teachers gain access to experienced teachers' content and PCK, thus developing their own content.

To provide evidence that CoRe is effective in developing PCK, Bertram (2014) used it with one teacher while Bertram and Loughran, (2012) used it with a group of science teachers. Bertram (2014) explained that completing a CoRe proved to be essential in scaffolding the beginning teachers' PCK. This is because during the planning stage, teachers answer the prompts on the CoRe that compel them to tap into different knowledge domains. In some cases, when preparing lesson plans, teachers concentrate more on how to define concepts and to give students procedures to follow when performing calculations, experiments and solving problems. More often, they do not plan the activities from which students may develop their own definitions, procedures to perform experiments and calculations, meaning that student competences are not tapped to the maximum.

In another form of PD targeted content knowledge, Mualem and Eylon (2009) conducted a 20-hour PD for physics teachers on the topic of mechanics. Teachers were taught physics using the approach that the researchers found to be effective with students. By applying this approach to teachers, the researchers explained that they wanted teachers to experience physics content the way they are expected to teach it to their students. They explained that this approach helped teachers to develop a qualitative understanding by exposing them to real-life problems which they solved by using different representations and steps. It was found that the teachers developed a qualitative understanding that in turn increased their confidence in terms of the knowledge and ability to teach physics. According to Mualem and Eylon (2009), this approach could be adopted in teacher training institutions. Instead of teaching physics teachers the traditional physics, which deals mainly with quantitative understanding, the main focus could be on helping them to develop a qualitative understanding, which appears to increase their self-efficacy.

Based on the idea that teaching practice is the source of PCK (Shulman, 1987; Van Driel, 1998) and that it is socially constructed in different contexts and through teachers' collaboration, House (2014) and Vrikki et al. (2017) used lesson study as a PD activity. Vrikki et al. (2017) explain that teacher learning could be achieved through collaboration. As a result, the researchers engaged mathematics teachers in a lesson study in which they planned, taught, observed and reflected on the teaching together. During the reflection session, teachers manifested their thinking and reasoning in an observable manner, thus assisting the researchers to understand how they think. Consequently the researchers revisited their own thinking and reasoning (Loughran et al., 2012; Mavhunga & Rollnick, 2013; Shamsudin et al., 2013). However, beneficial communication, researchers' point out, that it does not always yield productive results. The implication is that teachers should be trained on how to critique each other during both the planning and reflection sessions. Such training may help them to focus on the aspects of the lesson to concentrate on and to think in advance of what to talk about. In this way, communication becomes meaningful.

One of the challenges of teaching physics is that most students do not have an interest to understand it. In an attempt to assist the teachers to motivate students and thus teach physics meaningfully, Shamsudin et al. (2013) introduced an inquiry-based science teaching approach to trainee teachers. They asked the participating teachers to use inquiry-based strategies such as simulations, demonstrations, experiments and projects to motivate students. They found that when teachers write reflective journals regarding their lesson planning and classroom teaching, they become aware of their strengths and weaknesses.

Holubova (2015), on the other hand, contends that today's students are the World Wide Web or technology oriented type of students who prefer to find information on their own and to do things that are meaningful to them. Therefore, teachers should ensure that they keep students motivated by incorporating technology in their teaching and creating the learning experiences that nurture knowledge creation, rather than knowledge transmission. Holubova (2015)concurs with Edelson et al., (1999) that one way of solving problems of students' demotivation is to reform science teaching from information giving to information seeking activities such as constructing concept maps.

The following are the strategies that can be used to solve the challenges that teachers face when teaching physics

1. Providing professional development activities using different tools such as content representations (CoRe) so that teachers are helped to reflect on their teaching
2. Provide an environment where teachers participate in collaborative activities such as lesson study.

2.11. Summary of the chapter

The literature review chapter opened with a reflection on the importance of science education and its inclusion in the school curriculum. It then presented the concept of Magnusson et al. (1999) on the science teachers' PCK. This chapter reviewed the literature on the science teachers' knowledge as well as its components and importance in science teaching. The chapter further focused on science teaching and on the teaching of moments of force. The purpose for the review was to establish the findings of other researchers regarding effective science teaching, with reference to mechanics, especially moments of forces. The instructional strategies, which proved effective to teaching physics, ways of engaging students in learning and the challenges that teachers encounter when teaching physics, specifically when teaching moments of force, as well as how to overcome such challenges were also discussed.

Chapter 3.
Research design

3.1. Introduction

The focus of the study is to map science teachers' perceptions of their knowledge of the concepts of force to classroom practices. This chapter explains the research methodology and design that were employed. The data collection strategies, pilot study, population, sample and sampling techniques are presented. The validity and reliability of the data collecting instruments as well as the analysis and interpretation of the data are also discussed. Because the participants in this study are humans, I had to consider ethical issues and therefore the chapter also describes the ethical considerations that were taken.

3.2. Research paradigm

Any research work is inclined towards a worldview or paradigm, which has specific philosophical and methodological assumptions. A paradigm is defined as a way in which researchers view the world (Mackenzie & Knipe, 2006). Neuman (as quoted by Cameron, 2011:100) defines a paradigm as "[a] general organizing framework for theory and research that includes basic assumptions, key issues, models of quality research, and methods for seeking answers." It provides a concrete application of theories for solutions of typical problems. A paradigm therefore forms the basis for reasoning and knowledge creation, thus shaping the researchers' beliefs about the world and how research should be conducted. Examples of paradigms are positivism/post positivism and constructivism (McLaughlin, 2011). Paradigms can be described by their epistemology, ontology and axiology.

A paradigm can be described by its ontological and epistemological underpinning. On the one hand, ontology is defined by McLaughlin (2011) as "...the nature of the world." That is, whether knowledge or reality is a static entity that can be easily attained or whether it is a personal construct that can be constructed either individually or socially.

On the other hand, epistemology is the relationship between the researcher (knower) and the participants (known) (Teddlie & Tashakkori, 2009:83). It refers to whether researchers believe there is a relationship or not between them and the participants. These ways of thinking have brought about different paradigms that resulted in different approaches to conducting investigations.

Positivists or quantitative researchers view reality to exist external to the knower so that when conducting an investigation, they aim at getting an objective truth with the purpose of making claims about the representativeness of the findings (McLaughlin, 2011). Moreover, they do not have the opinion that there is a relationship between the researcher and the participants; hence they use methods that do not allow the participants to give their subjective meaning or understanding of the phenomena under investigation. Their main purpose when doing research, is to collect empirical data that can be verified and generalised to the whole population (Cohen, Manion & Morrison,2011), hence they employ systematic methods of data collection and analysis.

According to Teddlie and Tashakkori (2009:85), constructivist or qualitative researchers hold the view that there is "…local and specific co-constructed reality." They also hold the view that the researcher and participants are inseparable, because there are multiple constructed realities. That is, they refute the notion that knowledge is objective. They argue that society or the social world cannot be studied the same way as the natural sciences (McLaughlin, 2011). This is because, unlike the natural world, people have the cognitive ability to make decisions regarding the phenomena being studied. Thus qualitative researchers embrace multiple realities (Creswell, 2012) and regard knowledge as subjective in nature, depending on both time and context (McLaughlin, 2011).

Researchers seem to separate research as either quantitative or qualitative. This has been a concern for some researchers who believe that the world is neither objective nor subjective, but could be both (Creswell, 2014; Teddlie & Tashakkori, 2003). People construct the truth in multiple ways; hence they use both objective and subjective reasoning to construct their own understanding. As a result, pragmatism seems to allude to that thinking.

This study intended to investigate the physical science teachers' perceptions of their knowledge. That is, what they believe they know about the teaching of physics. This is the stance of interpretivists (Goldkuhl, 2012). The study further intended to understand how that knowledge translates into their teaching so that it appropriates the results and/or change in students' learning. It intended to answer the what (quantitative) and how (qualitative) questions. Pragmatism seems to be the appropriate paradigm to provide the philosophical tools necessary to answer the research questions (Tashakkori & Teddlie, 2017).

Furthermore, the epistemological stance of pragmatists is that, at different points in the research cycle, the researcher may interact with the participants (teachers), while at other points the researcher may not need to interact with them. This also clarifies why pragmatism provided the appropriate tools for this study. At one point during the study, I did not interact with the participants, because I was interested in what they believed they knew and not how they know it or why they think they know. However, at other points within the investigation, I interacted with the participants in order to verify whether they actually know what they believe they know and how their knowledge impacts their practice. Accordingly, my relationship with the participants cannot be categorised as either objective or subjective. The relationship existed on the continuum with different interactions at different points in the research process. During the survey and document analysis, I did not interact with the participants. Nonetheless, during the classroom observations I interacted with them to a limited extent.

3.3. Research approach

Creswell (2014:3) states that research approaches are "plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation." The research approaches that may be followed in research are quantitative, qualitative and mixed. The choice of an approach is based on the researchers' philosophical inclination and the type of research question being investigated (Creswell, 2012). Pansiri (2005) proposes that the mode of inquiry under pragmatism embraces both quantitative and qualitative methods and a mixture of them.

The mixed methods approach has different typologies and the frequently used ones are the six types that are given by Creswell (2012:540) as "the convergent parallel, explanatory sequential, exploratory sequential, embedded, transformative and multiphase designs.

3.3.1. Mixed methods

No single method can give a comprehensive understanding of a phenomenon. As a result, in this study I employed mixed methods approaches to investigate science teachers' perceptions of their knowledge and their classroom practices. Creswell (2014) and Gorard (2017) define the mixed methods approach as a combination of techniques and/or approaches that are regarded as both qualitative and quantitative. Moreover, Teddlie and Tashakkori (2009:14) define mixed methods as "a type of research design in which QUAL and QUAN approaches are used in types of questions, research methods, data collection and analysis procedures, and/or inferences". As a result, different terms, such as multi-method and mixed methodology are used to refer to a mixed methods approach. However, the recent literature refers to it as a mixed methods approach (Creswell, 2014).

The purpose of collecting both types of data is to integrate and corroborate the findings so that the researcher gains a better understanding of the phenomenon being studied (Creswell, 2012). The quantitative part is aimed at providing numerical data about the teachers' views of their knowledge base while the qualitative phase provides textual information and artefacts aimed to illuminate the relationship between their perceptions and classroom practices. Motivated by Creswell, (2012), the choice of mixed methods over other approaches is based on the paradigmatic inclination of the researcher, including the nature of the research problem and questions. The proponents of mixed methods research uphold that combining the two paradigms in one study sets out to minimise the weaknesses of one by the strengths of the other. It is possible that the quantitative findings contradict the qualitative ones. In this case, integrating the results from the two paradigms helped me to explain the discrepancies (Teddlie & Tashakkori, 2009).

This study sought to investigate the science teachers' perceptions of their knowledge of force and momentum and to understand how it shapes their classroom practices. It is in this regard that the mixed methods paradigm demonstrated its potential to assist me in achieving this intention. Rosenthal and Thayer (2013) point out that, through a mixed methods paradigm, the explanatory and interpretative nature of the research questions can be achieved.

As it is indicated that the mixed methods approach integrates both quantitative and qualitative methods, the two approaches are explained here. The quantitative approach is a systematic inquiry that is governed by the theories and laws (Cohen et al.,2011).Some of the strategies which it uses to collect data are experiments and surveys. Hence quantitative research uses the same methods of data collection on both the social and natural world (Creswell, 2014).The author further indicates that quantitative research uses statistical methods of data analysis, which enable the findings to be generalised over the whole population. On its own it is rooted in positivism.

In the quantitative phase of this study, a survey of science teachers' perceptions about their knowledge to teach force and momentum was done. This entailed the teachers' perceptions about their orientations towards science teaching and learning; knowledge of the goals and purposes of science teaching and learning; how students understand science; as well as its assessment and instructional strategies. Its premise is that teachers' knowledge does not exist in a quantitative form; however, the collected data was analysed using statistics so that unbiased results could be attained.

Qualitative research, on the other hand, is underpinned by interpretivism. Its use assumes that reality is socially constructed through the interaction of a social being with the context at which it is constructed; thus, for qualitative researchers, truth is subjective (Cohen, et al., 2011). Qualitative researchers do not detach themselves from the participants; instead they become involved in the everyday activities of the participants so that they experience and understand the world from the point of view of those who are living it. The data collected in this study was analysed using the narrative and not the numbers, as used in quantitative research. The ultimate goal was not to generalise, but to understand reality from the point of view of those who live it.

The interpretive approach uses methods that enable the researcher to be present as reality is lived and/or constructed (Teddlie & Tashakkori, 2009). I therefore collected data through classroom observations, post-observation semi-structured interviews and document analyses. In this way, I had the opportunity to experience how the teachers integrated their professional knowledge into their teaching practice and this enabled me to experience their frustrations and successful moments with them. Through the interviews, the teachers' intentions for different pedagogical decisions were understood from their perspective. This enabled me to not distort the meaning that teachers attached to their actions. In order to get an integrated understanding of the teachers' knowledge, I analysed the physical science syllabus and the teachers' lesson plan books. Data analysis in interpretive research is based on the researcher's interpretation by using words, not numbers (Creswell, 2014). This required me to be aware of my own biases and to take appropriate measures to not contaminate the results, as this would affect the validity of the study (Airasian, 2014).

The above discussion shows that this study integrated the two research approaches and used different methods of data collection. The purpose here was to collect comprehensive information that would minimise misinterpretation. It is in this regard that mixed methods as a research approach is said to be complex, difficult and labour intensive (Gorard, 2017). This is beneficial, because collecting data through different sources helps to minimise the weaknesses of one and capitalises on the strengths of the other; hence creating credible information (Airasian, 2014).

3.3.2. Research design: explanatory sequential design

Research designs, sometimes called strategies, are types of inquiry within the three research approaches, which offer the precise directions for research processes, in order to maximise the evidence of providing warranted answer to the research question (Gorard, 2017). In the case of a mixed methods approach, the design chosen gives directions about the types of data to be collected, the manner in which to collect and analyse it, as well as how to interpret it (Creswell, 2012). Four research designs associated with the mixed methods approach are convergent parallel, exploratory, explanatory and embedded designs (Creswell, 2012).

In the convergent parallel design, the quantitative and qualitative data are collected simultaneously (Creswell, 2012). Both sets of data are analysed and compared in order to determine whether quantitative data supports qualitative data. Creswell (2012) indicates that, alternatively, the two data sets are combined in order to discover themes or variables to be further tested or explored.

In the exploratory design, qualitative data is collected before the quantitative data. The purpose here is to generate a new instrument for the quantitative phase of the study (Creswell, 2012), which is not the purpose of this study. Creswell also indicates that qualitative data could be used to locate the instrument to pursue the quantitative phase of the study. As a result, the exploratory design was not found suitable, because its purpose did not match that of this study.

According to Creswell (2012), in the embedded design both sets of data are kept separate because they are based on different research questions. Both data sets can be interpreted simultaneously, indicating how one reinforces the other. The purpose for using this design falls outside the scope of this study, thus it was not found suitable.

In the explanatory sequential design, quantitative data is collected before qualitative data. Qualitative data in the second phase is used to explore the important quantitative results with a few participants. The purpose of which is to get an in-depth understanding of the quantitative findings.

In this study, the sequential explanatory design was deemed appropriate to answer the research question. In the first quantitative phase, I acquired a general picture of the research problem (Creswell, 2012) and the science teachers' perceptions of their knowledge to teach force and momentum, while the second qualitative phase, improved, extended and clarified the quantitative data analysis results. The purpose of the qualitative data was to explain the findings from the first phase. Therefore, aspects of teachers' perceptions of their knowledge base necessary to follow up on in the second qualitative stage were informed by the findings from the quantitative phase. The sequence of events in the explanatory sequential approach is as shown in Figure 3.1.

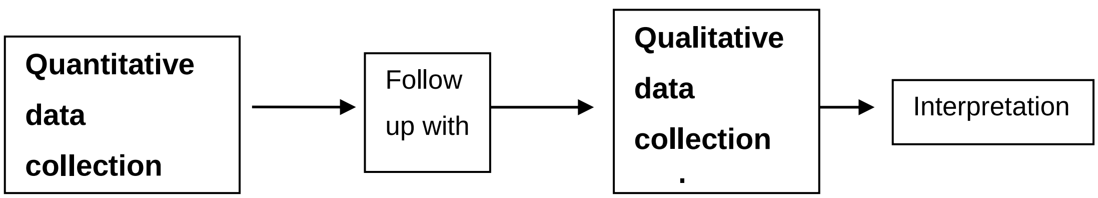


Figure 3.1 Explanatory Sequential Approach (Creswell, 2012: 541)

In the quantitative phase, I investigated the teachers' perceptions. For example, when responding to the questionnaire, the teachers indicated that they find out what students know about force before they teach it (item 17: Before I teach the topic force, I find out what students already know about it). In the second, qualitative, phase, I analysed the teachers' lesson plan books, observed their teaching and interviewed them. Among others, I wanted to find out whether and how they reveal students' prior knowledge. In general, the purpose of the qualitative study was to explicate how the attributes of teacher knowledge, which they demonstrated in the survey, come to the fore during classroom instruction and to establish whether they have an influence on the classroom practices (Creswell, 2012; Kothari, 2004).

The explanatory sequential design is straightforward, because data collection in the two phases is distinct and the qualitative data enables the exploration of the quantitative results (Ivankova & Stick, 2006). However, the design is time consuming due to different data sets to be collected sequentially (Ivankova & Stick, 2006). This was challenging for me because I collected the data while I was also employed full time. Moreover, because I was investigating a specific topic, I had to wait for the time when the teachers had planned to teach it. This also delayed the data collection.

In order to address the challenge of time, I delivered the questionnaires to schools, because my opinion was that it was important for me to meet with the participants and to explain the purpose of the study and ask for their consent. To ensure that I would receive the questionnaires on time, I went back to the schools to collect them. Another challenge was finding the participants for the qualitative study. One of the criteria used to select the teachers for observations was accessibility to the schools. Some of the teachers were not teaching grade 11, which was the target grade. In their schools, grade 11 was taught by student teachers who were doing their practical teaching.

3.4. Population, sample and sampling procedure

3.4.1. Target population

The target population was the physical science teachers, particularly those who taught physics in grades 11 and 12. Creswell (2012:142) defines a population as "…a group of individuals who have the same characteristics whereas a target population is a group of individuals…with some common defining characteristic…" to which the results of the study can be generalised. For this study, the population was the physical science teachers while the target population was the physical science teachers who teach physics in grades 11 and 12.

In Lesotho, there are 341 post-primary schools, 250 of which offer forms A to E, which are now called grades 8 to 12. Ninety-one of them offer grades 8 to 10 (Lesotho MoET, 2016). The population for this study was therefore physical science teachers who teach physics in the 250 post-primary or high schools in Lesotho. With the assumption that there were at least two physical science teachers in each school, 50 schools were selected with the aim of identifying 100 physical science teachers to participate in the study.

3.4.2. Sample and sampling techniques

The sample for this study, especially for the quantitative phase, was 100 physical science teachers who teach physics in grades 11 and 12. Because this is a mixed methods study, I used two types of sampling techniques for each of the phases, quantitative and qualitative.

For the quantitative phase, I used clustered random sampling to select the sample. I selected the teachers from five districts out of ten, based on their accessibility. This was because, due to the limitations of time and money, it would not have been possible to survey all the high schools in Lesotho (Teddlie & Tashakkori, 2009). With the assumption that most of the schools have one physics teacher, I sampled a total of 100 schools from the five districts. The numbers of schools per district were 51, 30, 26, 17 and 12. In order to ensure that the sample spreads proportionally across the districts, I worked out the proportion this way ($\frac{Number\ of\ schools\ per\ district}{Total\ number\ of\ schools\ in\ the\ five\ districts} \times population$) (Bordens & Abbott, 2011; Creswell, 2012:145). For example, in the district which had 51 high schools, I identified 37 teachers (schools) ($\frac{51}{136} \times 100 = 37.5$).

For the qualitative phase of the study, I purposely sampled four teachers from those who participated in the survey. Creswell (2012) highlights that, in the mixed methods approach, the second phase of the explanatory sequential approach follows up on the outliers that may have appeared in the first phase of the research. After having analysed the quantitative data, I purposely selected the four teachers, based on their demographics. I ensured that they were teaching grade 11 physics. One of their major subjects was physics; they have teaching experience of less than five years or more. Moreover, I ensured that they teach in the schools that I could access easily. Through my experience as a high school physics teacher, I know that the way teachers sequence physics topics is somehow similar. This means that there were high chances that they would teach the topic, force, around the same time. As a result, another criterion was that their schools were not more than one hour's drive apart. This was to make sure that I could observe teachers in more than one school, if physics were scheduled on the same day in their schools.

3.5. Researcher's role

In this study, I played several roles. I developed the data collecting instruments, delivered and collected the questionnaires, did classroom observations, compiled memos and field notes during field work, interviewed the teachers, and analysed the syllabus and the teachers' lesson plan books.

I delivered the copies of the questionnaire (**Appendix A**) and collected them. The day before each copy was collected, I called to find out whether it was ready for collection and arranged when I could collect it. However, in some instances I had to go back more than once in order to get the questionnaires from the teachers. The purpose of the survey was to investigate the teachers' perceptions about their knowledge base and classroom teaching. That is, to determine whether they feel that they have sufficient knowledge of force and momentum, whether they believe they know the aspects that facilitate or impede students' understanding of force and the strategies that they feel they use when teaching force and momentum.

After collecting the questionnaires and making a preliminary analysis, I conducted classroom observations with each of the four teachers. During classroom observations, I used an observation protocol (**Appendix B**). The purpose of the observations was to ascertain whether the teachers actually did what they thought they do when teaching. That is, whether, when and how they reveal students' prior knowledge, whether they vary the teaching strategies and what they assess. During the observations, I wrote reflective memos and completed an observation form. However, I did not participate in the lesson; rather, I took a non-participant approach. My knowledge and experience as a physics teacher as well as the experience of doing classroom observations, which I gained in my current work as a physics school inspector, enabled me to do the field work in this study. For every lesson that I observed, I asked the teachers for the lesson plan for that lesson. I captured it with my cell phone camera so that I could read and analyse the lesson plans at my own time and pace.

After each teacher had taught the complete topic, I conducted a structured interview, using the protocol (**Appendix C**) that I developed for this study. The purpose was to get clarification of some of the pedagogical decisions they made during the lesson. In order to help the teachers remember the incidences that I wanted clarification about, I narrated them. I captured the interview with an audio record on my cell phone and transcribed it verbatim on the same day when I got home.

3.6. Data collection instruments

3.6.1. Document analysis

Bowen (2009:27) defines document analysis or textual analysis as "[a] systematic procedure for reviewing or evaluating documents both printed and electronic…materials." Travers (2011) highlights that documents form an important part of our everyday lives and that much can be learned from them. At the beginning of the study, I tried to figure out the research problem. I read through different documents, such as the Lesotho curriculum and assessment policy (CAP) (2008) and the Lesotho General Certificate of Secondary Education (LGCSE) physical science syllabus. From the physical science syllabus, I intended to understand the aims and objectives, the knowledge and skills that students are expected to develop as well as how to assess learning. From the assessment policy, I sought to determine the aims of secondary education, which can be attained through science teaching.

During classroom observations, I asked the teachers for their lesson plans. I captured it with my cell phone camera so that I could access them at my own time and in my own space. In Lesotho, teachers are expected to write daily lesson plans for every subject and class that they teach. Therefore, I expected to have a number of these lesson plans which would equal the number of the lessons that I observed, for each teacher.

However, that was not the case. One of the teachers did not have written lesson plans at all, while the other three teachers did not compile lesson plans for some of the lessons. Therefore, the number of lesson plans did not equal the number of lessons that they taught. The purpose of studying their lesson plans was to ascertain the objectives they intended to achieve; the content matter they help students to learn; the prior knowledge they acknowledge as well as to uncover the knowledge base they used when planning their classroom activities.

Analysing the documents before observing the classroom activities and interviews provided the researcher with the background information regarding the aims and objectives teachers should strive to achieve through science teaching (Yin, 2011). It helped me during classroom observations and interviews to understand the teachers' practices better (Yin, 2011). Creswell (2012) indicates that documents provide a valuable source of qualitative data because they are often in the language and words of the participants who have given thoughtful attention to them. They are also ready for analysis, unlike observations and interviews which need to be transcribed.

3.6.2. Closed-ended questionnaire

A close-ended questionnaire is a quantitative research instrument used "…to identify trends in attitudes, opinions, behaviors [sic], or characteristics of a large group of people" (Creswell, 2012:21). In this study, I used a close-ended questionnaire (**Appendix A**) to identify the teachers' perceptions of their knowledge of force and momentum. A questionnaire enables the collection of data within a short period of time. However, it needs more time to construct and to pilot. Cohen et al. (2011) and Kothari (2004) caution that questionnaires should be short and that the instructions should be simple and clear. They indicate that if it is too long, the return rate may be low, as most people do not want to take too long completing it. Even those who may be motivated to fill it in may be discouraged if it is too long. They might therefore end up not giving genuine responses, thereby defeating the purpose of the study.

In this study, the guidelines outlined above were followed. I developed the questionnaire after reviewing some literature, particularly on perceptions of teacher knowledge. I could not find a questionnaire that addressed all the knowledge components which framed this study and none of them was specific to force and momentum. I wanted to determine the teachers' perceptions of their knowledge bases. These were perceptions of their knowledge of the science curriculum, how students understand science, and instructional and assessment strategies, including orientations towards science teaching. I selected items from different questionnaires, such as TIMSS 1999 and TIMS 2015, and modified and constructed some of the items. Table 3.1 shows some of the items adapted from TIMSS 1999. It shows how the items are worded in the source and in the instrument for this study.

Table 3.1 Sample of original and adapted questionnaire items

Wording from the source TIMSS 1999	Wording in the questionnaire
11. To be good at science at school, how important do you think it is for students to...	***Rate how important the following are to students when you teach science topics such as force***
a. Remember formulas and procedures	10. When learning the topic force students should remember formulas and procedures etc.
b. think in a sequential and procedural manner	11. Students should think in a sequential and procedural manner when learning science concepts such as force.
c. understand science concepts, principles, and strategies	12. Students should understand science concepts, principles, and strategies.
d. be able to think creatively	13. When learning force concepts, students should be able to think creatively
e. understand how science is used in the real world	14. Students should understand how science is used in the real world.
f. be able to provide reasons to support their conclusions	15. Students should be able to provide reasons to support their conclusions

I developed most of the items, based on what the literature says about the components of science teacher knowledge. Examples of self-constructed items are:

27. When I teach the topic force, I relate force concepts to students' daily life experiences.

28. As I teach force I ask students to explain their understanding to other students.

The questionnaire was divided into two sections. Section A asked for the teachers' biographical data while section B tapped on their perceived knowledge of how students understand science, of the science curriculum, instructional and assessment strategies, their orientations towards teaching and learning, as well as their classroom practices. This was in line with Bordens and Abbott's (2011) contention that, in a survey, participants are asked questions from which data pertaining to their beliefs, attitudes and behaviour could be discerned. Causal inferences cannot be made because independent variables are not manipulated. In this study, for example, it was not possible to deduce from the survey data why physical science teachers' knowledge was the way it was.

Cohen et al. (2011) and Kothari (2004) indicate that it is economical to mail questionnaires. As this method of questionnaire distribution is somehow impersonal, I decided to deliver them personally to the schools as that gave me the opportunity to meet with the teachers. I administered the questionnaires from August to October 2018. Meeting face-to-face with the teachers gave me the opportunity to explain the expectations, to answer the teachers' questions and to build rapport, which resulted in a high questionnaire return rate (Bordens & Abbott, 2011; Kothari, 2004). Meeting with the teachers impacted the teachers' responses, because all the teachers whom I managed to meet and talk to face-to-face when delivering the questionnaires, completed and returned them. Moreover, they acted as links between me and those whom I did not meet.

3.6.3. Classroom observation

Classroom observation is another strategy that I used to collect data. According to Creswell (2012), observations are the means of collecting open ended first-hand data and they enable people to be observed in their natural settings. Even though it may be difficult to get credible information due to the difficulty of establishing rapport and because of the danger of some participants engaging in deceptive behaviour, which they think will be acceptable to the observer, observations can provide rich data. By conducting observations, researchers are able to study the actual behaviour as it happens in its natural setting; information is recorded as it happens (Cohen, et al., 2011). In order to collect the needed data, Bordens and Abbott (2011) advise researchers to decide on what to observe specifically and how to record data. Therefore, based on the research questions and the results of the survey, I developed an observation protocol (**Appendix B**) which specified what to observe.

I observed the four teachers for the duration they devoted to teaching the topic force and momentum. Three teachers devoted three weeks to teach the topic, which meant a total of six observations per teacher. The other teacher devoted two weeks, which resulted in five observations. The prolonged time that I took in the teachers' classrooms helped them and the students to get used to my presence (Bordens & Abbott, 2011). The pretence and false behaviour, which they might have engaged in, eventually stopped, because they became used to the presence of a stranger.

I took a non-participatory approach and I ensured that my presence in the schools did not disrupt the normal daily activities of the schools and classrooms. Therefore, the teachers followed the set time table. Even during observations, I positioned myself in a way that students' sitting arrangement and movement were maintained. The non-participatory and structured observation allowed me to concentrate on observing how the teachers were teaching without interfering with the teaching-learning process. The teacher and students were able to interact as they normally would without being restricted by my presence.

I recorded the strategies that they used, that is, activities, demonstrations and representations, which both teachers and students did, as well as how and whether the teachers revealed students' prior knowledge. Moreover, I captured the lessons on an audio recorder. At the end of each day, I transcribed the audio recorded lesson and saved it electronically.

In order for classroom observations to be focused and to yield meaningful data that helped me to answer the research question, I decided on what to observe and how to record the data (Creswell, 2012; Kothari, 2004). As a result, I developed an observation protocol, a sample of which is shown in Table 3.1. The lesson proceedings were audio recorded and to supplement that, I recorded both descriptive and reflective field notes (Creswell, 2012) as measures to ensure that even pertinent information was gathered for reference during the data analysis and interpretation stages.

3.6.4. Semi-structured post-observation interviews

Cohen et al*.* (2011:409) state that “[t]he interview is a flexible tool for data collection, enabling multi-sensory channels to be used: verbal, non-verbal, spoken and heard.” In the context of research, the data collected could be quantitative or qualitative and in each case interviews are conducted differently (Cohen, et al., 2011). In this study, structured interviews were used as a method of data collection in the qualitative phase. The purpose was to gain a deeper understanding of the physical science teachers’ reasons for making particular classroom decisions.

For qualitative data collection, interviews are usually flexible; they are either semi-structured or open-ended. In semi-structured interviews, the interviewer prepares an interview guide or protocol, where themes that the researcher wishes to get information about are specified in advance. On the contrary, open-ended interviews are purely conversational and there are no predetermined themes; instead the interviewer begins by asking an open-ended question and participants elaborately express themselves with the interviewer asking some clarifying questions. However, in this study, I used semi-structured interviews. The questions were based on what happened during classroom observations. Below is a glimpse of the questions I asked teachers in order to ascertain the purposes of choosing particular instructional strategies.

5. You gave students written class and homework and discussions, why did you do it?
    Were there other activities you could have given them other than written assignments and discussions? Yes/no
    If YES, why did you choose these ones not those other ones?
    What are their strengths in helping students understand force as compared to other activities?
6. I realised that your students did class work individually, is it you who emphasise this behaviour? Why?

I developed an interview protocol (**Appendix C**) concurrently with classroom observations. Cohen et al. (2011) explain that interviews enable the researcher to access what is in the teacher's mind. This is why most of the questions I asked required teachers to explain what motivated their particular classroom decisions. After the participants had answered each question, I summarised the main points they mentioned. I did this in order to make sure that I did not misinterpret them. This ensured reliability of the data (Travers, 2011). I felt that it was imperative to do that. Qualitative researchers suggest that researchers should refrain from interpreting the participants' actions because they are often motivated by thinking and purpose. Rather, they should give teachers opportunities to explain why they did what they did. As a result, I wanted to get deeper into those motives and intentions of the teachers when making certain decisions (Cohen et al. 2011). I recorded the interviews with an audio recorder so that I could listen to it later. At the end of each day I transcribed the interviews in order to enable the analysis.

3.6.5. Field notes

Though Cohen et al. (2018) indicate that field notes are part of unstructured observation, I decided to compile them in this study. Before and after observations, I recorded some events that appeared interesting. For instance, in Mr C's classroom, when the teacher entered the classroom, all students stood up and greeted him and then they looked around to see whether there were pieces of trash or unwanted materials on the floor. If there were, they collected them and threw them in the dust bin. Though these behaviours may seem unrelated to teaching the concepts of force, which was the focus of the observation, I thought that they were worth noting as they might add more meaning to data during data analysis.

3.7. Data analysis

3.7.1. Quantitative data: questionnaire

Quantitative data analysis is a systematic way of investigation in which numerical data is collected or the researcher transforms the collected data into numerical data (Creswell, 2012). Quantitative data answers the questions “what” and “how many”. In this study, numerical data was collected through a questionnaire. I transformed the collected data into numerical form. The research questions in this study sought to answer what the perceptions of teachers about their knowledge base is and how they translate to the teaching practice.

The steps of analysing quantitative data involve coding questionnaire data, inputting data into a statistical package, data cleaning and manipulation (Bordens & Abbott, 2011). This process entails arranging data in different forms such as tables and/or charts. It reveals the patterns, similarities and differences that are likely to reveal the critical information needed to make sense of the collected data.

3.7.1.1. Descriptive analysis

The responses to the questionnaire were presented on a five-point Likert scale, strongly disagree (SD), disagree (D), neutral (N), agree (A) and strongly agree (SA) for knowledge of the science curriculum, students’ understanding and teacher orientations. The responses (SD, D, N, A and SA) were each assigned a number 1 to 5 respectively in order to calculate the frequencies, the mean and the standard deviations. However, for items 10 to 13 regarding the knowledge of the science curriculum, another scale was used: not very important, not important, not sure, important, and very important. The scales were also assigned numbers 1 to 5 from not very important to very important. A different scale of ‘*never, rarely, sometimes, often and always*’ was used for knowledge of instructional strategies, assessment of scientific literacy and classroom practices, with the weightings ranging from one (1) for *never* to five (5) for *always*.

For the purposes of data collection and analysis, the five-point Likert scales were collapsed to a three-point scale such that 1 and 2 were grouped together and assigned 1, while 3 became 2 and 4 and 5 were assigned 3. The grouping is shown in Table 3.2.

Table 3.2 Scale collapsing to create tri-chotomised scale

Original 5-point scale	1	2	3	4	5
Tri-chotomised scale	1		3	4	

(Adapted from Jeong & Lee, 2016)

When analysing data, the disagreement of the concept was considered to be when the responses fell within the range of 1 to 2.9, three (3) stood for neutral views; it served as a decision point whereas the agreement of the concepts was considered when the responses fell in the range 3.1 to 4. The means and standard deviations were also calculated. The mean gave the overall response of the participants for a particular item and concept while the standard deviation was calculated in order to find how wide the variation of any set of cases was. Table 3.3 is a sample of the descriptive statistics which were calculated and how they were presented.

Table 3.3 Sample of descriptive statistics and how they were presented

	Knowledge of science curriculum	Frequency(n)	DA%	N%	A%	Mean	S.D.
Knowledge of the importance of the topic force and momentum in the curriculum							
10	Students should think in a sequential and procedural manner when learning science concepts such as force	83	6.66	2.2	91.2	4.30	.920
11	Students should understand science concepts, principles and strategies	81	0.0	1.1	98.9	4.64	.508
12	When learning force concepts, students should be able to think creatively	81	3.3	2.2	94.4	4.47	.776
13	Students should be able to provide reasons to support their conclusions	81	0.0	2.2	97.8	4.69	.516
	Overall					**4.53**	**.680**

Spearman's correlation analysis was also calculated in order to ascertain whether there was a relationship between the knowledge components or not. Both the Spearman and Pearson correlation coefficients are used to determine the relationships between the dependent and independent variables (Bordens & Abbott, 2011). Both correlations are sensitive to outliers, which was not a threat in this study, because the responses must lie between 0 and 5. However, Spearman correlation was decided on because it is used when data are scaled on ordinal scales and/or when the purpose is to determine whether the relationship between variables is monotonic.

These statistics were used in order to answer the following question: "*to what extent do the domains of teacher knowledge relate to each other?*"

The null hypothesis "there is no association among the knowledge components" was accepted when the criterion (*p*) was greater than 0.05 **(p>0.05)**. While the criterion (*p*) was less than 0.5 **(p<0.05)**, the null hypothesis was rejected in favour of the alternative hypothesis "there is an association among the knowledge components".

3.7.1.2. Inferential statistics

a) Multiple linear regressions (MLR)

Multiple linear regressions were performed in order to identify the effect of teachers' perceptions of their knowledge base on classroom practices. The averages of the questionnaire domains, which reflected independent variables, were regressed against the averages of the domains, which reflected dependent variables.

The independent variables were:

1. knowledge of content of force and momentum (A1)
2. instructional strategies (C)
3. assessment methods (D1)

The dependent variables were:

1. knowledge of goals and purposes of students' learning of force and momentum (A2)
2. knowledge of how students understand science (B)
3. knowledge of aspects of force and momentum to assess (D2)
4. teachers' orientations (E)

5. approaches to teaching force (F)

A multiple linear regression analysis was performed in order to respond to the following specific question, which emanates from the third research question:

> To what extent do the teachers' knowledge of content of force, instructional strategies and assessment methods explain their classroom practices and how they approach the topic?

b) One-way analysis of variance (ANOVA)

In order to investigate the effect of the demographic variables on the questionnaire domains averages (which reflect the aspects of the teachers' knowledge base and classroom practices), one-way ANOVA was also calculated.

3.7.2. Qualitative data analysis

a) *Classroom observations*

Classroom observations comprised mostly an audio-recorded (verbal) form, which I transcribed into textual data. Because the purpose of classroom observations was to ascertain whether the teachers did what they said they would do when teaching, that is, how and whether they assess students on the activities of both teachers and students, the way they represented force concepts and the interactions between teachers and students as well as among students. The data analysis was guided by Park and Oliver's (2008) in-depth analysis of explicit PCK.

When I got home after conducting classroom observations, I transcribed the audio-recorded lessons verbatim, in order to avoid their piling up. When I had observed all the teachers, I read the transcripts critically in order to understand what they did. For example, I paid attention to what the teachers did when students seemed confused, displayed a misconception or failed to comprehend a concept. I coded each of those cases and named them PCK episodes. According to Park and Oliver (2008), a PCK episode is characterised by what the teacher did to help a group of students understand what they were taught. If a student displayed an alternative understanding when responding to a question, the teachers sometimes did not provide the correct answer. Instead they made a pictorial representation to make the student/s doubt their response. I marked this incident as a PCK episode. That is, I focused on how the teachers provided explanations and demonstrations, and how they probed students to respond to the questions. After identifying the PCK episodes, I explained each of them in detail, guided by the three questions: What did the teacher do? Why did he/she do it? What does the teacher know? For example, Table 3.4 shows a PCK episode from Mr C's observation. In this case, his students seemed to have the misconception that frictional force is applied only when contact objects are in motion. Consequently, he restated the students' response and provided an example of what they know and can test. He put a book on a table and then asked students to observe what happened to it when the desk was tilted. He tapped on the knowledge of instructional strategies and the purpose of science teaching.

b) *Semi-structured post-observation interviews*

I did post-observation interviews in order to allow the teachers to explain their classroom practices. The analysis clarified what teachers did and verified the knowledge domain/s that informed their instruction. Similar to observations, the audio-recorded interviews were transcribed into textual data. After identifying the PCK episodes and explaining what the teachers did, the interviews supplemented and elaborated on why the teachers did what they did during the classroom instruction and provided more insight regarding the knowledge base they drew from.

Table 3.4 Grid showing analysis of explicit PCK

PCK episode	What the teacher did	Why the teacher did it	What the teacher knew
Teacher - ...you are saying, force of friction will be between two objects, and you specified that those objects should be moving in opposite directions. So, I want to know, if we have frictional force between the box and desk when the box is pushed across the desk, you are saying the desk will be stationary and the box will be moving. Do we have frictional force in that case?**(*observation*)**	When introducing the topic, the teacher asked students to state and explain different types of force. When they explained frictional force, the teacher realised that students' understanding was incorrect. Instead of providing them with the correct explanation, he gave them a scenario in which one object is stationary and the other one is in motion and asked if there is no frictional force between them.	**Teacher** "…**I** realised that they don't understand friction…**I** did not want to tell them because I know that they are just confused, they know these things…so **I** wanted them to correct themselves" **(*interview*)** The teacher gave a different scenario to help students understand that the objects don't necessarily have to move for frictional force to be applied.	The teacher tapped on his knowledge of: Students' preconceptions**(KSU)** Examples to make **(KIS)** Purpose of teaching science-to explain what happens in environment **(KSC)**

Key: KSU- knowledge of students' understanding, **KIS**- Knowledge of instructional strategies, **KSC**- knowledge of science curriculum

c. Documents

The documents that I analysed were the LGCSE physical science syllabus and the teachers' lesson plan books. From the syllabus, I sought to determine the aims and objectives for students to learn physical science and which they will be assessed on, the content knowledge and skills to develop, and the activities they are supposed to do in order to develop the necessary competences. The analysis of the syllabus was done before classroom observations. I aimed to go to class with an understanding of what the teachers were supposed to teach and how they should teach it. This also helped me to develop the observation protocol.

I collected the lesson plans every day I conducted classroom observations. Consequently, I analysed them simultaneously with the observations. I analysed every aspect of each lesson plan, that is, the lesson objectives; the teaching materials and methods; teacher and students' activities; as well as the lesson evaluation and conclusion. I asked each teacher what he knew for each and every one of those aspects. For instance, Table 3.5 is an example of the lesson objectives of Mr L. I analysed these objectives by asking myself, what does the teacher know? In this example, the teacher seemed to have the perception that his students had different abilities. As a result, he was not expecting every student to reach the highest level of performance, which is calculating gravitational field strength. Moreover, the teacher seemed to have positive views about his content knowledge, as given in the LGCSE physical science syllabus, and its objectives.

Table 3.5 Lesson objectives by Mr L

Low-order objectives: **By the end of the lesson, learners should have begun to:**	**High-order objectives:** **By the end of the lesson, learners should be able to:**
1. discuss that mass and weight are related	1. calculate gravitational field strength from given mass and weight
	2. discuss the difference between mass and weight

Furthermore, I analysed whether there was alignment among all components in the lesson plan. This helped me understand the pedagogical reasoning that the teachers undergo as they plan to teach and the knowledge bases that informed their reasoning. I analysed the lesson plans after every lesson observation. This was because I usually received the plans before or after the observations, in the cases where they were available.

3.8. Exclusion of the fourth case

After analysis of qualitative data from the four teachers, I found that data from one of them was not adding value to the study. I therefore excluded it altogether. As indicated, the purpose of the qualitative phase of the study was to ascertain the knowledge base of teachers and how it manifested in practice. There was limited evidence of the fourth teacher drawing from different knowledge domains when teaching. The excerpt below gives a glimpse of how he taught

T - ...from our previous knowledge...we know that there are different types of forces. Let us try to discuss them. Let us list them here and see...we have different types of force from our background knowledge.

S – Frictional force

T – Frictional force or friction force, another one?

S – Tension force

T – Tension force. Yes another one

S – Gravitational force.

T – Gravitational force. From here we will be talking about the effects. Ok let's continue...

This pattern was followed in most of his lessons. As a result, not much of what the study sought for was attained; hence I excluded this data from the study.

3.9. Pilot study

A pilot study is defined by Van Teijlingen and Hundley (2002) as a small-scale version of the study that is intended to prepare for the major study. It serves the purpose of testing the research data collection instruments (Teddlie & Tashakkori, 2009). The goal here is to test the tools that will be used in the major study and its feasibility.

In accordance with Teddlie and Tashakkori's (2009) advice, I piloted the questionnaire with 23 physical science teachers who were not part of the study sample. One of the purposes of piloting the questionnaire was to test the clarity of the questions and whether they were workable. The characteristics of the participants in the pilot study were similar to those in the major study in that they were physics teachers for grade 11. However, they were teaching in schools which were in the other five districts, which were not selected for this study. The teachers were attending a three-week workshop in January 2018. So I asked them to participate in the pilot study while they were there. The piloted questionnaire had 83 items, including five which elicited the participants' demographics.

The pilot study helped me to assess whether the questionnaire items were clear and to assess their reliability and validity. The outcomes of the pilot study helped me to fine tune the questionnaire with regard to the length of question items, the language used and the length of the questionnaire itself.After measuring the reliability of the instrument, four items were deleted so that for the major study a 79-item questionnaire was used.

I also piloted the observation protocol by observing one teacher, who did not participate in the main study, for two 40 minutes' lessons when teaching velocity. The purpose was to ascertain if the tool was user-friendly and whether it would enable me to obtain the appropriate data.

3.10. Validity and reliability

According to Cohen et al. (2018:245), "…validity is the extent to which interpretations of data are warranted by the theories and evidence used." Validity means different things in quantitative and qualitative studies (Cohen et al.,2011). In quantitative research, it is the ability of the instrument to measure what it is supposed to measure (Bordens& Abbott, 2011) whereas in qualitative studies it refers to issues of honesty, depth, richness and scope, triangulation and objectivity of the researcher. That is, the extent to which the meaning and interpretation of the results of data are sound (Cohen et al., 2018). However, in mixed methods research, instead of validity, Cohen et al. (2018) suggest that it should be replaced with legitimation. The authors indicate that legitimation means ensuring that the results are dependable, credible, transferable, plausible, confirmable and trustworthy. Cohen et al. (2018) further explain that internal validity ensures that the explanation of a particular event, the issue or a set of data is supported by data and research. External validity refers to the extent to which the results are comparable and translatable to other situations.

a) Validity

When I delivered the questionnaires I asked the principals to allow me to meet the physical science teachers, especially those who teach physics in grade 11. In some cases, the principals asked me to leave the questionnaires and that they would distribute them to the teachers. Nonetheless, where possible, I asked them to let me meet the teachers. I informed the teachers about the study and its purpose, which was to identify the perceptions of the teachers' knowledge, not to judge them. I did this in order to increase the chances of the teachers' responding to the questionnaires (Cohen et al., 2018).

Furthermore, meeting with the teachers and explaining to them the purpose of the study and my expectations helped to increase the rapport between them and me, thus increasing the return rate of the questionnaires. In the schools where I talked to the teachers I obtained 100% return-rate. In general, the return-rate was high because, out of the 110 questionnaires which I delivered, 92 (84%) of them were returned. Furthermore, during the data reporting, analysis and interpretation stages, I provided evidence from the data, as shown in Table 3.4. Cohen et al. (2018) advise that for data to be credible, evidence from data should be provided as this increases the trustworthiness and legitimacy of the findings.

Using different research methods, namely survey, classroom observation, interviews and document analysis to collect data helped me to understand the teachers' perceptions and classroom practices from different angles. Teddlie and Tashakkori (2009:32) define triangulation as "…the combinations and comparison of multiple data sources, data collection and analysis procedures, research methods, investigations and inferences…" This definition indicates that there are different types of triangulation. However, in this study, I used methodological triangulation, which allowed me to check for the authenticity of the collected data. For example, classroom observations were made to check for the truthfulness of the survey data, while the post-observation interviews were done to cross-check the authenticity of what was observed.

b) Reliability

Bordens and Abbott (2011:274) define reliability as "…the ability of a measure to produce the same or highly similar results on repeated administrations." It is the precision and accuracy of the phenomenon as well as the instrument used to measure it (Cohen et al., 2018). The authors further indicate that an instrument is reliable when it measures what it is supposed to measure. In order to ensure that the instruments were reliable, appropriate measures were taken. The questionnaire was not too lengthy as there were 79 items, including five demographic items. The items were grouped by themes, such that those which were intended to elicit the teachers' perceptions about the knowledge of instructional strategies were grouped together, with the headings indicating to the respondents what information was required. It was also written in a clear and simple language (Creswell, 2012). Furthermore, I ensured the participants that their responses would be used only for research purposes. That is, their responses would not be linked or traced back to them or their schools in any way. As a result, they were requested to not write their names or those of their schools. This was in line with Cohen et al.'s (2018) warning that, in order to increase the reliability of the research, researchers should ensure anonymity and non-traceability as that attenuates reliability issues. When participants are convinced that the responses will not be linked to them, they are likely to respond truthfully, hence ensure reliable results (Cohen et al., 2011).

Furthermore, Cronbach's alpha coefficients were calculated for the individual themes and for the entire questionnaire. Cronbach's alpha coefficient measures the internal consistency of the questionnaire items (Gliem & Gliem, 2003; Tavakol & Dennick, 2011). According to Tavakol and Dennick (2011), the internal consistency of the items on a questionnaire describes the extent to which the items measure what they are intended to measure. That is, it signifies the accuracy of the items to elicit the information that they intended to. The authors further report that alpha (α) ranges from 0 to 1 and a high alpha value may not mean a high consistency, but the redundancy of the items. I conducted Cronbach's alpha for the constructs separately to avoid inflating the value due to the many items that would be involved (Tavakol & Dennick, 2011). The coefficients of the five components and items measuring the classroom practices are shown in Table 3.6.

Table 3.6 Cronbach's alpha of items

Components	Items	(α)	Items deleted	(α)	Items left
Knowledge of science curriculum	10	0.779	2	0.815	8
Knowledge of students learning	11	0.784	0	0.784	11
Knowledge of instructional strategies	15	0.830	2	0.857	13
Knowledge of assessment strategies	12	0.870	0	0.870	12
Orientations towards science teaching	16	0.918	0	0.918	16
Classroom practices	14	0.861	0	0.861	14

I also ensured that the study was reliable by conducting a pilot study. Piloting the instrument enabled me to test whether the instrument actually measured what it was supposed to measure: the teachers' perceptions of their knowledge.

For the qualitative phase, reliability refers to the trustworthiness and accuracy of the results (Creswell, 2012). I took several measures in order to increase the trustworthiness of the qualitative results. These include being aware of my personal biases, having a prolonged stay in the field and triangulation of the research methods.

My current job, which is mainly to monitor teaching and learning and to support teachers to provide quality instruction, might have slightly influenced the way in which I viewed the teachers' actions and behaviour during classroom observations and interviews. Through my experience as a physics teacher, I learned that students enjoy and understand physics when they are actively engaged. Moreover, in my current job, it is mandatory that I encourage and support physics teachers to teach it through student-centred strategies. As a result, I have my biases regarding how I view physics instruction. Nonetheless, I made an effort to guard against my preference for student-centred instruction. I was conscious about this preference, therefore I was always alert not to judge the teachers based on my inclination. However, it cannot be ruled out that in some instances I might have judged those who used and preferred teacher-centred instruction unfairly as opposed to those who used the student-centred approach.

Classroom observations were conducted for about two months, starting from mid-April to mid-June 2019. During this period, I spent six periods in each of the teachers' classrooms. Cohen et al. (2018) explain that a prolonged stay in the field enables the researcher to observe a series of events more than once in order to ensure the reliability of the data. The prolonged stay in the field enabled me to develop rapport with the teachers and students as they got used to my presence. Thus they relaxed and acted normally. This helped yield credible and accurate data. Moreover, I audio recorded the lessons. This also helped to make the data available without having to retrieve everything from memory or field notes.

Furthermore, classroom observations, interviews and document analysis helped me get data from different sources and thus understand the teachers' perceptions and practices. This was in alignment with Cohen et al.'s (2018) advice that triangulation helps the researcher to get reliable evidence. Moreover, it reduces biases in research and provides compensation between weaknesses and strengths of different methods. For instance, classroom observations enabled me to check the alignment of teachers' perceptions of their knowledge and practice with the actual practice. On the other hand, teacher interviews provided clarity on the teachers' classroom decisions.

3.11. Ethical issues

Ethics in educational research includes issues relating to being open and truthful to the participants about the research study. They can therefore be viewed as the standards of behaviour that guide the researchers' conduct and practices. Creswell (2014) as well as Cohen et al. (2018) advise that researchers should be ethical when conducting research in order to ensure that they do not harm the participants socially and psychologically. Some of the ethical considerations I had to adhere to when conducting this study were: seeking permission to conduct the study, getting informed consent, voluntary participation, anonymity, confidentiality, truthful reporting (Bordens & Abbott, 2011; Creswell, 2014).

3.11.1. Permission to conduct the study

One of the major ethical issues to be considered is to seek permission from all stakeholders to conduct the study (Creswell, 2014). As the first step to getting permission to conduct this study, I submitted a proposal to the Committee for Title Registration (CTR) of the University of the Free State. Then I worked on the ethics clearance application for this study and submitted it in the Research Information Management System (RIMS). I was granted clearance to collect the data for the study from August 2017 to July 2018 (**Appendix D**). Due to unforeseen challenges in the field I did not finish collecting data within that year. Therefore, I applied for an extension to collect the data. Permission was granted to continue to collect data from August 2018 to July 2019 (**Appendix E**).

Before going to the schools in order to collect the data, I also applied for permission, in writing, from the Ministry of Education and Training in Lesotho (MoET) (**Appendix F**) to do so. Even though there are government, church and privately owned schools, MoET is responsible for all registered schools.

3.11.2. Consent forms and voluntary participation

When I went to the schools for the first time, I introduced myself, handed over a copy of the permission letter from the MoET to the school principals and then explained the purpose of my study and how I wished them to assist me. Furthermore, I asked the principal to organise a meeting for me to meet the physical science teachers. Where possible, the principals called a meeting immediately and I explained the purpose of my study. I asked them to participate in the study (Cohen et al., 2018). However, I informed the teachers that their participation was not mandatory; it was voluntary. When the teachers agreed to participate I asked them to sign a consent form. I further told them that at any time during the duration of the study, they would be free to withdraw from it should they feel they are no longer comfortable (Cohen et al., 2018). In the case where I was not able to meet with the teachers, I left the questionnaires with the school principals. In other schools the principals granted me permission to talk to heads of science department with whom I left the copies of the questionnaire on which I had attached a cover page explaining the purpose of the study and the consent form.

3.11.3. Confidentiality and anonymity

I considered the confidentiality of the participants' responses. Confidentiality in the case of research indicates that the responses of the participants are not disclosed to a third person even if the researcher knows the owner (Bordens & Abbott, 2011). During the data reporting I did not disclose the names of either the teachers or the schools. I used pseudonyms. This was meant to hide the identity of the respondents so that the content of the study may not be traced to them or to their schools. Moreover, any information that indicated the identity of the participants was also filed safely where it could only be accessed by me.

3.12. Chapter summary

This chapter explained in detail the methodology employed in this study. It clarified the research approach used including the research designs. The use of both quantitative and qualitative approaches of data collection and analysis were clearly articulated. The sequence of data collection and analysis and how both data types would be analysed to give a comprehensive understanding and to answer the research questions were explained.

In the next chapter I present an analysis of the data collected through the quantitative data collection tools.

Chapter 4.
Quantitative data presentation, analysis and findings

4.1. Introduction

The purpose of this study was to understand physical science teachers' knowledge base necessary to teach force and momentum in grades 11 and 12, as described by the science teachers' PCK. It also sought to establish how their PCK shapes classroom practice. The study used a mixed methods approach to analyse the link between the nature of physics teachers' PCK and their classroom practices. Analysis of data was done in two phases in which quantitative data from the questionnaires were collected and analysed first, thereafter qualitative data were collected and analysed.

In the first phase, the quantitative data were cleaned, coded and entered into an Excel file. The data were analysed using the Statistical Analysis Software (SAS) and were presented in tables and bar graphs. The data analysis included descriptive statistics such as percentages, means and standard deviations. The Spearman's correlation coefficients, Linear multiple regressions (MLR) and a one-way analysis of variance (ANOVA) were calculated in order to determine the relationship among the teachers' PCK components as well as their classroom practices.

The chapter begins by explaining how the reliability and validity of the research instrument (questionnaire in this case) were ascertained, followed by a description of the study sample.

4.2. Reliability and validity of the research

This study used a questionnaire as a research instrument. The Cronbach's alpha coefficient, as shown in Table 4.1 below, was used to confirm the reliability of the questionnaire. According to Taber (2018), an alpha coefficient should be used with every scale, even when the alpha of a scale is published. This is because reliability is a characteristic of test scores, not of the test. In this study, the reliability of the scale was calculated during the pilot and in the main study (Bordens & Abbott, 2011).

The questionnaire was divided into themes that measured particular components of science teachers' PCK. The alpha coefficient was then calculated for the components and sub-components, as shown in Table 4.1 (Taber, 2018). Table 4.1 shows the alpha values calculated after the pilot study. In order to increase the reliability of the instrument, some items were deleted. For instance, there were ten items under the item knowledge of science curriculum in the pilot study, and two were deleted. As a result, there were eight (8) items in the main study. The alpha values of the questionnaire used in the main study ranges from 0.61 to 0.89. These alpha values suggested that the instrument was reliable, because they were within the alpha coefficient (**α)** range of 0.58-0.97, which Taber (2018) rated as satisfactory.

Table 4.1 Reliability test of questionnaire domains of knowledge

Knowledge components	Number of items in the pilot study	Cronbach's alpha (α)	Sub-components	Cronbach's alpha (α)	Number of items in the main study
Knowledge of science curriculum	10	0.78	Knowledge of science content and structure	0.89	4
			Knowledge of goals and objectives	0.61	4
Knowledge of students' understanding of science	11	0.78	Knowledge of students' understanding of science	0.70	11
Knowledge of instructional strategies	15	0.83	Knowledge of instructional strategies	0.81	13
Knowledge of assessment of science	12	0.87	Knowledge of assessment of science literacy	0.65	6
			Knowledge of assessment methods	0.68	6
Orientations towards science teaching	16	0.92	Orientations towards science teaching	0.71	16
Classroom practices	14	0.86	Classroom practices	0.81	14

4.3. Description of the study

Table 4.2 below describes the sample of this study. The expected sample size for the survey was 100 physical science teachers; however, only 92% of the sample was achieved. This return rate was still acceptable since, according to Fosnacht et al. (2017), a low return rate of about 50% is still acceptable because it does not affect the reliability of the study. For the qualitative part, three physical science teachers participated in the study. In both classroom observations and interviews, 100% participation was achieved because the three teachers were observed and interviewed as expected.

Table 4.2 Sample of the study

Instrument	Participants	Participants count	Expected sample	Participant percentage
Questionnaire	Physical science teachers	92	100	92%
Classroom observations	Physics teachers teaching grade 11	4	4	100%
Interviews	Physics teachers teaching grade 11	4	4	100%
Documents	Lesson plans	13	22	54.5%

4.4. Demographic data

The demographics of physical science teachers are presented in Figure 4.1 below. It includes gender, age, highest qualification, teaching experience and major subjects.

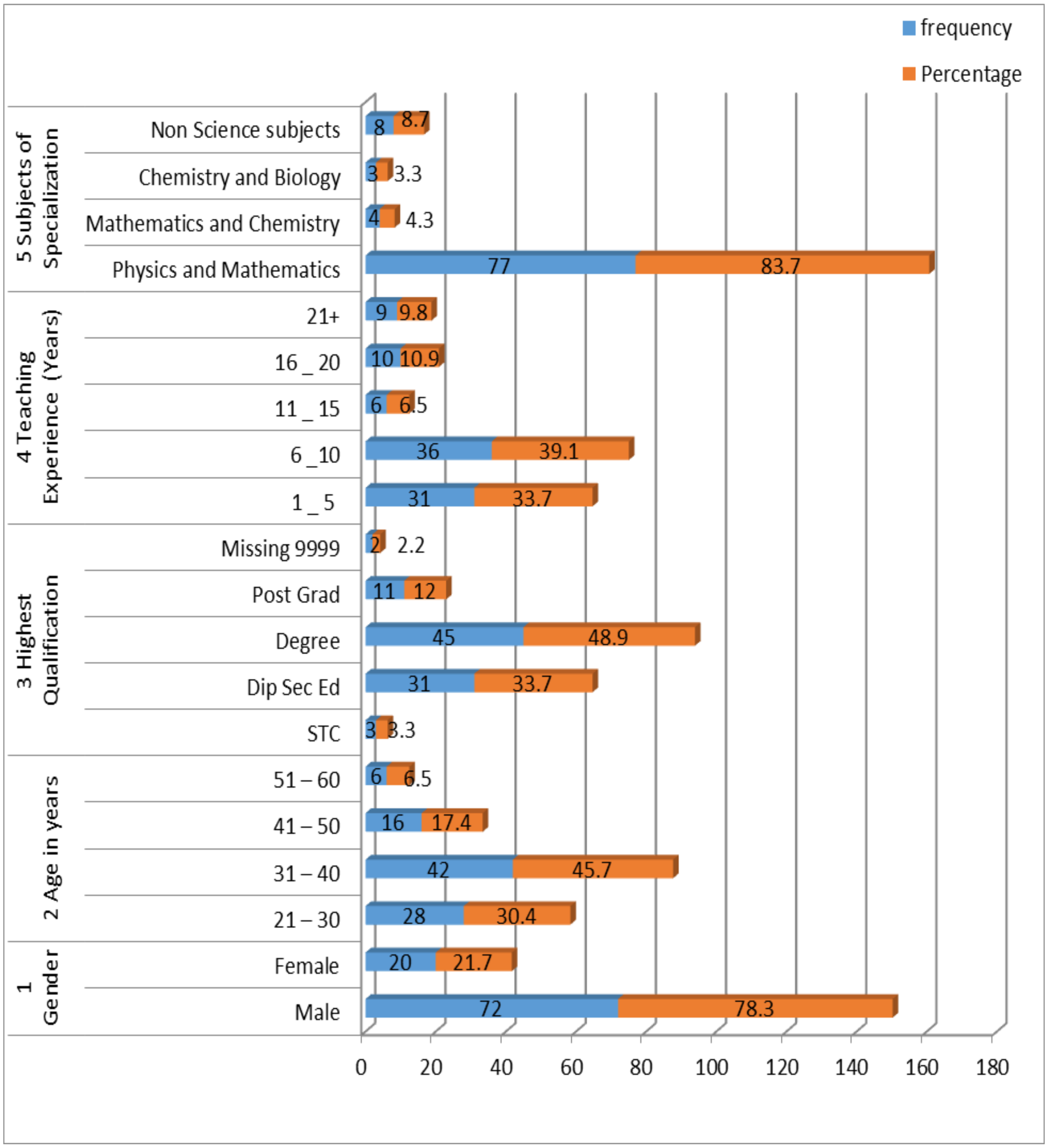


Figure 4.1 Physical science teachers' demographics

Figure 4.1 shows that there are more male physical science teachers (78.3%) than females (21.7%) in the sampled schools. The proportion of male teachers to female teachers is similar to the one reported by Qhobela and Moru (2014) whose sample was

66.7% male and 23.3% female teachers. The figure also indicates that the majority (45.7% and 30.5%) of the teachers are under the age of 40 years of age. This may be indicative of a very young teaching cohort for physical science teachers in the country generally. This claim will need to be confirmed once more recent census data of the country becomes available.

All the teachers in the sample are professionally qualified. That is, 48.9% of them hold bachelor's degrees in education, while 33.7% have a diploma in secondary education and 3.3% have a certificate in education. This finding is again similar to that of Qhobela and Moru (2014) who found that the majority (64.1%) of physics teachers in Lesotho have a bachelor's degree in science education (B.Sc.Ed). On the face of it, this may suggest that many of these teachers have gained adequate content knowledge exposure during their training as teachers. This claim was tested somewhat in this study. According to Etkina (2010:1) "Deep content knowledge is a necessary condition for the development of PCK." This means that the teachers who know how different concepts within a particular topic are developed and how they relate with each other are probably better prepared to be able to translate them for students' learning.

Figure 4.1 also shows that the majority of teachers (64.3%) have teaching experience of more than 10 years. It may therefore be expected that they have accumulated the necessary knowledge base for teaching, such as theoretical and experiential knowledge of teaching. Loughran et al. (2012) explain that the teachers' PCK develops substantially during the first five years of teaching practice.

Figure 4.1 shows that 83.7% of the teachers who teach physics have specialised in physics and mathematics, while less than 7.6% have specialised in other sciences. However, 8.7% did not specialise in any of the science subjects in their teacher training. Data also reveal a small number of teachers who are under-qualified. These are teachers who hold a secondary teachers' certificate (STC), but who are not qualified to teach physics in grades 11 and 12. This certificate was previously offered by the National Teacher Training College (NTTC), which has since changed its name to the current one, the Lesotho College of Education (LCE) for teachers who were going to teach forms A to C (currently referred to as grades 8 to 10). The STC was subsequently phased out by the college.

4.5. Quantitative data analysis

The teachers' responses regarding their knowledge base are discussed in this section. The questionnaire responses were rated on a five-point Likert scale of strongly disagree, disagree, neutral, agree and strongly agree with the weighting ranging from one (1) for *strongly disagree* to five (5) for *strongly agree*. This scale was used for the following themes: knowledge of the science curriculum, knowledge of students' understanding of science and orientations towards science teaching. However, for items 10 to 13 under knowledge of science curriculum, a different scale of not very important (1), not important (2), not sure (3), important (4), and very important (5) was used. Again, a different scale of 'never, rarely, sometimes, often and always' was used for knowledge of instructional strategies, assessment of scientific literacy and classroom practices, with the weightings ranging from one (1) for *never* to five (5) for *always*.

The teachers' views about the concepts were considered negative if the mean was within the range 1.0 to 2.9. Neutral was when the mean was 3.0, so it served as a decision point. The views were considered positive when the mean ranged from 3.1 to 5.0. The standard deviations (SD) ranging from 0.1 to 0.99 were considered to mean a cluster around the mean, whereas an SD of 1.0 and more indicated a wide variation from the mean.

The data were analysed using descriptive statistics based on the following:

1. Disagree (DA) (consisting of strongly disagree and disagree)
2. Neutral (N)
3. Agree (A) (consisting of strongly agree and agree)
4. Not important (combining not very important and not important)
5. Not sure
6. Important (combining important and very important)

4.5.1. Investigation of research question 1

What are the science teachers' perceptions of their knowledge base on the topic: force and momentum?

In order to answer this question, the data about the science teachers' knowledge of the curriculum, students' understanding, instructional strategies, assessment and orientations were analysed. The descriptive statistics used to analyse data were frequency, percentages, mean, standard deviation and mode.

4.5.1.1. Knowledge of the science curriculum

The study sought to find out the perceptions of science teachers about their knowledge of force and momentum as taught in grades 11 and 12. The knowledge of science curriculum, as one component of teacher knowledge, entails knowing the breadth and depth of the topic force and momentum, and the importance of the topic within the whole curriculum. Items 6 to 9 sought to understand the teachers' perceptions about how well they can explain concepts and how familiar they are with the force concepts they teach in grades 11 and 12. Items 10 to 13 were intended to ascertain the knowledge and skills that the teachers intended for the students to attain. The teachers' responses are presented in Table 4.3(a) and 4.3(b) respectively.

Table 4.3(a) Statistics for Knowledge of breadth and depth of topic force and momentum

	Knowledge of science curriculum	**Frequency (n)**	**DA %**	**N %**	**A %**	**Mean**	**S.D.**
Knowledge of breadth and depth of topic force and momentum							
6	I can clearly explain science concepts in the topic force	83	1.1	3.3	95.7	4.47	.687
7	I am familiar with the topic force when I am teaching grades 11 and 12	83	2.2	3.3	94.6	4. 45	.785
8	I have sufficient knowledge of force concepts to answer students' questions in learning	82	3.3	7.7	89.0	4.33	.832
9	I am familiar with the whole structure and directions of grades 11 and 12 physics syllabus concerned with force	82	2.2	15.4	82.4	4.13	.798
	Overall					**4.34**	**.775**

As shown on Figure 4.1, 92 teachers responded to the questionnaire. However, the frequencies count on Table 4.3(a) highlight that the teachers did not respond to all the items. Items 11 to 13 have the highest number of missing responses (11) while items 6 and 7 have the least missing responses (9). Despite the missing responses, the teachers perceive themselves to be knowledgeable about the breadth and depth of the topic (average mean score 4.34; SD=0.775 of items 6 to 9). They perceive themselves as able to explain force concepts clearly. Moreover, they regard themselves familiar with the force concepts they are supposed to teach, including how they are arranged. This is in line with the explanation that teachers should know the content they teach, including understanding that a proposition is so and why it is so (Ball et al.'s, 2008; Robertson et al., 2017). The teachers' perception about their ability to explain force concepts clearly, when teaching, may have a positive impact on their practice. This is because teachers can be expected to pursue activities they feel they are competent to do. Therefore, they may be more likely to provide clear explanations during instruction.

Table 4.3(b) Statistics for Knowledge of the importance of force and momentum in the curriculum

	Knowledge of science curriculum	Frequency(n)	DA%	N%	A%	Mean	S.D.
Knowledge of the importance of the topic force and momentum in the curriculum							
10	Students should think in a sequential and procedural manner when learning science concepts such as force	83	6.66	2.2	91.2	4.30	.920
11	Students should understand science concepts, principles and strategies	81	0.0	1.1	98.9	4.64	.508
12	When learning force concepts, students should be able to think creatively	81	3.3	2.2	94.4	4.47	.776
13	Students should be able to provide reasons to support their conclusions	81	0.0	2.2	97.8	4.69	.516
	Overall					**4.53**	**.680**

Table 4.3(b) shows the statistics for items 10 to 13. The overall mean and SD of items 10 to 13, knowledge of the importance of force and momentum in the syllabus, are 4.53 and 0.680 respectively. The mean indicates that the teachers have positive perceptions of their knowledge of why students learn this topic. Moreover, the SD shows that the responses do not vary much from the mean. The teachers seem to hold similar views regarding items 11 and 13. They agree that students should understand concepts, principles and strategies. They should also be able to think creatively. This is indicated by no teachers disagreeing with those views and having the highest percentage scores of 98.9 and 97.8. In general, there is agreement among the teachers that they know why students must learn force and momentum as well as the skills they should develop through science learning. The results are in line with Krajcik et al.'s (2014) contention that teachers should not only teach facts, but also help students construct explanations for phenomena.

4.5.1.2. Teachers' knowledge of students' understanding

Table 4.4 below presents the results of the teachers' perceptions about their knowledge of students' understanding of science. This knowledge component entails knowledge of students' preconceptions, including misconceptions and the difficulties students experience when learning the topic force and momentum.

Table 4.4 Statistics for teachers' knowledge of students' understanding of science

	KNOWLEDGE OF STUDENTS' UNDERSTANDING OF SCIENCE	**Frequency (n)**	**DA %**	**N %**	**A %**	**Mean**	**S.D.**
14	Before I teach the topic force, I anticipate difficulties that students might have about the force concepts (e.g. Moment of force).	91	3.3	12.1	85.7	4.15	.797
15	I begin every topic by giving students a test to determine what they know.	92	20.7	45.7	33.7	3.20	.986
16	I use a variety of teaching approaches or strategies to develop students' understanding of the topic force.	92	0.0	5.4	94.6	4.53	.601
17	Before I teach the topic force, I find out what students already know about it.	92	0.0	3.3	96.7	4.63	.549
18	I am aware of the misconceptions that students have about force concepts.	91	2.2	15.4	73.6	4.05	.705
19	I realise the errors that students make when solving problems related to force concepts (e.g. identifying forces acting on objects).	92	0.0	8.7	91.3	4.35	.637
20	I know that students sometimes misinterpret force for other concepts.	92	7.6	17.4	75.0	4.07	.935
21	I know some of the possible sources of students' difficulties to learn force concepts.	92	10.9	33.7	55.4	3.55	.906
22	I know what students need to know before learning force concepts in grades 11 or 12.	91	3.3	16.5	80.2	4.13	.806
23	I know how to plan activities which are interesting to students when I teach the topic force.	89	0.0	13.5	86.5	4.16	.778
24	I give students activities similar to those that are in their real life situation.	91	0.0	5.5	94.5	4.42	.598
	Overall statistics					**4.11**	**0.75**

Table 4.4 shows that teachers hold positive views about their knowledge of how students learn science (mean= 4.11, SD = 0.75). The mean score indicates that the teachers are agreeable that they know the factors that enhance students' understanding of the topic force and momentum. The teachers' knowledge of how students learn science entails knowing their preconceptions, including misconceptions and difficulties,

as well as their different strengths and abilities. Furthermore, it entails knowledge of the skills students should have before learning a particular topic, as well as what is appealing to students. As shown by the average mean score, the teachers agree that they consider those aspects of students learning. Item 17 enjoys the highest mean (4.63) and smallest SD (0.549). This indicates that the teachers perceive themselves able to review students' prior knowledge before teaching the topic force and momentum. This could mean that most teachers take students' prior knowledge into consideration during instruction. However, item 15 has the smallest mean of 3.2 and largest SD of 0.986. Though the statistics show positive views regarding giving a test to determine what they know before teaching it, the majority of the teachers are unsure (N=45.7%). This could mean that they use other methods to determine what students know about a new topic. Some of those strategies are interviewing students before instruction, in order to assess their conceptual understanding (Bryce & MacMillan, 2005) and annotated students' diagrams (Bulunuz, 2019).

4.5.1.3. Knowledge of instructional strategies

Knowledge of instructional strategies to use when teaching force and momentum encompasses science specific classroom strategies and topic specific representations and activities (Magnusson et al., 1999). However, in this study, the focus is on the activities and representations of this component. Table 4.5 presents the results of the teachers' knowledge of classroom instructional strategies for the teaching of force.

Table 4.5 Teachers' knowledge of instructional strategies to teach science

	Knowledge of instructional strategies	Frequency (n)	Very Rarely%	Sometimes%	Most Often %	Mean	S.D.
25	When I teach the topic force, I relate force concepts to students' daily life experiences.	92	0.0	13.0	87.0	4.15	.797
26	When I teach force I ask students to explain their understanding to other students.	92	8.7	40.2	51.1	3.20	.986
27	I ask students to complete challenging exercises that require them to go beyond the instruction that they receive on force concepts.	92	15.2	54.3	30.4	4.53	.601
28	I encourage classroom discussions among students as they learn the topic force.	92	4.3	21.7	73.9	4.63	.549
29	I engage students in the whole class discussions.	92	4.3	25.0	70.7	4.05	.705
30	I link new content about force to students' prior knowledge.	91	2.2	7.7	90.1	4.35	.637
31	I ask students to decide on their own problem solving procedures.	89	19.1	48.3	32.6	4.07	.935
32	I encourage students to express their ideas about force in class.	92	3.3	30.4	66.3	3.55	.906
33	I have students work in small groups when they learn about force.	92	6.5	39.1	54.3	4.13	.806
34	I give students a chance to make formal presentations to the rest of the class (e.g. on individual or group assignments, projects).	91	19.8	46.2	34.1	4.16	.778
35	When I teach force I give students activities in which they represent data using tables, charts, graphs etc.	92	29.3	40.2	30.4	4.42	.598
36	When I teach force, I present students with a series of force diagrams for them to analyse.	92	21.7	31.5	46.7	4.15	.797
37	I ask students to complete exercises on force before instruction.	90	44.4	32.2	23.3	3.20	.986
	Overall					**4.05**	**0.90**

The overall mean (4.05) and SD (0.90) show that the teachers have positive views about their use of different instructional strategies when teaching the topic force. These strategies include small group and whole class discussions (items 28, 29 and 33); making presentations (items 26, 32, 34); using different representations of force (items 35 and 36); completing exercises about force (items 27 and 37) and connecting students' prior knowledge to new knowledge to be learned (items 25 and 30). The results support Tomara et al.'s (2017) explanation that teachers should know a variety of activities and representations to use when teaching force concepts. Moreover, as preliminary to classroom discussion, teachers could give students reading assignments so that they come prepared to participate in classroom discussions (West, 2018).

Item 31 was meant to ascertain whether teachers encourage students to use their own problem-solving procedure or not. Data shows its mean score of 4.07 and the majority (48.3%) of the teachers who are not sure whether they give students opportunities to use their own methods when solving problem.

Items 35 and 36 measured the teachers' use of multiple representations of force such as graphs and tables. The mean of items 35 and 36 is 4.42 and 4.15, while their SD is 0.598 and 0.797, respectively. These results indicate that the teachers' views about the use of different representations are positive and fairly homogeneous. According to Furwati et al. (2017), teachers should use different representational modes in order to enhance understanding of force concepts.

4.5.1.4. Knowledge of assessment of science

Table 4.6(a) below presents the results of the teachers' perceptions about their knowledge of assessment methods to use when teaching force and momentum.

Table 4.6(a) Teachers' knowledge of methods to assess force and momentum

	KNOWLEDGE OF ASSESSMENT OF SCIENCE LEARNING	Frequency(n)	Very Rarely%	Sometimes%	Most Often %	Mean	S.D.
Assessment methods							
38	I use standardized tests produced outside the school when I assess students' learning of force.	92	10.9	31.5	57.6	3.59	.916
39	I give students teacher-made short answer or essay tests that require students to describe or explain their reasoning.	92	14.1	40.2	45.7	3.39	.972
40	I use teacher-made multiple choice or true-false or matching tests to assess students learning of force concepts.	92	41.3	37.0	21.7	2.72	.976
41	I assess how well students do on homework assignments.	92	14.1	35.9	50.0	3.51	1.022
42	I assess how well students do on practical or laboratory exercises.	91	19.8	25.3	54.9	3.51	1.079
43	I observe students as they do experiments or practical work to assess their experimental skills.	92	17.4	12.0	70.7	3.92	1.188
	Overall					**3.44**	**1.03**

The results on Table 4.6(a) shows that the teachers perceive themselves knowledgeable about different assessment methods (mean = 3.44; SD = 1.03), because they agree to using them in their classrooms. However, the SD indicates that the responses are not homogeneous. This means that the teachers' views regarding the assessment methods that they use are divergent and perhaps not consistent. On the one hand, the results indicate that teachers assess students' learning through written tests (items 38, 39 and 40) and assignments (item 41). They also prepare their own questions (mean = 3.39) and sometimes they use externally set questions (mean = 3.59). On the other hand, the results show that teachers do not use multiple-choice, or true or false or matching questions (mean = 2.72); rather, they use essay and short answer questions (mean = 3.39). Gurel et al. (2015) explain that good multiple-choice, true or false or matching question items take time to prepare. This could be the reason why teachers in this study do not use these assessment methods as test items.

In addition to written tests, teachers assess students' learning through homework assignments (mean = 3.51 and SD = 1.022). The higher SD highlights that the teachers' responses are not homogenous. Similar to these results, Kukliansky et al. (2014) explain that science teachers hold mixed views about the values of homework assignments. Some teachers view them as an effective tool to assess students' learning, while others do not see it as effective because students copy from others or they ask other people to do homework for them.

Items 42 and 43 were intended to ascertain whether teachers assess students' experimental skills. Data indicate that they assess students through observations while they conduct experiments (mean = 3.51 and 3.92). However, the results are not homogenous as shown by the SD of 1.079 and 1.188 respectively. The lack of homogeneity could be due to the complexity of issues concerned with assessing scientific skills such as insufficient laboratory materials in schools (Qhobela & Moru, 2014).

Below is Table 4.6(b) which presents the results of the teachers' knowledge of the aspects of science to assess when teaching force and momentum.

Table 4.6(b) Knowledge of aspects of force and momentum to assess

	KNOWLEDGE OF ASSESSMENT OF SCIENCE LEARNING	Frequency (n)	Very Rarely%	Sometimes %	Most Often %	Mean	S.D.
Aspects of science to assess							
44	I assess students' ability to write definitions or other short writing assignments about force concepts.	92	9.8	31.5	58.7	3.44	1.03
45	I give students small investigation(s) or data gathering assignments related to the topic force.	92	26.1	42.4	31.5	3.70	.980
46	I assign students' individual work on experiments of force concepts.	92	25.0	33.7	41.3	3.04	.971
47	I assign students work in small groups on experiments of force concepts.	91	6.6	22.0	71.4	3.14	1.115
48	I assign students work to find the uses of the content covered under the topic force.	92	12.0	25.0	63.0	3.84	.885
49	I ask students to prepare oral reports of the investigations they did.	92	35.9	35.9	28.3	3.61	.972
	Overall					**3.37**	**1.01**

The results presented on Table 4.6(b) highlight that the teachers hold positive views (overall mean = 3.37; SD = 1.01) about their knowledge of the aspects of science to assess when teaching the topic force and momentum. The aspects of science, which the teachers indicate that they assess, are students' ability to recall facts, such as writing definitions of concepts (item 44), experimental skills (items 45, 46, 47and 48), ability to identify the uses of force concepts (item 48) and oral communication (item 49). However, the SD is greater than 1.0 and it indicates that the responses are not homogeneous. Nonetheless, the teachers perceive themselves knowledgeable about the different aspects of scientific literacy students should learn because they indicate that they assess them though it may not be at all times.

4.5.1.5. Orientations towards science teaching

Teachers' orientations are believed to manifest in their teaching. As explained in literature, teaching is influenced by teachers' beliefs about teaching, learning, students and the subject (Campbell et al., 2017). This section of the questionnaire aimed at ascertaining the teachers' perceptions about science: teaching, learning, concepts and students. Table 4.7 shows the analysis of the teachers' orientations towards science teaching.

Table 4.7 Teachers' orientations towards teaching force and momentum

	ORIENTATIONS TOWARDS TEACHING	**Frequency (n)**	**DA %**	**N %**	**A %**	**Mean**	**SD**
50	When I teach the topic force, I pay more focus on students' ability to make observations.	91	4.4	14.3	81.3	4.00	.789
51	I emphasize that students draw their own conclusions of experiments	91	6.6	12.1	81.3	4.11	.936
52	When I teach the topic force I emphasize that students should know definitions.	92	1.1	14.1	84.8	4.34	.760
53	I make sure that students know scientific facts.	92	0.0	6.5	93.5	4.50	.620
54	When teaching force concepts, I give students situations for them to explain.	91	0.0	9.9	90.1	4.11	.547
55	I give students challenging questions and probe them for answers.	92	2.2	16.3	81.5	4.13	.759
56	I give students activities which help them discover science concepts related to the topic force (e.g. elastic limit, moments of force).	92	2.2	15.2	81.5	4.24	.835
57	When I teach the topic force, I ask students to work in small groups.	91	4.4	12.1	83.5	4.03	.781
58	I engage students in determining what to investigate.	91	8.8	22.0	69.2	3.80	.897
59	When teaching about force, I give students hands-on activities (e.g. Draw diagrams, do experiments etc.).	92	4.3	13.0	82.6	4.14	.884
60	When teaching the topic force, I give students activities from which they solve real life problems.	92	2.2	16.3	81.5	4.12	.837
61	A quiet classroom is generally needed for effective learning.	92	48.9	29.3	21.7	2.61	1.204
62	Students are not ready for "meaningful" learning until they have acquired basic reading and scientific skills.	91	30.8	25.3	44.0	3.26	1.219
63	It is better when the teacher not the students decides what activities are to be done.	91	33.0	24.2	42.9	3.14	1.160
64	Students' projects often result in students learning all sorts of wrong "knowledge."	90	53.3	28.9	17.8	2.48	1.104
65	How much students learn depends on how much background knowledge they have.	92	21.7	23.9	54.3	3.42	1.160
	Overall					**3.78**	**0.91**

The results on Table 4.7 indicate that the teachers have positive perceptions about science teaching, learning and students (mean = 3.78, SD = 0.91). In general, the teachers hold positive views about students' involvement during instruction (items 50 to 60) and the conditions for meaningful learning (61 to 65). For items 50 to 60, the mean responses are all greater than 3 and the SD less than 1.0, showing that their views about involving students in knowledge construction during instruction are positive and homogeneous. The mean responses for items 61 to 65 are also greater than 3, except for items 61 and 64. However, the SD for all five items is greater than 1.0 indicating varying teachers' views about the conditions for meaningful learning. Though the mean responses of items 61 and 64 are less than 3.0, that is, 2.61 and 2.48, respectively, they indicate positive perceptions. Item 61 states that "a quiet classroom is generally needed for effective learning." Since the average mean (2.61) response for this item is less than 3.00, it indicates that the teachers do not agree with that view. Thus, their responses can be interpreted to mean that they hold the view that effective learning does not necessarily need students to be quiet. On the other hand, item 64, with an average mean of 2.48, states that "students' projects often result into students learning all sorts of wrong knowledge." This can also be interpreted to mean that the teachers do not hold the view that projects result into wrong learning.

In general, the results suggest that teachers hold both constructivist and transmissive views about teaching and learning. These results support those of Campbell et al. (2017) who found that teachers' views about teaching, learning and science are not constant. The authors explain that teacher practices change with contexts and topic.

From the investigation of research question 1 presented in **Section 4.5.1**, it is found that the teachers generally hold positive views about their knowledge of content of force and momentum as well as the goals and objectives of teaching the topic. Regarding knowledge of how students learn the topic force and momentum, they indicated that they know areas of the topic that students find difficult to understand and their causes as well as their preconceptions and misconceptions of force. Under the knowledge of instructional strategies, they further indicate that they know different activities and representations of force to use when teaching the topic. Moreover, the teachers held high expectations about their knowledge of methods to use when assessing students' understanding of science aspects. They seem to hold both knowledge transmission and construction orientations.

4.5.1.6. Classroom practice when teaching force: teachers' perceptions

This section presents the results of the teachers' perceptions of their classroom practices when teaching force and momentum in grades 11 and 12.

Table 4.8(a) Statistics for classroom practice/approaches that promote knowledge transmission

	CLASSROOM PRACTICE/APPROACHES TO TEACHING FORCE	Frequency (n)	Very Rarely %	sometimes %	Most Often %	Mean	S.D.
Knowledge transmission							
66	I ask students to listen as I explain to the whole class.	91	12.1	13.2	74.7	4.04	1.173
67	I ask students to keep quiet and listen as I teach.	92	10.9	33.7	55.4	3.74	1.185
68	I ask students to watch as I demonstrate an experiment (e.g. verification of Hooke's law).	91	20.9	14.3	64.8	3.67	1.283
69	I begin the lesson by explaining the concepts.	92	20.7	34.8	44.6	3.35	1.094
	Overall					**3.70**	**1.184**

Items 66 to 69 in Table 4.8(a) were intended to depict whether the teachers' believe that their classroom actions encourage knowledge transmission or not, whereas items 70 to 79 were intended to ascertain whether the teachers' actions encourage knowledge construction and the development of scientific skills or not.

The overall mean and SD of items 66 to 69 in Table 4.8(a) are 3.70 and 1.184 respectively. The results show that the teachers' classroom practices are inclined towards knowledge transmission, because the mean is greater than 3.0. However, the SD is fairly large, indicating that teachers have mixed feelings regarding whether their practice favours knowledge transmission or not, thus their perceptions regarding their practices are not homogeneous. This could mean that the teachers' practices and approaches when teaching force concepts are both knowledge construction and transmission.

Table 4.8(b) below presents the results of the teachers' perceptions about their classroom practices that enhance knowledge construction.

Table 4.8(b)Statistics for classroom practice/approaches that promote knowledge construction

	CLASSROOM PRACTICE/APPROACHES TO TEACHING FORCE	Frequency (n)	Very Rarely %	sometimes %	Most Often %	Mean	S.D.
Knowledge Construction							
70	I ask students to make predictions based on the action of force.	90	4.4	31.1	64.4	3.76	.769
71	I ask students to explain their predictions.	90	6.7	24.4	68.9	3.84	.847
72	I ask students to observe natural phenomena, such as force, and explain what they see.	90	5.6	25.6	68.9	3.84	.820
73	I ask students to design experiments about force.	91	31.9	45.1	23.1	2.90	1.023
74	I ask students to conduct experiments or investigations related to force.	90	11.1	24.4	64.4	3.68	.897
75	I ask students to present data from experiments or investigations.	90	8.9	27.8	63.3	3.87	1.008
76	I ask students to interpret data from experiments.	90	6.7	18.9	74.4	4.04	1.016
77	I ask students to use evidence from experiments and investigations to support conclusions.	92	4.3	10.9	84.8	4.26	.900
78	I begin the lesson by giving an activity which needs students to use their prior knowledge.	92	0.0	28.3	71.7	4.01	.763
79	I give activities from which students will be able to explain concepts on their own.	91	2.2	27.5	70.3	3.92	.778
	Overall					**3.81**	**.882**

Items 70 to 79, in Table 4.8(b) inquired about the teachers' perceptions about classroom behaviour, which supports the development of scientific process skills. The overall mean and SD are 3.81 and 0.882 respectively. The results show that the teachers perceive that students accomplish expertise by developing qualitative changes in thinking. This perception is indicated by the overall mean score (3.81), which highlights that teachers' classroom practices support knowledge construction. Moreover, their practices when solving problems seem to include explanations and predictions (Dancy & Henderson, 2007). On the contrary, the mean and SD of item 73 are 2.90 and 1.023 respectively. The item sought to ascertain whether the teachers give students opportunities to design experiments about force. These results show that even though teachers provide these opportunities to a little extent, their views about this practice are not homogeneous. However, Tomara et al. (2017) explain that engaging students in the design and implementation of experiments and explaining them to others enhances learning.

The results of sections 66 to 69 and 70 to 79 show a contradiction. In the former case, the teachers indicated that their practice favours knowledge transmission whereas in the latter case it favours knowledge construction. These mixed views regarding teacher practice is explained by Campbell et al. (2017) who contend that classroom practices are influenced by many factors, such as the nature of the subject matter, students' characteristics and the teachers' goals for teaching a particular concept. In the context of science teaching, especially teaching the topic force and momentum, these mixed views could mean that the teachers who participated in this survey teach in different contexts and have different goals of teaching science, hence their practices vary.

The findings of the second research question that addressed the approach used by teachers to teach the topic force and momentum reveal that teachers transmit information whilst also giving students opportunities to construct their own understanding. The main finding is that the teachers use both transmission and constructivist approaches to teaching.

4.5.2. Investigation of research question 4

> How can the teachers' perceptions of their knowledge base and practices be understood and/or explained?

Research question four was first answered by doing correlation analysis. The correlation analysis is intended to explain if there is a relationship among the knowledge components so that the teachers' practices can be understood.

4.5.2.1. Correlation (cross tabulation) between knowledge components

The question I used to explore these correlations is:

- To what extent do the domains of teacher knowledge relate to each other?

Table 4.9 below presents a correlation analysis of the questionnaire knowledge domains: knowledge of science curriculum (SC), students' understanding of science (SUS), instructional strategies (IS), and assessment of science (AS), teachers' orientations (TO) and approaches to teaching (AT). Knowledge of science curriculum (A) has two parts. One part (A1) measures the teachers' perceived knowledge of the content while the other part (A2) measures knowledge of goals and objectives of teaching science respectively. Knowledge of assessment (D) of science also has two parts. One part (D1), measures knowledge of assessment methods while the other part (D2) measures knowledge of scientific literacy to be assessed.

The data in this study are ranked on the ordinal scale; as a result, Spearman Rank-order correlation is used to ascertain if there is a relationship among the knowledge components.

Table 4.9 Correlations between knowledge components

Spearman Correlation Coefficients, N = 92 Prob>Irl under H0: Rho= 0								
	A1 Content knowledge	A2 Goals and Objectives	B Students' Understanding of Science	C Instructional Strategies	D1 Assessment methods	D2 - Assessment of scientific literacy	E Teachers Orientations	F Approaches toTeaching
A1 **Content knowledge**	1.00000	0.088 0.4066	0.316 0.0022	0.05064 0.6317	0.14950 0.1549	-0.00173 0.9869	-0.01463 0.8899	-0.11022 0.2956
A2 **Goals and Objective**	0.088 0.4066	1.00000	0.211 0.0436	0.140 0.1850	-0.014 0.8929	0.256 0.0138	0.229 0.0285	0.187 0.0744
B **Students' Understanding of Science**	0.316 0.0022	0.211 0.0436	1.00000	0.470 <.0001	0.337 0.0010	0.395 <.0001	0.384 0.0002	0.317 0.0021
C **Instructional Strategies**	0.051 0.6317	0.140 0.1850	0.470 <.0001	1.00000	0.470 <.0001	0.658 <.0001	0.375 0.0002	0.455 <.0001
D1 **Assessment Methods**	0.150 0.1549	-0.014 0.8929	0.337 0.0010	0.470 <.0001	1.00000	0.595<.0001	0.457 <.0001	0.515 <.0001
D2 **Assessment of scientific literacy**	-0.002 0.9869	0.256 0.0138	0.395 <.0001	0.658 <.0001	0.595 <.0001	1.00000	0.427<.0001	0.559 <.0001
E **Teachers Orientations**	-0.015 0.8899	0.229 0.0285	0.384 0.0002	0.375 0.0002	0.457 <.0001	0.427 <.0001	1.00000	0.555 <.0001
F **Approaches to Teaching**	-0.110 0.2956	0.187 0.0744	0.317 0.0021	0.455 <.0001	0.515 <.0001	0.559 <.0001	0.555 <.0001	1.00000

*Significant value (p =0.05)

The correlation test was conducted to show the association that existed among the five knowledge components, including teachers' perceptions of classroom practices in the questionnaire. The null hypothesis was that "there is no association among the knowledge components". The criterion (*p*) had to be a probability of less than 0.05, implying that the null hypothesis is accepted if *p* is greater than 0.05 **($p>0.05$)**. The highlighted cells indicate the knowledge components whose *p* is less than 0.05**($p<0.05$),** hence the correlations are significant at **$p<0.05$** and the null hypothesis is rejected.

The results on Table 4.10 show weak **($0<r< 0.4$; $p<0.05$)** and moderate (**$0.39<r<0.7$; $p<0.05$)** positive correlation among the knowledge components. This suggests that though one knowledge component may have a relationship with others, the relationship of one to the other may not be strong. Among all five components, knowledge of science curriculum, comprising A1 and A2, correlates with few components. On the one hand, the teachers' perceptions of their knowledge of science content (A1) shows a weak correlation with only students' understanding of science (SUS) **(0.316)**. That is, the more science content knowledge the teachers believe they have, the more they believe they know how students learn science. On the other hand, knowledge of goals and objectives for students' learning (A2) have a weak correlation with SUS **(0.219)**, assessment of science literacy **(0.256)** and teacher orientations **(0.22851)**. It is surprising though that knowledge of science content correlates only with SUS. Nonetheless, the results confirm those of Park and Chen (2012) and Catalano et al. (2019), who found limited integration of the knowledge of science curriculum with other components, as well as those of Catalano et al. (2019), whose results showed a moderate negative relationship between content knowledge and science teachers' self-efficacy.

Knowledge of SUS seems to have a significant but weak correlation with most components **($0.211 \leq r \leq 0.395$, $p< 0.05$)**. However, it correlates moderately with knowledge of instructional strategies (IS) **(0.470)**. These results also confirm those of Suh and Park (2017) who explain that knowledge of SUS and IS was most strongly connected with each other, implying that teachers made decisions about instructional strategies and representations based on students' understanding.

The highest relationship observed is between the teachers' perceptions of their knowledge of instructional strategies(IS) and the perceptions of aspects of science to assess **(r=0.658; *p*=0.0001)**. There is moderate correlation between them. The results refute those of Aydin et al. (2017) who found no relationship between knowledge of instructional strategies and assessment. There is also a moderate relationship between knowledge of assessment methods and scientific literacy **(r=+0.595; p=0.0001)** and approaches to teaching **(r=+0.515; 0.0001)**. This finding could mean that teachers, who know which domain of scientific literacy the topic is aimed to teach, often engage in classroom activities which help students achieve that particular competency and therefore use appropriate assessment methods to test the attainment of the set goal.

From the correlation analysis, it may be suggested that the relationship between the teachers' perceptions of classroom practices and their knowledge base is not strong. The teachers' perceptions of their knowledge of content do not have a strong relationship with other knowledge domains. However, the perceptions of their knowledge of instructional strategies have a relationship with knowledge of assessment methods and aspects of the topic to assess.

Summary of correlations

In summary, the correlations show that

- There is a small to medium correlation among the knowledge domains.
- There is a small to medium correlation between knowledge of how students learn and all other knowledge domains.
- The teachers' orientations and knowledge of aspects of science to assess have a relationship with all knowledge domains except knowledge of the content of force.
- Knowledge of content marked a relationship with the knowledge of how students understand science only.
- Teachers' knowledge of how students understand science has the weakest positive relationship with the knowledge of goals and objectives for science teaching.

- Teachers' knowledge of the aspects of science to assess has the strongest positive relationship with knowledge of instructional strategies.

4.5.2.2. Multiple linear regression analysis (MLR)

Besides the correlation analysis, MLR were performed in order to determine the effect of teachers' knowledge base on classroom practices. In order to find the relationship, the averages of the questionnaire domains reflecting independent variables were regressed against the averages of the domains which reflect dependent variables.

The independent variables

- knowledge of content of force and momentum (A1)
- instructional strategies (C)
- assessment methods (D1)

The dependent variables

- knowledge of goals and purposes of students' learning of force and momentum (A2)
- knowledge of how students understand science (B)
- knowledge of aspects of force and momentum to assess (D2)
- teachers' orientations (E)
- approaches to teaching force (F)

A multiple linear regression analysis was performed to answer the following specific question which emanates from the third research questions:

- To what extent do the teachers' knowledge of content of force, instructional strategies and assessment methods explain their classroom practices and how they approach the topic?

Table 4.10 presents the estimates of the regression coefficients for the independent variables and the associated significant values, in brackets. For this study the significance value is calculated at **p=0.05**. A p-value of <0.05 indicates more than 95% probability that the results are not by chance.

Table 4.10 Independent variables as predictors of teachers' classroom practices

DEPENDENT VARIABLES					
INDEPENDENT VARIABLES	**A2** **Goals and objectives of students**	**B** **Knowledge of how Students Understand force**	**D2** **Science aspects to assess in a topic**	**E** **Teacher Orientations**	**F** **Approaches when teaching force**
A1 **Content knowledge**	0.121 (0.118)	0.075 (0.168)	-0.072 (0.295)	-0.095 (0.073)	-0.158 **(0.014*)**
C **Knowledge of Instructional Strategies**	0.214 (0.078)	0.325 **(0.0002*)**	0.660 **(<0.0001*)**	0.118 (0.151)	0.299 **(0.003*)**
D1 **Knowledge of assessment methods**	-0.047 (0.626)	0.066 (0.334)	0.334 **(0.0002*)**	0.274 **(<0.0001*)**	0.351 **(<0.0001*)**

*Significant value (p<0.05)

Table 4.10 shows that the teachers' knowledge of content of the concepts of force is statistically significant for how teachers perceive their approaches to teaching force and momentum **(p=0.014)**. Unexpectedly, this suggests that high content knowledge predicts poor approaches when teaching force and momentum **(b=-0.158)**. This seems to suggest that teachers with high content knowledge do not necessarily have best approaches to teaching force and momentum. The results are similar to those of Catalano et al. (2019) who found a negative relationship between the elementary science teachers' self-efficacy and science content knowledge.

The teachers' knowledge of instructional strategies (C) shows high regression coefficients, which are statistically significant at **p=0.05**. The independent variable, teachers' knowledge of instructional strategies, shows positive effects on teachers' knowledge of how students understand science **(p=0.0002),** knowledge of assessment of scientific literacy **(p=0.0001)** and the approaches to teaching the topic **(p=0.003)**. This suggests that knowledge of different instructional strategies predicts classroom practices, which tap into students' preconceptions, reveal misconceptions and address students' difficulties. Furthermore, it predicts practices that promote assessment of different aspects of science learning and approaches that enhance comprehension.

The teachers' knowledge of assessment methods is statistically significant for assessment of scientific literacy **(p=0.0002)**, teacher orientations **(p=0.0001)** and approaches when teaching force **(p=0.0001)**. This means that better knowledge of assessment methods has a positive predictive power on the classroom practices, which promote assessment of different aspects of understanding the concepts of force. In addition, knowledge of assessment methods seems to have a relationship with how teachers' orientations shape classroom practices. That is, as teachers accumulate more knowledge of different assessment methods, the higher the chances to change the way they view teaching, learning and science. Furthermore, more knowledge of assessment methods seems to have the predictive power of approaching the topic in a manner that enhances understanding.

Summary of MLR

In summary, MLR show that:

- Content knowledge revealed a negative relationship with how the teachers approach the teaching. This means high content knowledge does not necessarily mean best approaches to teaching.
- Knowledge of instructional strategies predicts approaches that recognise the best ways students need in order to learn.
- Knowledge of assessment methods has a positive relationship with approaches to teaching; teacher orientations and practices that focus on assessing important elements of science learning.

4.5.2.3. A one-way analysis of variance (ANOVA)

A one-way analysis of variance (ANOVA) test was conducted in order to investigate the effect of the demographic variables on the questionnaire domains averages (which reflect the aspects of the teachers' knowledge base and classroom practices). All domain averages were analysed using one-way analysis of variance (ANOVA) fitting the demographic variables one at a time. These ANOVAs yield the following statistics:

- Overall F-test and associated P-value for the demographic variable.
- Mean values of the dependent variable for each category of the independent variable.

For the demographic variables that have more than two categories, the following additional statistics for each dependent variable were calculated:

- Pairwise p-values comparing each demographic category with each other.
- Ranking of the means of the dependent variable from large to small, together with a "lines" display. That is, means sharing the same letter are not statistically different from each other at 0.05 significance level and pairs of means that do not share a letter differ statistically significantly.

Effect of gender

Table 4.11 below presents the ANOVA test for the averages of the questionnaire domains and the teachers' gender.

Table 4.11 ANOVA test for independent variable, gender

Teacher knowledge	**Gender Mean**		**F**	***p***
	M	**F**		
A_extent (content knowledge)	4.34	4.42	0.21	0.65
A_important (knowledge of goals and objectives for students)	4.51	4.57	0.17	0.68
B_knowledge of how students understand	4.10	4.12	0.05	0.82
C_knowledge of instructional strategies	3.54	3.57	0.04	0.84
D1_aspects of science to assess	3.41	3.46	0.10	0.75
D2_assessment methods	3.35	3.42	0.19	0.67
E_teacher orientations	3.76	3.81	0.26	0.61
F_classroom practices and approach	3.75	3.86	0.74	0.39

Significant value ($p<0.05$)

Table 4.12 shows that there is no statistically significant difference between genders and the teachers' knowledge base **($p>0.05$)**. This suggests that the teachers' gender has no effect on their knowledge base.

Effect of age

A further test was done to determine if the teachers' age have an effect on their perceived knowledge and practice. The results of the test are presented in Table 4.12.

Table 4.12 ANOVA Test for the age of the teacher

Teacher knowledge and approaches	**Age (years)**			**F**	***P***
	Mean				
	21-30	**31-40**	**41-50**		
A_extent (content knowledge)	4.44	4.27	4.42	0.65	0.53
A_important (knowledge of goals and objectives for students)	4.68	4.43	4.50	2.24	0.11
B_knowledge of how students understand	4.16	4.04	4.12	1.08	0.34
C_knowledge of instructional strategies	3.70	3.49	3.46	1.91	0.15
D1_aspects of science to assess	3.49	3.40	3.39	0.21	0.81
D2_assessment methods	3.58	3.33	3.13	**3.14**	**0.05**
E_teacher orientations	3.81	3.73	3.82	0.49	0.62
F_classroom practices and approach	3.81	3.87	3.54	**3.07**	**0.05**

Significant value($p<0.05$)

Table 4.12 shows that there is no statistically significant difference between the age of the teachers and most of the knowledge bases. Nonetheless, a statistically significant difference is observed between age and knowledge of assessment methods **($F(2,87)=3.14$, $p=0.05$)** and their approach to teaching the concepts of force **($F(2,87)=3.07$, $p=0.05$)**.

In order to find out where the difference lies, a pairwise p-value and the rankings of the means were calculated as highlighted in Table 4.13.

Table 4.13 Mean values of A_extent and summary display of pairwise comparisons of age groups

Dependent Variable	Age group	Mean[b]	Pairwise comparison of age groups[c]	
A extent (content knowledge)	21-30		A	
	31-40		A	
	41+		A	
A important (goals and objectives of students)	21-30	4.7	A	
	31-40	4.5	A	B
	41+	4.4		B

- [b]Mean estimates from one-way analysis of variance (ANOVA) model with age group as fixed effect.
- [c]Means sharing the same letter are not statistically different from each other at 0.05 significance level; pairs of means that do not share a letter differ statistically significantly.

Table 4.13 above shows that there is no statistically significant difference between the means of the ages of the teachers and their views about the extent of their content knowledge. However, there is a statistically significant difference between their mean age and perceptions about the knowledge of the goals and purposes of force and momentum (importance). The largest mean **(4.7)** of teachers aged 21 to 30, differs statistically significantly from the lowest mean **(4.4)** of teachers aged from 41 and above. This suggests that teachers aged 21-30 know different assessment methods and their approaches to teaching differ from those of teachers aged from 41 and above.

Another pairwise p-value and the rankings of the means were calculated in order to find out whether a difference exists between the averages of the teachers' knowledge of different assessment methods and aspects of force to assess. The results are shown in Table 4.14 below.

Table 4.14 Mean values of D_learning and homework and summary display of pairwise comparisons of age groups

Dependent Variable	Age group	Mean[b]	Pairwise comparison of age groups[c]	
D learning (aspects to assess)	21-30		A	
	31-40		A	
	41+		A	
D homework (assessment methods)	21-30	3.6	A	
	31-40	3.3	A	B
	41+	3.1		B

Significant value (p<0.05)

Table 4.14 shows that there is no statistically significant difference between the mean ages of teachers and the aspects of scientific knowledge to be assessed. To the contrary, a statistically significant difference is observed between the mean of teachers' knowledge of assessment methods. That is, the teachers aged 21-30 years of age **(mean=3.6)** seem to have more knowledge of assessment methods than those who are aged 41 years of age and above **(mean=3.1)**. These results seem to suggest that young teachers' assessment methods may be better than those of the older teachers.

Effect of teachers' qualifications

Table 4.15 shows the effect of the teachers' qualifications on the knowledge bases and approaches.

Table 4.15 ANOVA Test for teachers' qualifications

Teacher knowledge	Mean			F	*p*
	STC and Dip Sec Ed	Degree	Post grad		
A_extent (content knowledge)	4.27	4.34	4.31	0.67	0.52
A_important (knowledge of goals and objectives for students)	4.48	4.53	4.62	0.34	0.71
B_knowledge of how students understand	4.03	4.17	3.95	1.72	0.19
C_knowledge of instructional strategies	3.65	3.54	3.26	2.61	0.08
D1_aspects of science to assess	3.49	3.49	2.97	**3.52**	**0.03**
D2_assessment methods	3.50	3.32	3.11	1.88	1.16
E_teacher orientations	3.83	3.77	3.63	1.72	0.32
F_classroom practices and approach	3.89	3.75	3.53	2.23	0.11

Significant value($p<0.05$)

Table 4.15 above, shows no statistically significant effect of qualifications on the teachers' knowledge bases and approaches **($p>0.05$)**. However, a statistically significant difference was observed between qualifications and the aspects of science to assess **($F(2,87)=3.52$, $p=0.03$)**. In order to investigate where the difference lies, a pairwise p-value and rankings of dependent variables means was calculated as shown in Table 4.16 below.

Effect of teaching experience

Table 4.16 shows a one-way ANOVA for teaching experience.

Table 4.16 ANOVA test for teaching experience

Teacher knowledge	Mean			F	*p*
	Less than 11 years	11-15	More than 15 years		
A_extent	4.56	4.18	4.49	2.09	0.13
A_important	4.59	4.53	4.44	0.62	0.54
B_knowledge of how students understand	4.12	4.06	4.14	0.34	0.72
C_knowledge of instructional strategies	3.67	3.49	3.48	1.43	0.24
D1_aspects of science to assess	3.48	3.36	3.44	0.30	0.74
D2_assessment methods	3.61	3.28	3.17	**3.99**	**0.02**
E_teacher orientations	3.79	3.72	3.83	0.58	0.56
F_classroom practices and approach	3.75	3.90	3.63	2.20	0.12

Significant value ($p<0.05$)

Similarly, Table 4.16 shows that the independent variable, teaching experience, has no effect on most of the knowledge bases, except knowledge of assessment methods **($F(2,87)=3.99$, $p=0.02$)**.

A pairwise p-value and the rankings of the mean were calculated in order to investigate where the difference in the means lie.

Table 4.17 Mean values of D_homework (assessment methods) and summary display of pairwise comparisons of age groups

Dependent Variable	Teaching experience (years)	Mean[b]	Pairwise comparison of age groups[c]
D homework (assessment methods)	5 years and less	3.6	A
	6 – 20	3.3	B
	21 years and more	3.2	B

Significant value ($p<0.05$)

From Table 4.17 it seems that there is a statistically significant difference between the highest mean and the other two means. This indicates that teachers with teaching experience of less than five years seem to have better knowledge of assessment methods than those with more than five years.

Effects of subject specialisation

Table 4.18 presents the ANOVA results of subject specialisation and knowledge bases.

Table 4.18 ANOVA test for subject specialisation

Teacher knowledge	Mean				F	*p*
	Physics and Math	Math and Chemistry	Biology and Chemistry	Others		
A_extent	4.39	3.63	4.20	4.44	1.84	0.15
A_important	4.54	4.13	4.75	4.50	1.09	0.36
B_knowledge of how students understand	4.09	4.23	4.14	4.10	0.15	0.93
C_knowledge of instructional strategies	3.54	3.69	3.77	3.49	0.27	0.85
D1_aspects of science to assess	3.41	3.63	3.17	3.52	0.32	0.81
D2_assessment methods	3.35	3.42	3.67	3.42	0.19	0.90
E_teacher orientations	3.75	3.97	3.88	3.86	0.60	0.62
F_classroom practices and approach	3.74	3.93	3.93	3.99	0.77	0.51

Significant value ($p<0.05$)

Table 4.18 shows that there is no statistically significant difference between the means of the teachers' subject specialisation and their knowledge bases. This is evidenced by the p-values which are greater than 0.05.

Summary of ANOVA

The one-way ANOVA tests show that

- Teaching experience has a relationship with how the teachers assess students' knowledge. Further analysis highlights that teachers with experience of five years and less use more variation in assessment methods than those with more experience.

Chapter 5.
Qualitative data presentation, analysis and the findings

5.1. Introduction

In this chapter, I present and analyse the qualitative data. The chapter starts by presenting the qualitative data collected from the three participants' cases. Each case is chronicled on how each teacher enacted teaching and how their pedagogical content knowledge (PCK) seem to manifest in the observed classroom practice.

Classroom observations were analysedusing Park and Oliver's (2008) in-depth analysis of explicit PCK, which aligns with their definition of PCK adopted in this study. The PCK episodes were identified from the data collected from classroom observations in order to determine what each participant did and why, and to establish what the teachers know. For each episode, the three questions: What did the teacher do? Why did the teacher do it? What does the teacher know? were answered. Teachers' interviews, lesson plan books and the physical science syllabus were analysed for content, using the analysis protocol attached as **Appendix I**. Lastly, the main findings are presented in summary form.

5.2. Qualitative data presentation and analysis

The study followed an explanatory sequential mixed methods approach in which both quantitative and qualitative data were collected sequentially. This section presents the findings of the study according to the qualitative data. The purpose of the qualitative data was to either confirm or refute the quantitative results, which might enhance the validity and reliability of the study. The different methods of data collection used to generate these results were classroom observations, teacher interviews, as well as an analysis of the LGCSE physical science syllabus and the teachers' lesson plan books.

The ethical considerations taken when presenting these results include maintaining confidentiality of the participants. In order to ensure this, pseudonyms are used when referring to the teachers who were observed as participants for this qualitative part of the study. They are referred to as Mr M, Mr L and Mr C.

5.2.1. The case of Mr C: A master at drawing students' attention but a failure at sustaining it.

5.2.1.1. Mr C's background

Mr C is an enthusiastic male teacher. He has a bachelor's degree in computer science (B.Sc.) and a post-graduate diploma in education (PGDE), with physics and mathematics as his major subjects. Since he started his teaching career ten years ago, he has been teaching at the same school. He was always punctual for class and so were his students. He teaches physics, which is not offered as a subject on its own, but as a component of physical science. Physical science was allocated six periods per week and the six periods were shared equally between physics and chemistry.

5.2.1.2. Context of the class

I conducted classroom observations in a grade 11 class that has three streams; my focus was on grade 11C, which was taught by Mr C. There were 50 students in grade 11C. The grade 11 students were not allocated to their class according to any criteria. They had various abilities.

I observed five lessons over a period of three weeks. On the timetable, physics was allocated two periods. One of them lasted for 80 minutes and the other 40 minutes. The 40-minutes' lesson was scheduled every Monday from 13:10 to 13:50, while the 80-minute lesson was scheduled on Wednesdays from 13:10 to 14:30. Both lessons were scheduled after the lunch break.

The students used single desks, which were arranged in columns of three desks each. Along the back wall, the columns were not defined according to the desks. During the first observation, which took place on a Monday, 48 students were present. When we entered the class, all students stood up and the teacher greeted them. They all responded “*Good afternoon sir*” and he signaled with his hand for them to sit down. As they sat down, they looked around and I saw some of them picking up some pieces of paper that were on the floor and put them in the waste paper basket behind the door. At that moment one student was cleaning the board. It seemed like a normal routine for students to stand and greet the teacher and to keep the classroom tidy by picking up any trash that might be on the floor before sitting down. I observed the same practice for the three weeks that I spent at the school. When all the students had settled down, Mr C told them, “*Today you have a visitor but you don’t have to act differently, this is a normal class like any other.”*

My presence was already causing some discomfort for some students, so I decided not to sit at the back of the class, because as indicated above, the desks were very close to each other at the back. My opinion was that some students would be uncomfortable if I were to sit very close to them. I therefore decided to sit in the front, but in such a way that I was able to see everybody without having to turn my head

5.2.1.3. Teacher’s knowledge base when teaching force and momentum

5.2.1.3.1. Knowledge of science curriculum

This is another aspect of teacher knowledge, which was evident in Mr C’s teaching. It includes the teacher’s ability to explain scientific concepts and to address the curricular goals of science learning when teaching all topics. His knowledge of this component was evident in his explanations, as presented below.

A. <u>Mr C’s goals and purposes of teaching force</u>

According to the LGCSE physical science syllabus, one of its goals is to help students “to develop abilities and skills that: …are useful in everyday life” (ECOL, 2018:4).

In the post-observation interview, MrC indicated that his goals and purposes of teaching science and the concepts of force is to help students to apply what they have learned in their daily lives; “…*to apply what they have learned and relate it to other things that they come across in life*…”

B. <u>Explanations of concepts</u>

Below is a glimpse of how Mr C explained some concepts, namely inertia, terminal velocity and the limit of proportionality, which are introduced for the first time at this level. In order to explain 'inertia,' he first presented a scenario of people experiencing a jerky movement when a speeding car suddenly comes to a stop.

> T – ...we have this one inertia. For those of you who had the chance to be in a bus, you will remember that when you are standing and supporting yourselves with the bar in the bus...when the bus starts moving, the normal reaction that you see or...experience…is that you do something like this (*demonstrating the jerky movement*). It is because when the bus was stationary we are all at rest, and when it starts moving, your feet move before the upper body…since your feet are the first to move with the bus…your upper body will still be left at the original position. That is why you feel like you are pushed backwards. You are not pushed backwards it is just because your upper body was left behind and then it joins the bus later…

The excerpt shows that MrC made a lengthy explanation. He started the explanation by introducing the term inertia and then presented a scenario to explain the phenomenon. Thereafter, he provided the reasons why people behave the way they do when the bus starts moving. He took students gradually into what happens and why it happens. From the excerpt, it seems that he reinforced his explanation by selecting a scenario familiar to most students, thus making use of their prior knowledge. Thereafter he demonstrated with his body to give the students a picture of what happens. I observed this with most of the concepts.

From the excerpt it seems that Mr C modeled how to make a scientific argument, one of the skills students are supposed to develop, according to the science curriculum. He started by making a claim or an observation in this case. Then he explained the observation, "why there is a jerky movement".

The way Mr C shaped his instruction further seems to align with one of the goals of teaching force and momentum, as he mentioned during the interview.

> …they should be able to <u>apply what they have learned, relate it to other things that they come across in life</u>. For example, if we are talking in terms of force, there are many applications of force, and what happens when force is applied…

He highlighted that by learning force, students are able to relate what they have learned to the things that they come across in life. It seems, therefore, that his instruction was shaped by his goals for teaching force and momentum and by his knowledge of the science curriculum. The way he explained force concepts seemed to model how students should explain science concepts. Moreover, he used real-life examples and/or scenarios, which help students to understand their world and why things happen the way they do.

5.2.1.3.2. Knowledge of students' understanding

In this section I present data about the teacher's knowledge of how students learn and understand science.

A. <u>Revealing students' preconceptions</u>

During instruction, especially when he introduced the lessons, Mr C attempted to uncover students' prior knowledge. When he introduced the topic, he reviewed what students had learned in the lower grades. That is, the definition of force, stated the units and instrument to measure force, and discussed different types of force.

> T – …can you give me the types of forces that you know?
> S1 – Gravitational force
> T – ...which is?
> S2: – It is applied by the earth
> T – It is applied by the earth on objects

Even though the LGCSE physical science syllabus does not specify that the types of force should be taught, Mr C asked students about them, because this forms the base of what they were expected to learn in that particular lesson and subsequent ones. In the post-observation interview, he indicated that he assumed that students had prior knowledge on force:

> They already had the knowledge of what force is and the types of forces that they normally or usually come across whether during teaching or through experience.

In addition to reviewing what students had learned in previous grades, he presented them with a situation they experience in their everyday lives:

> T: Say you are in the van, and you are sitting at the corner of its base. As the speed of the car increases, you will feel more air resistance, right?
>
> Students (In unison): -Yes sir
>
> T – When the speed of the car increases… air resistance will be high, and that tells you that as the car increases its speed, even the force at which it is cutting through the air increases. When that happens, you also feel more air trying to blow the van away. If you are standing by the roll bar and wearing a blanket…we will see when that car moves at high speed…the impact of the force, air resistance, that is the action and reaction force.

The excerpt shows that the teacher introduced a physics concept by directing students' attention to a situation which most of them have seen or experienced in their daily lives. By doing this, he once again helped students to use what they knew and extended their knowledge by making sense of what they had seen or experienced.

In general, it seemed that Mr C recognised students' preconceptions when teaching and used their knowledge as the basis for instruction.

B. <u>Knowledge of students' misconceptions</u>

As he endeavoured to uncover students' understanding, Mr C also revealed their misconceptions. When they were discussing the types of force and how to describe them, he exposed students' non-scientific view of frictional force. Below is a glimpse of what happened in the lesson.

> T – You explain that force of friction will be between two objects, and you specify that those objects should be moving in opposite directions. So I want to know whether we have frictional force between the box which is pushed across the desk. This is because the desk is stationary while the box moves, so do we have frictional force in that case?
>
> S1 – Frictional force is the force applied when two objects are [*inaudible*] with each other

T – …The question is, for this frictional force to be applied, must there be movement? Especially movement of two objects, that is, when one object slides on another…can we say we still have frictional force?

Students (In unison) - We can

T – What about when there is no movement at all, you just have this desk here, there is no movement at all, can we say we don't have frictional force?

S1 – Yes

S2 – Sir I think in that case ... we have potential energy like when we put a book on a desk, I think we have potential energy

The excerpt shows that Mr C realised that his students had alternative views about frictional force. Their opinion was that frictional force is applied only when objects, which are in contact, move. The teacher therefore made a deliberate effort to help them realise that their understanding is not scientifically correct. He probed students and presented a scenario hoping that they would be able to realise that even when objects are stationary, they are in contact. There is frictional force between them.

It seemed that Mr C was able to notice when students presented alternative conceptions and was able to act accordingly. In general, the teacher seemed to hold the view that knowledge is best constructed when connected to what is already known. His instruction seemed to take note of students' prior school and out of school knowledge. He was also able to notice when they had difficulties understanding concepts.

A further analysis also shows that the teacher used students' responses to inform instruction. That is, Mr C realised that his students had an alternative understanding of frictional force. He used that feedback to inform his next instructional move. Based on the definition of formative assessment, as posted by Herman et al. (2015) that "…it is the process used by teachers and students during instruction that provided feedback to adjust on-going teaching and learning…" this could be interpreted to mean that he used formative assessment practices.

5.2.1.3.3. Knowledge of instructional strategies

Knowledge of instructional strategies is realized when teachers use multiple representations of concepts and when they give students a variety of activities. In this section, I present the activities and representations that dominated Mr C's classroom teaching.

A. <u>Teacher and students directed discussion</u>

Mr C used whole class discussions in almost all the lessons I observed. In lesson 1, students reviewed the types of force by stating and describing them. In lesson 2, the teacher had just explained inertia before the students had the discussion. In lesson 3, the students reviewed the homework before they started the discussion.

Table 5.2 Sample of how Mr C conducted whole-class discussions

Lesson 1	**Lesson 2**	**Lesson 3**
T – ...another type of force S1 – Elastic force. It is the type of force where we pull an object and it comes back to its original position. T - Why are you raising your hand? S2 – I would like to rephrase... T – Ok S2 – I think elastic force is involved in stretching objects T – Stretching objects or stretched objects? S2 – I think stretched sir, like a rubber band T – Yes when does it have elastic force that you are mentioning? S3 – When it is stretched T – Yes! S4 – ...I think Mpho is correct because we still have tension force in stretched objects, so this one has to specify that they have to return to their original size after they are released.	T -…Can you think of any other example where inertia takes place? S1 – when the person is spinning for a long time, when she stops spinning, her body will continue, the legs will stop spinning but the body will continue spinning T – Yes! S2 – I have a question T – so you don't want to answer mine, ok you can ask S2 – when riding on a donkey my feet are not in contact with the floor, does inertia apply there? T – You mean you are in the bus? S2 – no, on a donkey Students laugh T – Donkey? S1 - yes sir	T - Ok let's move on to mass and weight. What do you normally measure when you stand on a bathroom scale? In unison -Mass, weight T – Mpho, what do you normally measure on a bathroom scale? Mpho – Mass T – Why are you changing yet you said weight? S1 – I measure weight T – Why did you say weight on a bathroom scale? Bokang Bokang – I don't know. T – You don't know? You just hear most people say mass and you choose mass. Bokang why did you choose mass? S2 – Sir I usually hear people say weight but when I read I see mass and another thing sir why I say weight is because I hear people say, use this to lose weight, so it is weight.

From Table 5.2, it seems that Mr C initiated all the three discussions. In lessons 1 and 3, he initiated the discussion by asking a low order question, which required students to recall what they had learned, namely the types of force and what a bathroom scale measures. He asked questions and probed students to respond, thus determining the direction of the discussion. Nonetheless, he gave students the opportunity to explain their answers. An analysis of both students' and teacher responses indicate that he communicated more than the students did.

On the other hand, in lesson 2 he initiated the discussion, but the initial question was open. It did not require students to recall what they were taught. Instead, they provided examples or situations they had experienced or observed. So the discussion was more an opportunity for students to make sense of what happens around them, rather than recalling what they were told. Moreover, the students seemed to be directing the discussions, because what transpired thereafter was based on the examples that they provided.

From these lesson segments it seems that Mr C's classroom discussions were both teacher and student-centred. He allowed students to ask questions and he responded to them. His classroom discussion therefore seems to be an amalgamation of both teacher and student-centred lessons.

B. <u>Lecturing</u>

Together with whole class discussions, Mr C also provided students with most of the information through lecturing. In the lesson about air resistance, lesson 4, he answered students' questions by himself. When a student told him that he had read about terminal velocity but did not understand it, he provided the information by explaining what happens when an object falls in the presence of air resistance. This is how he did it:

> T – Yes the object is falling through the air. Its acceleration will be due to gravity. This means that its speed will increase by 10 meters every second. This means that the further down it goes, the more the speed it will have. The more speed it has, the more the air resistance acts on it. The faster the speed of the falling object is, the greater the air resistance. If the air resistance is the force acting in the opposite direction to the falling object, it means that it increases with the speed. At one point the air resistance, which is the force, is equal to the weight of the object, which is also a force. We will have two forces acting on your object.

He provided the explanation without involving his students through asking questions, for example, which could help them to analyse the situation. This was common during the lessons when he introduced new concepts.

He introduced Newton's first law of motion by reviewing the effects of force. One of the effects of force students mentioned was that force can produce motion. The teacher asked students whether objects move every time they apply force. In order to demonstrate that force does not always produce motion, he gave them a scenario in which a desk or a fridge does not move, even when it is pushed:

> T – …under which conditions do we apply force but we don't see anything happening…I want to move this desk from here to the front, I have applied a force but I don't see the desk moving forward. Do you get the results that you want every time you apply force?
>
> Students in unison - No
>
> T – Ok that happens most of the time but not always. Sometimes you may try to shift a fridge, in your home, from one point to another, what causes that fridge not to move?
>
> S1 – I think the resisting force is higher than the pushing force
>
> T – The resisting force?
>
> S2 – Yes
>
> T – To be more specific in that case where you are pushing a desk across the floor but it doesn't move… what is the name of that force?
>
> S2 – Friction
>
> T – It is the force of friction. The force of friction which acts in the opposite direction is greater than the one that you apply and if that is the case, then you are not going to see any effect.

The glimpse of the above lesson shows that the teacher gave students a scenario in which force does not always result in motion. He explained this behaviour in terms of Newton's first law and the resultant force. Following this, he provided the information regarding why the box does not move and what the resultant force is. A further analysis of the segment shows that the length of the teacher's response is longer than that of the students. Two students participated in the discussion and they responded with one word and/or a short sentence, as opposed to the teacher who presented a lengthy discussion.

C. Representations of force

As indicated that Mr C demonstrated knowledge of how students understand force and momentum, he portrayed it when he represented one concept differently. Two of those concepts were “inertia” and “terminal velocity”. He introduced inertia in the second lesson by giving students a scenario of a person standing in a moving bus. The excerpt below illustrates how he put it:

> T – ...we have this one, inertia. Those of you who have had the chance to be on a bus will remember that when you are standing and supporting yourselves with the bar in the bus... when the bus starts moving, the normal reaction that you see or ...experience when standing in a bus is that when it starts to move you are going to do something like this (*demonstrates the jerky movement*). This is because when the bus is stationary we are all at rest. When the bus starts to move, the part that moves with the bus first is your feet. The upper body is left at the position it was before the bus started moving. Because your feet are the first to move with the bus, obviously your legs are going also the first ones to move with the bus and your upper body is still left in its original position. That is why you feel like you are pushed backwards…

The segment shows that the teacher called students’ attention to a situation that is probably experienced by most students. He followed up on this with a verbal explanation of why they behaved the way they did. While still explaining the same concept, Mr C illustrated what he meant by reluctance to change the state of the object. This is how he put it:

> What about when… you are putting this marker on a page and then if you pull that page fast enough, the marker remains at the position where it was. However, the page is out (He demonstrates with a marker and a page)

This shows that the teacher made three representations of inertia: example/scenario, verbal explanation and demonstration.

He reinforced his explanation of terminal velocity with the following diagram.

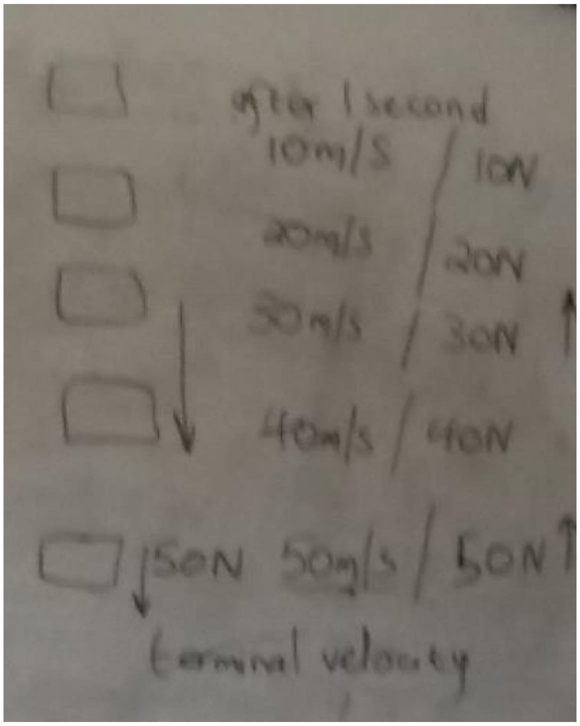


Figure 5.1 Mr C's representation of terminal velocity

The above excerpts show that Mr C used different representations when explaining concepts. The representations appealed differently to different students. Some of them understand better when they visualise, while others understand best when they listen.

In general, Mr C displayed a broad knowledge of various instructional strategies. He used whole class discussions, lecturing and multiple representations.

5.2.1.3.4. Knowledge of assessment of science

The teacher's knowledge of assessment of science constitutes knowledge of assessment methods, which are suitable for measuring particular knowledge and skills. In this section, data indicate the aspects of science that the teacher assesses, as well as the methods used.

A. <u>Oral questioning</u>

Oral questioning is inevitable when teaching. This is why it was dominant in Mr C's classroom. During classroom instruction, he assessed students' understanding by asking oral questions, as shown in Table 5.3.

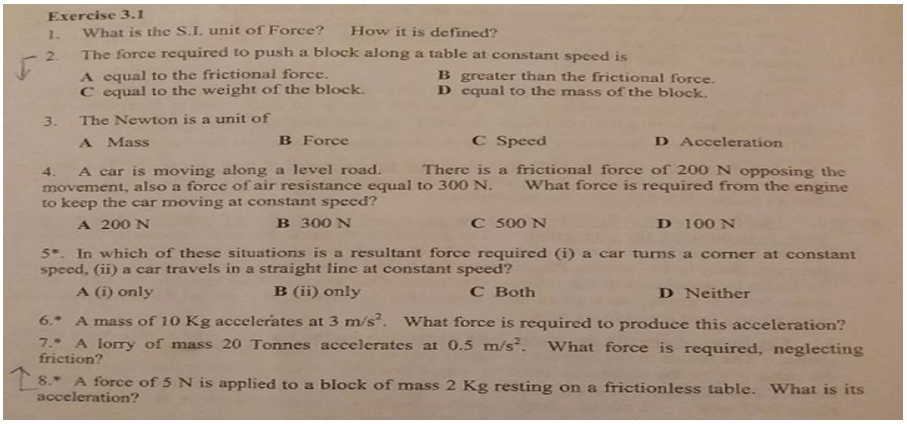
Table 5.3: Mr C's oral questioning

Lesson 1	
Lesson introduction	**Lesson development**
T -…from your previous knowledge, what is force? S1 – Force is a pull or push, T – This push and pull just happens out of the blue? S2 – The pull or push applied by one object on another T – …Is it in all cases that we havea push or a pull whenever force is applied?	T – Can we have a case where a force was applied and we managed to change the shape but the size was not changed? Students (In unison) - No T – Yes! S1 – Sir I think the change of shape and size is conditional because in non-contact forces, gravitational and magnetic, there is no change of shape and size. T – …You are applying the force and you see the change of shape…Can you have the change of shape without the change of size? Can you have the change of one without the other?

From Table 5.3, it seems that Mr C asked a mixture of low-order and higher order questions. When he introduced lesson 1, he asked a recall question, but followed it up with a question that required an explanation from the students. As he developed the lesson, he asked questions that required students to think. He seemed to assess both the recalling of facts and the ability to think and to justify their answers, as shown by the questions that he asked in the lesson development.

B. <u>Written assignment</u>

In the five lessons I observed, Mr C gave students three written instructions: two homework assignments and one classwork. He assigned the first homework after teaching the three laws of motion, while the second one was given after teaching elastic deformation. The last written work, which was class work, was given after teaching the complete unit, which was about the effects of force.



Exercise 3.1

1. What is the S.I. unit of Force? How it is defined?
2. The force required to push a block along a table at constant speed is
   A equal to the frictional force. **B** greater than the frictional force.
   C equal to the weight of the block. **D** equal to the mass of the block.
3. The Newton is a unit of
   A Mass **B** Force **C** Speed **D** Acceleration
4. A car is moving along a level road. There is a frictional force of 200 N opposing the movement, also a force of air resistance equal to 300 N. What force is required from the engine to keep the car moving at constant speed?
   A 200 N **B** 300 N **C** 500 N **D** 100 N

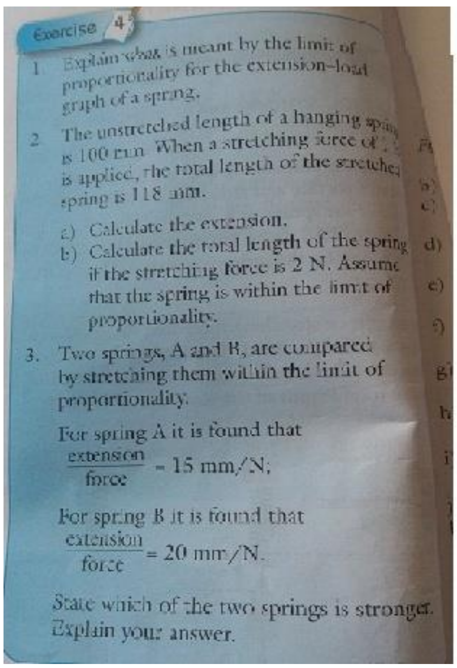
5*. In which of these situations is a resultant force required (i) a car turns a corner at constant speed, (ii) a car travels in a straight line at constant speed?
   A (i) only **B** (ii) only **C** Both **D** Neither

6.* A mass of 10 Kg accelerates at 3 m/s^2. What force is required to produce this acceleration?

7.* A lorry of mass 20 Tonnes accelerates at 0.5 m/s^2. What force is required, neglecting friction?

8.* A force of 5 N is applied to a block of mass 2 Kg resting on a frictionless table. What is its acceleration?

Figure 5.1 Homework 1



Exercise 4

1. Explain what is meant by the limit of proportionality for the extension–load graph of a spring.
2. The unstretched length of a hanging spring is 100 mm. When a stretching force of [illegible] is applied, the total length of the stretched spring is 118 mm.
   a) Calculate the extension.
   b) Calculate the total length of the spring if the stretching force is 2 N. Assume that the spring is within the limit of proportionality.
3. Two springs, A and B, are compared by stretching them within the limit of proportionality.
   For spring A it is found that
   $\frac{\text{extension}}{\text{force}} = 15\ \text{mm/N}$;
   For spring B it is found that
   $\frac{\text{extension}}{\text{force}} = 20\ \text{mm/N}$.
   State which of the two springs is stronger. Explain your answer.

Figure 5.2 Homework 2

As shown in Figures 5.1 and 5.2, it appears that in assignment 1, five out of seven questions required students to make some calculations, while in the second assignment two of the three questions also required some calculations. Other questions required students to provide explanations (assignment 2, question 1). Question 1 in assignment 1 assessed whether students have misconceptions. This shows that Mr C assessed students' conceptual understanding, their ability to calculate and to explain.

In general, Mr C seems to know how to assess students' knowledge. He assessed different aspects of science learning, that is, the students' ability to handle numerical data using calculations, and factual and conceptual understanding. However, he used limited assessment strategies; oral questions and answers as well as written assignments.

5.2.1.3.5. Mr C's orientation towards teaching

This section highlights the characteristics of the teacher's instructional practices as well as the possible reasons for his classroom decisions.

Characteristics of Mr C's teaching

As indicated in the data presented in the preceding sections, Mr C led most of the classroom activities. He asked questions, provided examples and explained most of the concepts. The students participated by answering the questions orally, doing written classwork and writing their own notes. On a few occasions, students directed the discussions by asking questions.

In order to understand this practice, I held post-observation interviews with Mr C. Below are the reasons that guided his decision-making and instructional practice.

Factors determining Mr C's classroom practices

i) Students' strengths and weaknesses

It was observed that when giving students written work, Mr C marked most of it during the class period. He explained: "*I normally mark in class so that I talk to each and every one of them (students).*"

Furthermore, he highlighted that as students do classwork he ensures that they do not copy and that they do not wait to do all the questions before they can be marked.

> I ask them to do one question and come to be marked because if I wait for them to finish the whole exercise then others will just sit there, they won't come, they wait to get the chance to copy from others.

It seems that the teacher believed in independent work. This is why he made sure that students complete the work individually. This perception translated into his classroom practice, because for the whole observation period, students were not given the opportunity to work collaboratively. All the written work was done individually. He further explained that he preferred exercises where students work individually. Through experience, he learned that when they work in groups, only a few of them participate. He says:

> If you ask them to form groups and discuss and then you ask them to present maybe one member from each group, no one will be willing to do that. If you…have people who are willing… it will be the same people with a better understanding. You won't see someone who is struggling to be the presenter of the day.

Mr C's comments about why he preferred individual work over group work could mean that he lacked the competence to orchestrate and manage group work. Hence he developed a negative attitude towards it.

ii) Examinations

It also appears that Mr C's classroom decisions were motivated by the imperatives of the examination. This is how he explained why most of his assignments involved calculations:

> I prefer to give them exercises and even in their exams; those theoretical questions you will find that there is just one question throughout the paper. You will be stressing the importance of knowing things, being able to explain them, trying to talk about them in class, where are they going to apply those things? So most of the time they do calculations.

From this response it can be concluded that part of the teacher's main purpose of teaching was to help the students to pass the examinations. This was despite him having said that his goal for teaching science, the concepts of force in particular, was to help students to be able to solve everyday problems and to apply their knowledge to understand the environment.

> ...they should be able to apply what they have learned, relate it to other things that they come across in life. For example...if one owns a car...why should it have good tires all the time, what is the importance of that in the proper working of the car, why do I need petrol for this car...

Comparing his articulated goal, which he indicated was to help students apply their knowledge to solve their everyday problems, and those illustrated in the syllabus, I determined that there was alignment between them. In the syllabus the abilities and skills were not explicitly stated in the goals, but in the content section they were. The syllabus indicated that students should be assessed on the following abilities and skills:

> A: Knowledge with understanding
> B: Handling information and problem solving
> C: Experimental skills and investigations (ECOL 2018:5)

From the analysis of Mr C's practice and the reasons for such decisions, it can be concluded that his beliefs about teaching and learning the concepts of force were inclined towards traditional beliefs. Therefore, these beliefs seem to impact his explanations and practices. When he explained how he prepared for teaching, he used phrases such as "deliver": *"As I plan I go through the same book… and while I am <u>delivering</u> the content…"* The way he communicated about teaching and how he planned his lessons seemed to be consistent with traditional teacher-centred beliefs. He went through the book to study the content, which he planned to "deliver" to students.

5.2.1.3.6. Approaches when teaching force and momentum

A. <u>Lesson planning</u>

<u>Mr C's perceptions regarding lesson planning in practice</u>

It seems that Mr C did not have written lesson plans because of his workload. He said:

> We have a lot of work to do here, most of the time I don't do preparations, the written ones. I used to do them but I no longer do.

He supported his statement by explaining what his lesson planning entails:

> I don't write on a piece of paper I just go through the material today that I want to teach tomorrow. I will read if I think some of the things are missing. I will go through the syllabus, I have to pass this to them, I have to teach this and that...

Mr C made it clear that he does not write lesson plans, but his plan consists of prior reading of the subject matter regarding the intended lesson. His statements about lesson planning suggest that he does plan how to deliver content. It seems that to him planning means reading the subject matter that should be passed on to students.

Though there was nothing to validate what he told me, he pointed out that he usually reads content for two consecutive lessons (the current and the next), since his pace is determined by students' responses. He explained that, based on experience, he did this to avoid running out of what to teach in the middle of a lesson:

> …I go to that class knowing what I intend to do in the next class after today. Because sometimes you find that...I have planned to go from here to there, but depending on the behaviour of the students, you may even go further or your class will end...earlier and if you don't know what will follow this means your class will have to stop there and you won't have anything to do.

However, he acknowledged that it is the right thing to have a lesson plan and that experience has taught him that it is important to have written lesson plans. Nonetheless, not having a written lesson plan did not stop him from doing his job.

> …preparing for classes, reflecting after class, I have done those things and I have seen that it is very important for me to go to class knowing what I am going to do…I know it is the correct procedure of teaching; you have to make a lesson plan, have a preparation book, those things even if I don't have them they don't stop me from doing my work. I can't go to class unprepared

From the data presented, it seems that Mr C believes that a lesson plan is an official document teachers should have before teaching. However, it seems as if, to him, written lesson plans form part of planning, but it is not the only way of doing so. His plan seems to be in his mind and not on paper. This observation seems to be in line with Ball et al.'s (2007) argument that most of the teachers' planning is in their minds.

B. Interactivity and instructional decision

As highlighted in the preceding discussion, Mr C used both classroom discussions and lecturing as main instructional strategies. He directed the discussion most of the time. Though it was to a small extent, he allowed students to drive the discussions. Table 5.4 shows both teacher- and students-driven discussions.

Table 5.4 Mr C' students' and teacher's driven discussions

Students' driven discussions	**Teacher-driven discussions**
S1 – …I know that in cold air the particles are very close while in hot air they are scattered. Therefore, when we drop two objects one in cold air and the other in hot air will they arrive at the same time? Will this one in hot air travel faster than this one in cold air sir? T – You know that warm particles are closer to each other than cooler particles and you want to know if two objects falling in air pockets with different temperatures will fall at the same rate? S1 – Yes sir. T – ...let me ask you this question, if you have 100 Maloti and 1 Maloti in your pocket and if I ask you how much money do you have, under normal circumstances, what will you say?... you will say I have one hundred Maloti because when you...compare one Loti to one hundred you don't take it to be money... So even if these particles are this close and these ones are this far (draws dots close to each other and far from each other to represent cold and warm air particles), but the difference that will be brought by this (cold air) will be so small...that you can't say when an object is going through cooler or warmer air that terminal velocity will be affected...	T – ...are you saying we can have the change of speed without the change of direction? S – Yes. T – Let us look at it this way; from what we discussed under the graphs of motion, can we have a change of direction without a change of speed? Students (In unison) - No sir T – For moving objects...we can have a change of direction when moving in a circular manner...it is the one on the curve that gives us the change of speed... S – Yes sir T – I want to agree with him that we can have a change of speed but in one direction. For an object moving this way (straight line) it can change speed because of force applied still moving in the same direction, but when it comes to change of direction due to force applied can we have that change of direction without the change of speed?

Subsequent to the student-driven discussions, the teacher explained terminal velocity. Following the teacher's explanation, the students directed the discussion by asking their own questions, as shown in Table 5.4. The analysis of the excerpt shows that even though the content of the lesson was still terminal velocity, the issues and examples discussed were initiated by the students. This was one of the exceptional cases in which students determined the content of the discussion.

In the teacher-directed discussion, the teacher directed the discussion by asking questions and making clarifications as well as suggestions. Moreover, the analysis of the length of teacher and students' responses reveal that he did so more than his students did.

One point worth noting is that Mr C sometimes rephrased students' questions inaccurately. In the first column in **Table 5.4**, S1 he said *"...in cold air the particles are close..."* When he rephrased he said *"...warm particles are closer..."* which is not scientifically correct. The rephrasing did not seem to be correct, because warm air particles move faster than cold air particles. They are more spaced apart than they are in cold air. The same inaccuracy is observed in the second column of the table. The teacher asked "*are you saying a change of speed without the change in direction*?" He later rephrased his question and said "*can we have a change of direction without a change of speed?*"

The inconsistencies the teacher made when rephrasing either students' or his own questions could be interpreted differently. On the one hand, it could imply that he did not pay attention to students' questions, because he was in a hurry to give them information. On the other hand, it makes one wonder whether his tendency to misrepresent students' responses could be the reason why he directed the discussions and allowed less student-centred approaches.

The teacher's classroom approach when teaching force and momentum seems to be a mixture of both traditional teacher-centred and a little bit of student-centred methods. This became evident during instruction.

5.2.1.3.7. Summary of the findings from Mr C's case

The data suggest that Mr C knows the goals of teaching force and momentum, which he demonstrated by stating the goals of teaching science and his ability to explain force concepts. Moreover, he used real-life examples and/or scenarios, which helped students understand their world. He also displayed knowledge of how students learn science by incorporating their prior knowledge and noticing when they experienced difficulties understanding concepts. Furthermore, he displayed knowledge of both assessment and instructional strategies. He used oral questioning and written assignments to assess students understanding of factual and conceptual knowledge, including handling numerical data. However, he mostly used lecturing, teacher-directed whole-class discussions and used multiple representations of concepts. He displayed both teacher and student-centred practices and orientations.

5.2.2. The case of Mr L: A shy soft-spoken person.

5.2.2.1. Teacher background

Mr L is a qualified physics teacher with a bachelor's degree in science education (B.Sc.Ed.). He was in his second year of teaching at the time of this study. He was always in a hurry when coming to class. He talked slowly and softly even when he was in class. When students misbehaved, he would pause and look at them without saying anything. Often students would immediately stop to misbehave. In this school, grade 11 students are streamed according to subject choices. They choose between physical science and accounting. Those who were in Mr L's classroom, grade 11 A, had chosen physical science.

5.2.2.2. Overview of grade 11

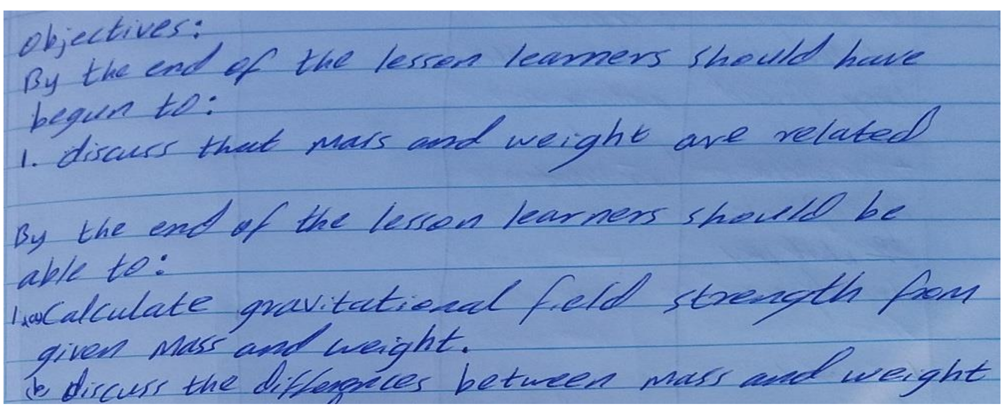
There were two grade 11 classes, but my focus was on grade 11A, the class where Mr L was teaching physical science. Some subjects, including physical science, were optional. Students can choose between physical science and accounting. Those who were in Mr L's classroom, grade 11 A, did physical science, not accounting. Physical science was allocated six periods per week of which physics was allocated three periods. They were taught as three 40-minute periods. There was a total of 50 students in grade 11A. They were seated in four rows so that there were three students per desk at most of the desks. The desks seemed very close to each other. There was not enough space for the teacher to move freely between them.

5.2.2.3. Knowledge that Mr L used during lesson planning

The analysis of the teacher's lesson plan book revealed that he compiled lesson plans for some of the lessons, but not for all of them. The format of his lesson plan had four parts. The first part constituted date, class, topic, duration of the lesson and the number of students. The second part entailed the lesson objectives, teaching methods and teaching materials, while the last two parts were the conclusion and evaluation.

<u>Nature of lesson objectives</u>

Mr L's lesson plan comprised two levels of objectives, as shown in Figure 4.3 below.


Objectives:
By the end of the lesson learners should have
begun to:
1. discuss that mass and weight are related

By the end of the lesson learners should be
able to:
1(a) Calculate gravitational field strength from
given mass and weight.
(b) discuss the differences between mass and weight

Figure 5.3(a) Mr L's sample objectives

The objectives have different stems, which signal that they portray low and higher levels of students' performance. However, objective 1, which states; "*By the end of the lesson the learners should have begun to discuss that mass and weight are related*" and objective 1(b) which reads "*By the end of the lesson the learners should be able to discuss the differences between mass and weight*" seem to be expecting the same level of performance. Even though the objectives have different stems–"should have begun…" and "should be able to…"–, they both show that students are expected to "discuss". Discussion, as explained in the physical science syllabus (ECOL, 2018:42) "requires the candidate to give a critical account of the points involved in the topic." This is a high order performance since giving a critical account needs one to analyse and provide a detailed explanation.

The way in which Mr L formulated the objectives shows that he attempted to formulate objectives which cater for students of different abilities. However, the students were expected to display a similar competence; "discuss." Nonetheless, it seems that Mr L incorporated knowledge of curricular goals and objectives when planning the lesson.

The nature of teaching methods

Mr L's lesson plan comprised more than one teaching method, as shown in Figure 5.3(b).

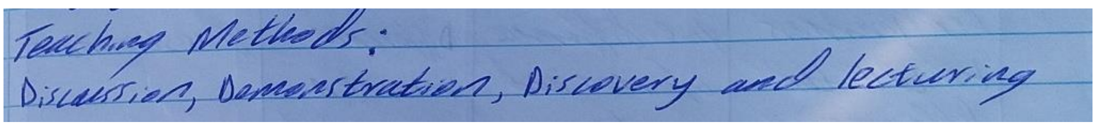


Figure 5.3(b) Mr L's planned teaching methods

The list shows that Mr L planned to use a variety of teaching methods, three of which can be classified as student-centred (discussion, demonstration and discovery). From his choice of teaching methods, it seems that he intended to promote some of the scientific skills and also to cater for the various students' needs.

Lesson development

The teacher's lesson development constitutes teacher and students' activities, assessment criteria and assessment methods, as shown in Table 5.4.

Table 5.5 Mr L's sample of lesson development

	Teacher activities	students' activities	Assessment criteria (what to assess)	Assessment method (how to assess)
1.	Draw a table of mass and weight and ask students to fill the columns.	Calculate the missing values of the given column.	Gravitational field strength	Questionnaire
2.	Ask students to find the average of the values they found and ask them whether it is familiar to what they know.	Find mean of their values and tell the teacher whether their answer is familiar or not.		
3.	Ask learners to tell the difference between mass and weight.			

Teacher and students' activities

Table 5.5 shows that the teacher's activities were statements or instructions that he gave students while the students' activities comprised execution of the teacher's instructions. The first teacher's activity "*draw a table of mass and weight and ask students to fill the column*" shows what the teacher planned to do and the instruction he was to give to students. In response to teacher instruction, the students were to "*calculate the missing values of the given column*". However, it is not clear how the activities were to be done. That is, were they to calculate individually, in small groups or did they have make calculations on the chalk board?

A look at the teacher's third activity shows that there is no corresponding activity indicating how students will determine the difference between mass and weight. This seems to suggest that the teacher's planning may be rather superficial. He did not seem to put adequate effort into deciding how to help students engage with the subject matter.

<u>Assessment criteria and method</u>

Table 5.5 shows that the teacher will assess gravitational field strength. However, it is not clear exactly what the teacher will assess. The lesson objectives constitute the ability to discuss the differences between mass and weight and the ability to calculate gravitational field strength. Nonetheless, the analysis of assessment criteria does not highlight any evidence that the differences between mass and weight will be assessed. **Table 5.5**also indicate that the teacher will use a questionnaire to assess gravitational field strength. However, the details of the sample of the questionnaire were not provided.

<u>Conclusion of the lesson</u>

Planning how to conclude a lesson is essential for effective teaching. Figure 5.3(c) shows a sample of how the teacher planned to conclude the lessons.

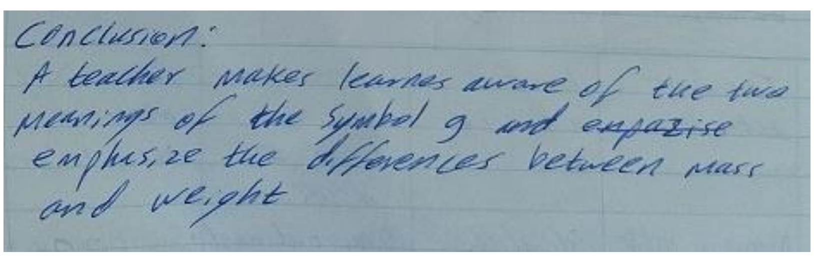

Conclusion:
A teacher makes learnes aware of the two meanings of the symbol g and emphasize the differences between mass and weight

Figure 5.3(c): Mr L's sample of the planned conclusion

Figure 5.3(c) shows that Mr L planned to conclude the lesson by emphasising the meaning of the symbol "*g*" and the difference between mass and weight. However, it is not evident how he would make the students aware of the meaning of the symbol "g" and the differences between mass and weight.

The analysis of the components of Mr L's lesson plan reveals that there is no alignment among the components. Within the lesson development, it is not clear how the teacher would help the students to discuss the differences between mass and weight. Even the conclusion did not highlight how he planned to consolidate the main points of the lesson so that students could easily access it and have something to take home.

In general, it does seem as if Mr L's lesson planning was somewhat informed by the syllabus goals and that students differ in ability. This was reflective of the curriculum knowledge and how students understand science.

5.2.2.4. Knowledge base when teaching force and momentum

For the five lessons that I observed, the post-observation interview and analysis of Mr L's lesson plans helped me investigate the knowledge base which informed Mr L's planning and teaching as well as what informed his classroom decisions.

5.2.2.4.1. Knowledge of science curriculum

This domain of teacher knowledge comprises the mandated goals and objectives of science education, including knowledge of the depth and breadth of the curriculum, which arerealisedby the ability to explain the concepts and to relate them to others within the topic and across the topics and subjects.

A **<u>Teacher's purpose and goals for teaching force and momentum</u>**

In the post interview, I asked Mr L about his goals and purposes of teaching science and this is what he said:

> I think one of them is for them (students) to be able to do manipulations; yes…they should be able to do things at home to solve such problems, also to discover.

It seems that Mr L aimed to help the students to develop manipulative and problem-solving skills and to be able to make discoveries. His goals seem to align with some of the mandated goals of teaching physical science, as stipulated in the LGCSE physical science syllabus:

> "…to develop abilities and skills that are…useful in everyday life science process" (ECOL, 2018:4)

The syllabus does not explicitly state the skills students should be helped to develop. However, Mr L stated the manipulative and problem-solving skills.

When asked about the importance of including the topic force in the science curriculum, he highlighted that it equips students with knowledge to understand their environment:

> Force is very important because basically most of the things, such as walking, happen around us because of force. We are able to walk because of friction. So when students know this they are able to explain why we are able to walk.

Mr L indicated that inclusion of the topic *force* is important because it helps students understand why things happen the way they do in their environment. He added that most of the everyday phenomena such as why people are able to walk with ease are better explained when one understands force.

B **Explanation of concepts and examples**

Mr L was observed making a deliberate effort to explain why facts are the way they are. However, there were differences in how he explained concepts, as shown in Table 5.6.

Table 5.6: Sample of how Mr L explained force concepts

Inertia	**Newton's First Law**	**Resultant force**
T – Good! So this part, inertia, is the resistance of the object to…change in motion … when people are moving in a car, we said they gain the speed of the car…When the car suddenly stops, they resist the change in the motion. That is why they have that forward movement; they still want to continue in motion. So…inertia means the resistance in change of motion. Even the object at rest, in order to get it moving, we need to apply force. Even the one which is moving in order for it to stop we need to apply force. The objects with larger masses have large inertia because they need more force to get them moving or more force to stop them.	*Teacher writes the law as: an object will remain at rest or will continue moving with constant velocity in a straight line if there is no resultant force acting upon it* T -If I throw this chalk and there was no frictional force, it will move forever. So it stops because of the resultant force or frictional force. That is what this law is stating.	T – …it is the force we get after adding or subtracting two forces acting on an object. But force is a vector quantity, meaning it has the direction. If they act in the same direction, we add them, if they act in opposite directions, we subtract…

As Table 5.6 shows, when Mr L explained inertia, Newton's first law and the resultant force, he provided a theoretical account and a mathematical explanation of the resultant force, *"…we get after adding or subtracting..."* When explaining inertia, he started by defining it and providing a real-life example. After the example he repeated the definition, which could also be confusing to some students because he did not clarify what he meant by *"resistance in change".*

Furthermore, it seems to be a trend that he provides one example when explaining concepts. He gave an example of throwing a piece of chalk, without elaboration, when he explained Newton's first law. Sometimes he tried to concretise force, as shown in the following excerpt:

> T – How can it (force) change the direction? Give an example where it can change the direction of an object.
>
> S1 – Can I give an example of shape and size, sir?
>
> T – Yes...
>
> S1 - When the sponge is squeezed it becomes smaller.
>
> T – This means that it changes the shape and size of the object.
>
> S1 – Yes sir
>
> T – Ok who can give me an example under this one (gravity)?
>
> S2 – When a stone is thrown up, the gravitational pull will change the direction of the stone from going upwards to going down.

The excerpt above shows that the teacher asked students to give examples in order to ensure that they understand that force can change direction and shape. He did not give examples, but he solicited them from the students.

It seems that Mr L knows the science curriculum well, as evidenced by his ability to state the mandated goals of science teaching as well as the ability to explain the concepts and to provide relevant examples.

5.2.2.4.2. Knowledge of students' understanding

There are different aspects of students' understanding of science which teachers should observe during the instruction. In this section, I present evidence of the aspects of Mr

L’s knowledge of how students understand science. This emerged during the instruction.

A. Students’ prior knowledge

Analysis of Mr L’s lessons revealed that he tapped into students’ prior knowledge during the instruction. However, there were variations in how he did it. On the one hand, he introduced the lesson by asking the students questions, which needed them to recall what they had learned previously. On the other hand, he introduced a new concept by asking students about their everyday experiences.

Table 5.7: Segments that show students’ prior knowledge which Mr L revealed

Lesson 1	**Lesson 2**	**Lesson 4**
T - I hope you know what force is, what do you know force to be? It is not your first time to hear about force S1 – Force is a push or pull on an object T – Ok that is his opinion…What do we use to measure force? S2 – spring balance T – Spring balance. Is force a scalar or vector?	T - …Ok when people are in a car, moving with a very high speed, when it suddenly stops, they move forward. Have you ever seen that happening? Students (In unison) - *Y*es sir	T - So let us talk about balanced forces. What happens when balanced forces act on an object but in opposite directions? For example if you have a rope and I pull on one end and someone pulls on the other end, what will happen to the rope or just any object experiencing these forces?

Table 5.7 shows how Mr L used students’ prior knowledge in lessons 1, 2 and 4. It seems that Mr L introduced the concepts by stating them and then asking the questions, which require students to reveal what they know, as shown in lessons 1 and 4. He started by asking students whether they know about force. In the same manner, in lesson 4, he told the students that they were going to discuss balanced forces. He then presented a situation and asked students about the resultant force, based on a situation that was familiar to them, thus tapping into their prior experiences.

B. <u>Students' misconception</u>

Although it was not common for Mr L to reveal students' misconceptions, I observed him modifying students' definitions of force by indicating that there has to be an interaction between objects in order for force to be applied. In another incident, which occurred during lesson 1, Mr L displayed a non-scientific view when explaining contact forces.

Table 5.8 How Mr L handled students' misconceptions

Lesson 1	
S1 – Force is a push or pull on an object T – …Other opinions different from his… S2 – I was going to say the same thing T - It is a pull or push upon an object but those objects need to interact in order for force to be present, those two must interact.	T – So what are non-contact forces? S – Non-contact force is the force that acts upon an object while the <u>source of force</u> … the source of force is not in contact with the object which is going to experience force T – The two interacting objects are not in physical contact. How is that possible? These objects are not in contact but they are experiencing the force, how is it possible?

In the first incident, it seems that Mr L modified students' definition. When asked why he did not leave the definition as a push or pull, he indicated that leaving it as such, implies that force is applied only when there is contact.

> It is because…most people believe that for force to occur objects must be in contact physically…I was trying to show them that even if they are apart, there is a field between them; so, they can still interact.

So, in order to help students not to develop that misconception, they should know that objects must interact, as interaction can happen even when objects are not in contact.

However, in the second incident, also shown in Table 5.8, he accepted the student's explanation although they used the phrase "source of force". This phrase may be interpreted to mean that force has a source. This could mean that, similar to the student, Mr L might have the misconception that force has a source or maybe he was not as mindful of the language used by the students during instruction.

Among the components of the teacher's knowledge of how students understand science, Mr L seems to be addressing one aspect, students' prior knowledge. He was not attentive to students' misconceptions; rather, he used language that is likely to cause students to develop misconceptions. In general, his knowledge of how students understand science seems to be limited.

5.2.2.4.3. Knowledge of instructional strategies

The knowledge of instructional strategies constitutes teachers' abilities to describe and enact different strategies suitable to teach science. This includes using activities that engage students in a scientific enquiry.

A. <u>Whole class discussions and lecturing</u>

Mr L seems to blend whole class discussions with lecturing. While he was teaching about elastic deformation, as an introduction to Hooke's law, he started the discussion by explaining and defining elastic materials. This was followed by a discussion of how plastic materials behave when they experience force. Below is a glimpse of how he mixed discussions with lecturing methods of teaching.

> T - We have elastic materials and plastic materials. For...elastic materials, when force is applied or let us talk about stretching force...Here when you stretch an object with a certain force and that force is removed, the object will go back to its original shape, we say that material is elastic. This means if a material goes back to its original shape when the force is removed they are referred to as elastic materials. What about plastic, the opposite?
>
> S1 – Those ones just stretch, instead of going back to their original shape they will either err… what can I say? …get cut
>
> T – Yes. The changed shape is called deformation. So for elastic materials, deformation is not permanent because when the force is removed the body goes back to its original shape, but for plastic, the deformation is permanent, even when the force is removed, it keeps that new shape. Can you give me an example of elastic materials?
>
> S2 – A rubber band

T – ...when you stretch it and remove the force, it goes back to its original shape. What about plastic?

S2 – It is cut

T – What about if you do not exert a lot of force

S3 – It does not break

T – So what?

S4 – It does not return to its shape

T – Now give me examples of plastic materials.

The excerpt shows that the teacher introduced the concepts by providing an elaborate explanation of elastic materials. Further analysis indicates that he probed students with questions, perhaps trying to enable them to construct their own understanding of plastic materials. However, students' responses were much shorter compared to his. As the excerpt shows, he does not seem to probe students' responses persistently. His questioning skills are limited, hence there is no evidence of phrasing and framing his questions in order to elicit information from the students. Consequently, he ended up providing most of the information. This reflects elements of teacher domination and transmission of knowledge, therefore making the strategies more teacher-centred.

B. <u>Representations of force</u>

In addition to verbal and mathematical representations of force, as presented in the preceding sections (cf. 5.1.2.4.1), Mr L further used diagrams to represent force. In the first lesson he explained what resultant force is and illustrated it with a diagram, as shown in Figure 5.4 below.

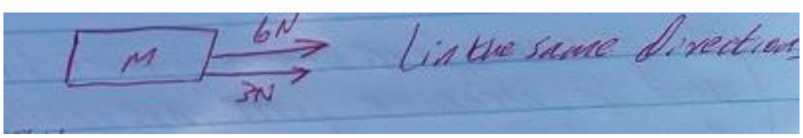


Figure 5.4 Mr L's representation of resultant force

From Figure 5.4, extracted from the notes in Mr L's written lesson plan, it seems that Mr L used arrow diagrams as another way of presenting force. He drew the same diagram during the lesson. An analysis of the diagram shows that the lengths of the arrow lines are not equal. The longer arrow represents a stronger force while the shorter one represents a weaker force. Therefore, the magnitude of a force is represented by its length.

The preliminary findings on Mr L's knowledge of instructional strategies seem to indicate that his teaching methods are limited to discussion and lecturing. Furthermore, he presented the same illustrations: arrow diagrams, verbal and mathematical, to represent the concepts of force.

5.2.2.4.4. Knowledge of assessment of science

This domain of teacher knowledge sought to establish whether Mr L was aware of different assessment methods and different aspects of force and the momentum to assess.

A. Assessment of force and momentum

An analysis of the physical science syllabus reveals the following assessment objectives:

A: Knowledge with understanding
B: Handling information and problem solving
C: Experimental skills and investigations (ECOL 2018:5)

The assessment objectives indicate that, at the end of the LGCSE course, students should demonstrate knowledge of different force concepts, laws and principles; they should be able to handle different forms of information and solve problems related to force as well as demonstrate that they have developed experimental and investigative skills. I therefore compared Mr L's assessment practices to the expectations stated in the syllabus.

B. Question and answer method

In the preceding discussion (cf. **5.2.2.4.3 a)**, I mentioned that Mr L used a mixture of whole class discussions and lecturing. During discussions, he asked students some questions in order to uncover their understanding. It appears, therefore, that this is the strategy he used regularly to assess students' understanding. As a way of introducing inertia, they engaged in a question and answer session. The glimpse of the lesson below shows how the sessions unfolded:

> T - …Ok when people are in a car that is moving at a very high speed and it suddenly stops, they move forward. Have you ever seen that happening?
>
> *In unison* - Yes sir
>
> T – What do you think causes that? What do you think is the reason for that? Yes, people in the car that is moving at a very high speed move forward when the car suddenly stops. What do you think causes that? Monosi?
>
> Monosi – I think since the car was still moving those people who were in the car they were pulled back on their seats by the resultant force which was against the car and the air.
>
> T – Do you mean that force was inside the car?
>
> Monosi – no sir, but…when it stops…
>
> T – Ok anyone else to help?
>
> S1 – I think when the car was moving with people inside, these people gain speed along with the car
>
> T – Aha!
>
> S2 – So when the car stops these people were still at that speed, so they need to be stopped

From the lesson segment above, Mr L appears to present a scenario and then ask students whether they are familiar with it. He followed this up by asking them to explain the cause of that jerky movement. He followed up the student's responses with a question, which was meant to elicit further explanation. Doing this he could get the level of students' thinking as well as their ability to relate everyday experiences to science.

C. <u>Written work</u>

In addition to the question and answer method, he gave students a written assignment in the form of classwork. The work comprised calculations that they had to do on the chalkboard. The following excerpt shows the question his students had to answer after teaching them about Newton's laws:

The teacher wrote the following question on the chalk board:

> An object initially at rest accelerates uniformly to 4 m/s in 2s. Its mass is 10kg
>
> a) Calculate the acceleration of the object

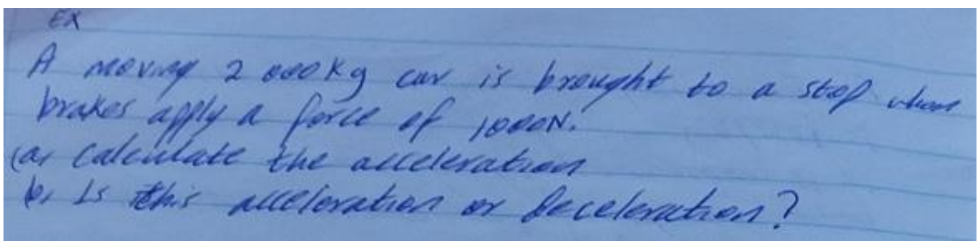
b) Calculate the force acting on the object

T – Let us calculate the acceleration. Who can come to do it on the board?

One student did the calculations on the chalkboard. This is what she wrote

a = (v-u)/t = (40-0)/2 = 20m/s^2; F = ma; F = 1

It seems that the question required the students to recall the formula and then use it to calculate acceleration and force. The analysis of the teacher's lesson plan book revealed two questions about force and motion. However, I did not observe him asking students to do this exercise as either class work or homework. This is how he explained why he did not give students written work during the lesson: *"As I explained that I am under the pressure of time, I give students work during the afternoon study period. So they do not do most of the work during the lesson*." One of the questions is shown in Figure 5.5 below.



EX
A moving 2 000kg car is brought to a stop when brakes apply a force of 1000N.
(a) Calculate the acceleration
(b) Is this acceleration or deceleration?

Figure 5.5 Sample homework question by Mr L

Similar to the question done as classwork, this also required students to recall the formula "*F=ma"* and to use it to answer the question.

Comparing Mr L's assessment practices with the assessment objectives that were highlighted at the beginning of this section, it seems that his assessment practices were focused on addressing assessment objectives A and B.

In general, Mr L seems to be comfortable with the use of two assessment methods, namely question and answer, and written assignments. His assessment focuses more on testing factual knowledge and using formulas in calculations.

5.2.2.4.5. Mr L's orientation towards teaching

This section is concerned with the characteristics of a teacher's instruction practices and the reasons which guide his decisions.

A. Characteristics of Mr L's teaching

As presented in **Section 5.2.2.4.1**, Mr L's goal of teaching science was to help the students develop scientific skills, such as problem solving, manipulative exercises and inquiry. Contrary to the envisioned goals, his instruction depicted different goals. The data presented in the preceding sections showed evidence that students did not perform manipulative exercises and that the class work assignments constituted recalling and using formulas. However, during the questioning sessions, some of the questions were contextual and required students to explain their environment. So the exercises had some elements of problem solving.

B. Factors determining Mr L's classroom practices

After observing Mr L for two weeks, I conducted a post-observation interview with the purpose of understanding his practice. When introducing the topic, Mr L reviewed students' knowledge of force by asking the students some oral questions. I therefore asked him why he reviewed their knowledge and this is what he said:

> … So that I know where to begin when teaching force. It will help me to know that the students know this but they don't know that. This is why I begin by teaching them this. If I don't, they will not understand the new lesson.

It seems that his purpose for reviewing students' knowledge was to inform himself about what they knew or did not know so that he can structure the instruction accordingly. I also asked him why he decided to use the question and answer method when he reviewed the topic and as main instructional strategy.

> R – Were there other ways through which you could have reviewed their knowledge other than orally?
>
> Mr L – Yes, giving them class work is the other way I could have done it.
>
> R – But you decided to do it orally; can you explain why?

> Mr L – It is because class work was going to take a lot of time because I was supposed to mark it. Oral work takes a short time.

It seems that Mr L decided to use the question and answer method as the main strategy because he was running behind schedule. His view was that other strategies need more time to execute. He further explained his reliance on the question and answer method:

> We are under the management, so we are told that by such and such a time we should have covered this much. The head of department (HOD) will tell the teachers that by such a time they should have covered so much. He asks, time and again how far they are. Even if he does not tell them that they are moving slowly, they feel his persistent questions indicate his wish for them to move faster.

It seems also that Mr L's classroom decisions were based on the expectations and demands from the school management. The goal of school management is for the teachers to complete the syllabus. His classroom decisions were informed by those expectations.

My study intended to identify alternative strategies that he could have used had it not been for the factors that he stated. This is what he said:

> R – Are there other ways that you could have used to introduce your lesson other than the ones that you used?
> Mr L – Yes. One is posing a problem and letting them (students) solve it. When they get stuck then I can tell them that this is solved this way and that way.
> R – Why didn't you use those ways
> Mr L – As I already said, I was trying to save time, because giving problems means that I have to mark the work. This is challenge when the class is big.

The excerpt shows that Mr L had an alternative method he could have used to introduce this topic. However, he still seemed to hold the view that teaching is telling. His statement, as shown in his first response *"…I can tell them…."* shows that he regards teaching to be about transmission of knowledge.

In addition to the issue of saving time, Mr L points to the large number of students in the class as another factor shaping how he teaches. He indicates that in a large class, assessment of the work of all the students is time- consuming.

In the lesson about mass and weight, the teacher gave students hypothetical results of an experiment and asked them to evaluate the ratio mass to weight. When asked what motivated him to take this approach, he responded:

> Mr L – I wanted them to see that the number that they will get in each row was approximately the same. I wanted them to discover this gravitational field strength is a constant quantity.
> R – Why did you want them to discover that?
> Mr L – It is because sometimes they ask themselves why this number is chosen while there are so many other numbers.

His response shows that he based this decision on students' needs.

In general, Mr L's beliefs and goals for teaching do not seem to align with his practice. There was a mismatch between espoused and enacted goals. Moreover, the characteristics of his instruction had elements of teacher dominance. It also seems that his classroom decisions were motivated by time, the number of students in his class, and pressure from the school management, all of which were contextual. However, there were times when his decisions were motivated by the students' needs. He therefore displayed mostly traditional teacher-centred orientations.

5.2.2.4.6. Mr L's approaches when teaching force and momentum

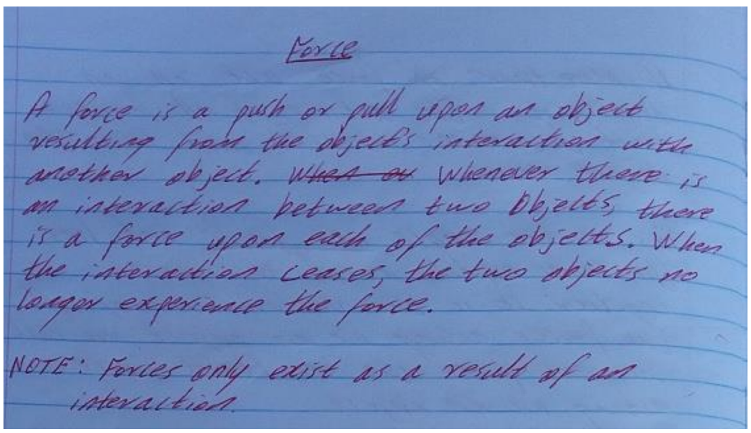
This section presents the way Mr L approached his teaching of the concepts of force. This entailed preparation and enacted instruction. As highlighted in **section 5.2.2.3**, Mr L compiled a lesson plan in preparation for classroom instruction. His planning was informed by the syllabus, knowledge of instructional strategies and how students learn.

A. Interactivity

During the classroom instruction, Mr L provided most of the information, while the students participated by answering his questions and by copying notes. Consequently, there was minimal interactivity in his classroom. Teacher-student interactivity was dominant, with minimal student-teacher and no student-student interaction. His approaches were teacher dominated.

B. Notes writing

Mr L wrote notes for his students. Figure 5.6 is a glimpse of the notes that he had prepared in his book.



Force

A force is a push or pull upon an object resulting from the object's interaction with another object. ~~When or~~ Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force.

NOTE: Forces only exist as a result of an interaction.

Figure 5.6 Glimpse of Mr L's prepared notes

Figure 5.6 is a sample of the notes Mr L had prepared for the lesson. He wrote these notes on the board after students had defined force as a push or pull.

It seems therefore that Mr L's approach to teaching force and momentum was teacher-centred.

5.2.2.4.7. Summary of the findings about Mr L's knowledge base

The preliminary findings about Mr L's knowledge base are that:

- His planning was informed by his knowledge of the curriculum, how students learn and instructional strategies.

- His knowledge of the science curriculum was evidenced when he stated the mandated goals of science teaching as well as when he explained the concepts and made relevant examples.
- Knowledge of how students understand science was observed when he addressed students' prior knowledge. However, he was not observed exposing students' misconceptions. He rather used language which has the potential to create more misconceptions. In general, his knowledge of how students understand science seems to be limited.
- The knowledge of instructional strategies was observed from his use of discussion and lecturing as teaching strategies and by representing the concepts differently.
- He used two assessment methods, question and answer as well as written assignments. He assessed factual knowledge and used formulas in the calculations.

  He displayed teacher-centred practices and orientations.

5.2.3. The case of Mr M: Hardly organised and always in a hurry

5.2.3.1. Teacher background

Mr M holds a Bachelor of Science (B.Sc.) degree in chemical technology. He did a postgraduate diploma in education, with physics and chemistry as his major subjects. He has been teaching at the same school for the past nine years. Mr M was hardly ever organised and ready to teach. I often arrived a few minutes before his lessons started and had to wait in the staffroom for the class to commence. If he was around, he would be completing the writing of his lesson plan. In the six lessons that I observed, he was late twice. In one incident, he was coming from another class where he apparently taught beyond the allotted time. On another occasion, he went to class late because he was still writing his lesson plan. During the class, he seemed disorganised.

5.2.3.2. Overview of Mr L's class

There were two grade 11 streams at Mr L's school and both of them taught physical science. Though Mr M was the only physics teacher at the school and taught both streams, my focus was on one class, grade 11B, with 26 students. Similar to the situation in other schools, physics is allotted three periods of 40 minutes each. So in grade 11B, physics was allocated one 80-minute and one 40-minute lesson per week.

The students sat in four rows, all facing the front where the teacher spent most of the class time. There was enough space between the rows, thus enabling ease of movement by the teacher so that he was able to reach every student.

5.2.3.3. Lesson planning

Depending on whether I found Mr M free when I went to observe his teaching, I took time to copy his lesson plan before we went to class or sometimes after the lesson. My purpose for studying his lesson plans was to find out what his lesson objectives and content were, his intended teaching methods and teaching materials, students' prior knowledge that he intended to reveal and the assessment methods he planned to use. Out of the six lessons that I observed, Mr M had written lesson plans for four. Figures 5.7(a) to 5.7(e) present the samples of his lesson plans.

Lesson objectives

Figure 5.7(a) shows the six lesson objectives of Mr M.

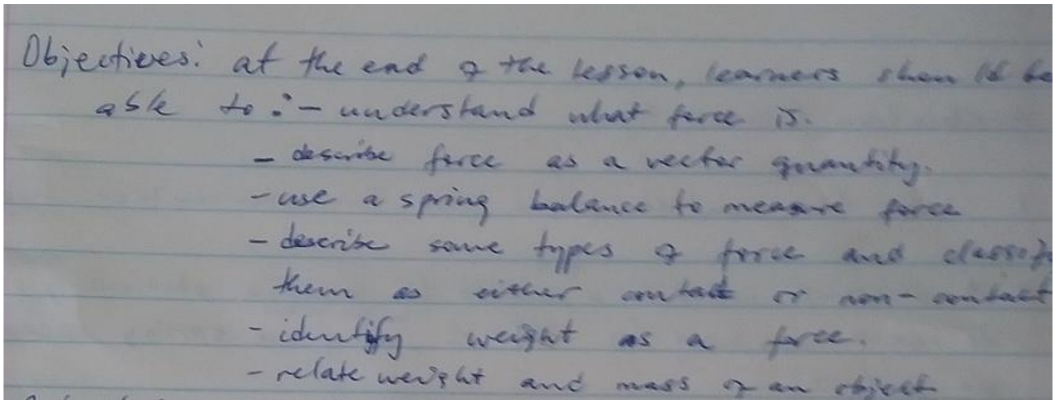

Objectives: at the end of the lesson, learners should be
able to :- understand what force is.
- describe force as a vector quantity.
- use a spring balance to measure force
- describe some types of force and classify them as either contact or non-contact
- identify weight as a force.
- relate weight and mass of an object

Figure 5.7(a) Mr M's Sample Lesson Objectives

The analysis of the lesson objectives shows that Mr M planned to help his students to measure force. Measuring is one of the scientific skills that students are expected to develop. Moreover, he planned to help students describe different concepts as they are stipulated in the LGCSE physical science syllabus. It seemed that Mr M's objectives were informed by his knowledge of the syllabus. This in itself is an indication of the knowledge of the science curriculum.

Teaching methods

Mr M further indicated the teaching methods that he intended to use. Figure 5.7(b) shows the methods which he planned to use.

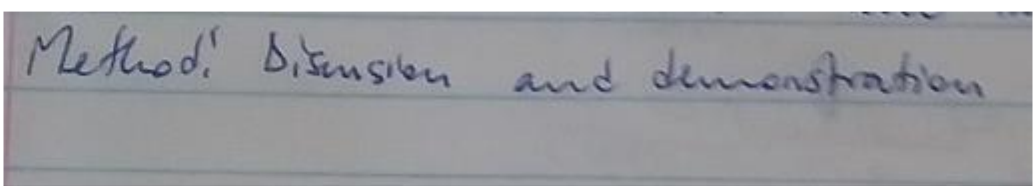

Method: Discussion and demonstration

Figure 5.7(b) Mr M's Sample Teaching Methods

Figure 5.7(b) shows that Mr M planned to use two methods. Both of them seemed to have the potential to engage the students and to enable them to use students' listening, communication and observation skills.

Lesson development

Furthermore, Mr M's lesson plan included both teacher and students' activities, as shown in Figure 5.7(c).

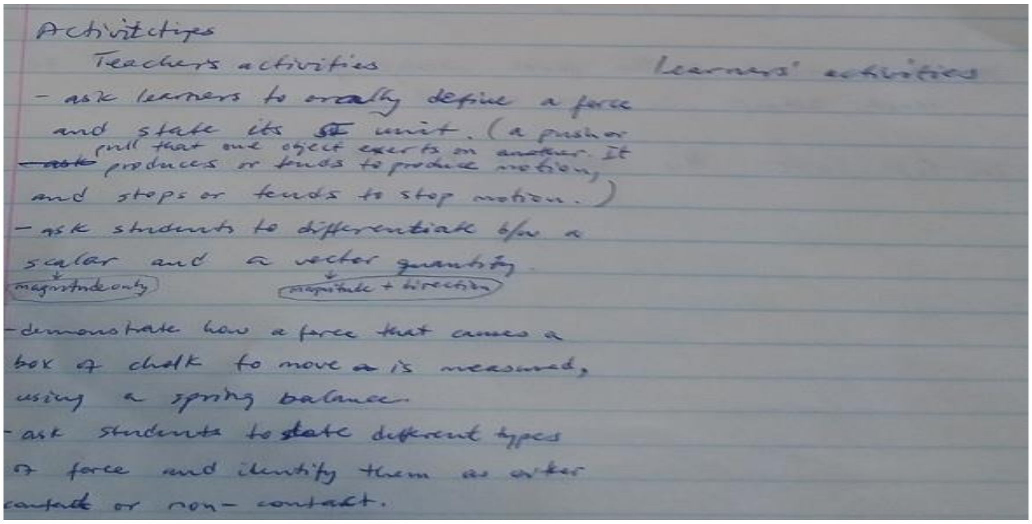


Figure 5.7(c) Mr M's Sample of Teacher and students' activities

This section of the lesson plan looks like rough work. It does not look professional. It paints the picture of being negligent. There are students' activities. This may be interpreted as a rush through the planning activity a few minutes before the lesson. Mr M did not have time to complete it.

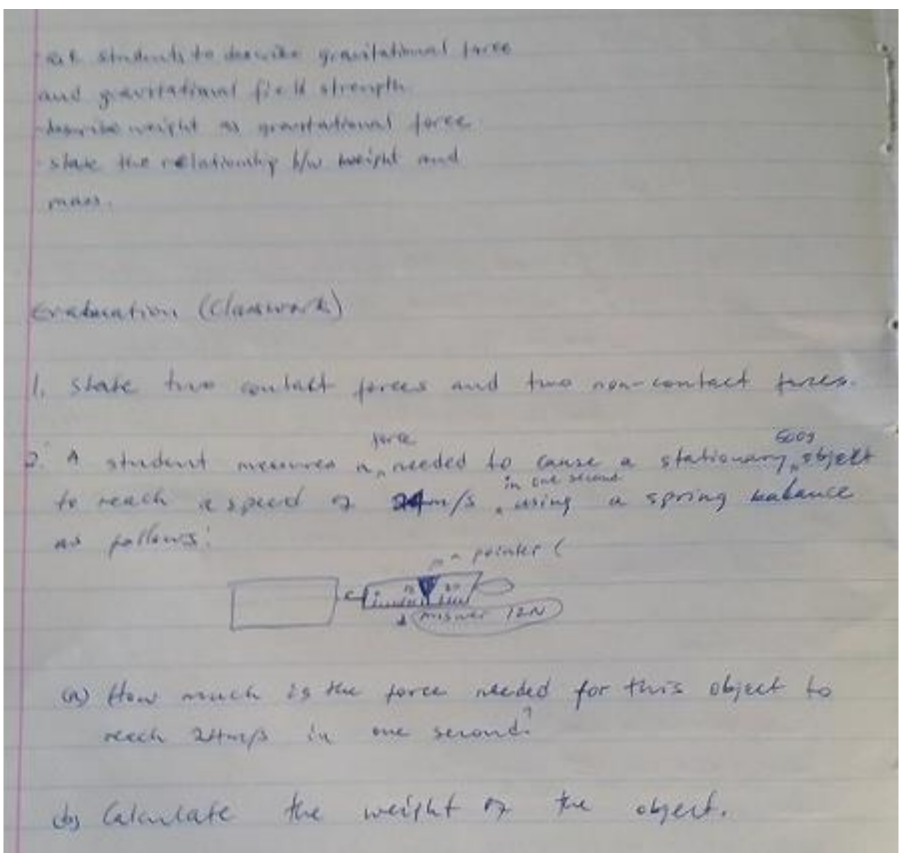
An analysis of the contents of the plan shows that the teacher's activities included asking questions and demonstrating how to use a spring balance. He did not write down the students' activities. Nonetheless, a closer look at the teacher's activities shows statements and words which are circled and enclosed in curly brackets. They seem to be the expected responses. In another lesson plan, as shown in Table 5.9, the students' activities entailed the expected responses.

Table 5.9 Mr M's Sample activities in the lesson development

Teacher's activities	learners' activities
- Ask learners to describe effects of force on the movement or motion of an object	State that force can cause: - A stationary object to start moving - A moving object to increase its speed (accelerate) - A moving object to change its direction of motion
- Ask learners to identify a pair of opposite forces and their direction, acting on a falling paper	State the forces as: - Gravitational force (weight) - Up-thrust force (air resistance)

Evaluation

Figure 5.7(d) shows how Mr M planned to evaluate the lesson.



and gravitational field strength

- describe weight as gravitational force
- state the relationship b/w weight and mass.

Evaluation (Classwork)

1. State two contact forces and two non-contact forces.

2. A student measures a force needed to cause a stationary 500g object to reach a speed of 24m/s in one second using a spring balance as follows:

(a) How much is the force needed for this object to reach 24m/s in one second?

(b) Calculate the weight of the object.

Figure 5.7(d) Mr M's Sample Lesson Evaluation

Figure 5.7(d) shows that Mr M's lesson evaluation entailed assessing the level of students' understanding. It seems that he assessed the recall of factual knowledge, ability to read a scale and to perform the calculations. However, the scale was hand drawn and it might have been difficult for some students to read. Comparing the lesson objectives and the assessment questions shows that Mr M did not assess the achievement of all the objectives he had planned to achieve.

It seems that Mr L's lesson planning was informed by the syllabus. This is indicative of the knowledge of the science curriculum. The lesson plan seems to be informed by his knowledge of assessment and instructional strategies.

5.2.3.4. Teacher's knowledge base when teaching force and momentum

5.2.3.4.1. Knowledge of science curriculum

Mr M's goals and purposes for teaching force

In the post-observation interview, I asked Mr M to share his goals for teaching the concepts of force with me. He explained, "*I want to develop a confident science student, someone who can confidently address problems which are science related*…" His goals seem to be in line with some of the goals of the LGCSE physical science syllabus (ECOL, 2018:4) which are to

- *Enable candidates to acquire sufficient understanding and knowledge*
- *Become confident citizens in a technological world and to take or develop an informed interest in scientific matters*
- *Develop abilities and skills thatare relevant to the study and practice of physical science*

Explanation and illustrations of concepts

When explaining force concepts, Mr M made an effort to provide the reasons why things are the way they are. In the first lesson, when the teacher and students discussed different types of force, he asked whether a duster and a piece of paper would experience the same amount of gravitational pull. Students expressed the view that a duster would experience more pull than the piece of paper. He then illustrated that the rate at which the earth pulls the duster and the paper is the same. He drew an object of mass 4.5kg and partitioned it into 1kg bits to show students that they experience the same amount of gravitational pull.

> T - *…*I want you to differentiate between this gravitational field strength and gravitational force. Let us suppose that I have an object that has a mass of 4.5kg (*draws an object and partitions it into 1kg sections)* here is 1kg, 2kg. When the earth pulls, this object it is going to pull the first one kilogram (1kg) with how much force?
>
> S1 – Ten Newton
>
> T – With 10N; what about the second kilogram?
>
> S2–Twenty Newton
>
> T – No! Just the second kg
>
> S3 – Ten
>
> T - Yes even the third and the last one which is just half kg, so how much force?
>
> S5– Forty five Newton
>
> T – …total force, 45 N, is what we call gravitational force but the rate at which it pulls 1kg, which is…10N/kg is what we call the gravitational field strength. The gravitational force is the total force which the earth pulls the object with while the gravitational field strength is the rate at which 1kg of mass is pulled….

From the excerpt, it seems that Mr M made an effort to concretise gravitational force and field strength. By partitioning the whole into one kilogram bits and pieces he helped the students to differentiate between the two abstract concepts likely to confuse the students. Furthermore, he used different representations, numbers and a diagram, to explain and illustrate gravitational force and field strength as well as how they differ. His explanations constitute verbal, mathematical and diagrammatic representations.

In general, it seems that Mr M’s instruction was informed by some of the physical science mandated goals and objectives. When providing explanations, he took cognisance of the students’ diverse needs and different abilities.

5.2.3.4.2. Knowledge of how students understand science

Students' prior knowledge and examples

Mr M made an effort to use students' prior knowledge to explain the concepts. This involved both the content that they learned at school and the understanding they constructed from their daily experiences. However, in this case, Mr M was observed using situations students have encountered in their daily experiences as the base for introducing and/or explaining the new concepts.

For instance, Table 5.8 shows the examples he used when introducing the effects of force on motion and when explaining up-thrust force.

Table 5.8 Sample of Mr M's examples and the students' prior knowledge

T – So let us think about a soccer ball. When it is stationary and a force is applied on it what effect does that force has on the ball, in relation to motion? It can make the stationary object to… Students (In unison) – Move T – ...we can have another effect. Let us suppose that I push this wall...	T – Even in water…when you place your hand inside water or trying to force your hand down, you will feel that water particles are resisting the downward motion of your hand. That is, water particles are resisting the motion of your hand. They push your hand up. Is that not true? Students (In unison) – It is true T - That is an up-thrust force. Let's continue with another type of force.

Table 5.8 shows that Mr M used an example of a soccer ball to explain how force changes motion. In the same way, he explained an up-thrust force by referring to what happens when placing a hand in water. Both examples are familiar to students so he used what they knew to develop a new understanding.

The analysis of the discourse in the two examples shows that he channelled how students should think, as shown by this statement: "…*it makes the stationary object to*…" In the second column, after giving the scenario, he asked students "*is that true*?" This could supress students' thinking ability as they know that the teacher will give them a hint.

In another case, still in the first lesson, Mr M realised that students have alternative views about gravitational force. The following excerpt shows what happened.

> T - I want us to discuss more about gravitational force…when I am in contact with the earth is the earth pulling me or not?
>
> S - Not pulling
>
> T - It is no longer pulling?
>
> S1- Yes
>
> T – …Does the earth only pullme when I am a distance away from it? Is it no longer pulling when I am on the ground?
>
> S1 - Yes
>
> T - …do you all agree with what he is saying?
>
> S2 - No
>
> T –Do you have a different opinion?
>
> S2 - I think the earth is still pulling because if there is a lot of air, the air can move us
>
> T – Meaning...the earth is still pulling; if not I will be weightless...any amount of air...force...will...move me...This means that for an object, regardless of whether it is in contact with the earth or not it is still pulling. The earth is still pulling. For example, when you stand on snow what happens? …When you stand on snow are you going to remain there?
>
> Students (together) - no sir
>
> T -what's going to happen?
>
> S3 - we are going to sink

The excerpt shows that, informed by his students' understanding, Mr M changed his instruction. He presented a scenario that eventually helped them to realise that gravitational force is applied to objects whether they are in direct contact with the surface of the earth or not. This practice is characteristic to formative assessment, as explained by Bulunuz (2019).

<u>Students' difficulties and misconceptions of force</u>

In the first lesson, when students were describing the types of force, the students displayed a non-scientific view of frictional force. Table 5.9 illustrates two incidences in the first lesson where students displayed difficulties and how Mr M responded.

Table 5.9 Mr M's response to students' misconceptions

Lesson 1	
T -...I want us to discuss further about gravitational force. We have just highlighted that gravitational force is the downward force that is...applied by the earth...on different objects. Now when I am in contact with the earth, is it still pulling me or not? S1 - Not pulling T - It is no longer pulling? S2- Yes T – Meaning…the earth is only pulling me when I am a distance far from it and that when I am on the ground it is no more pulling? S1 - Yes T - What about others, do you all agree with what he is saying S2 - No	T - We have frictional force let us define it… S3 - It is the type of force which happens when two objects are in contact T - Not happens, correct terminology, there is either exerted or is applied to... S3 - It is the type of force applied where two objects are in contact T - Meaning when my two hands are just in contact you mean there is frictional force? S4 - When two objects are in contact and there is a movement of those two objects T - ...she is saying that frictional force is the force that exists when two objects in contact are moving in opposite directions. When one hand is moving forward and the other backward and they are in contact, frictional force is between them. There is frictional force when two objects are in contact and are in motion.

In the first column, it seems that Mr M noticed when the students had difficulties in understanding gravitational force. He probed them to determine whether most of them hold the same view about gravitational force.

In the second incident, as shown in the second column in Table 5.10, Mr M realised when the students used inappropriate terminology "happens" and insisted that they use the correct term; "applied or exerted". Nevertheless, he affirmed the students' view that frictional force is applied only when objects are in motion. This suggests that he also has some misconceptions about force.

Even though he said that students do not have misconceptions about force, it seems that he was able to notice them in class. This could mean that he was not aware that those were misconceptions, probably because he also held the same views.

5.2.3.4.3. Knowledge of instructional and assessment of science

Whole-class discussion and lecturing

Class discussion is one of the student-centred strategies often used when teaching. Similarly, Mr M used whole-class discussions as one of the dominant strategies in his classroom. However, he mixed discussions with lecturing as shown in the excerpt below.

> T - Now...electrostatic force...Is it contact or non-contact?
>
> S1 - Contact
>
> T- Is it a contact, electrostatic force?
>
> S1 - Contact
>
> T - …can you give an example? Can you give me example where we observe... that electrostatic force is taking place?
>
> S2 – Let's say we have a ruler rubbed on a woollen...
>
> T – ...material or woollen jersey
>
> S2 - Yes sir, and when we bring the...charged ruler near the pieces of paper the paper will be attracted to the ruler
>
> T - Meaning the key word there is near. Did she say the ruler has to be in contact with paper?
>
> Students (In unison) - No
>
> T - Just when it is above the pieces of paper they will be attracted to the ruler, meaning that type of force is contact or non-contact?
>
> S3 - Non-contact

The segment shows that Mr M initiated the discussion by posing a question. The analysis of the segment shows that he started with a yes or no question, yet as the discussion progressed, he attempted to increase the level of the questions; "…*can you give example*…" as the discussion proceeded, he made an effort to make the discussion student-centred. He asked them to give examples that then became the focus of the discussion. Further analysis, however, shows that the teacher converses more than the students as can be seen by his longer sentences, compared to the students'. This could mean that even though the discussion was based on the students' examples, he seems to be providing most of the information, thus making the discussion teacher-dominated.

Whole-class discussion and assessment

The analysis of Mr M's discussions also showed that he incorporated the assessment of students' understanding, as illustrated in the following segment:

> T – …Let's suppose that the cart is stationary. If frictional force is 50 Newton and the applied force is 50 Newton, what's going to happen to the cart?
> S1 – The cart will not move.
> T – Meaning when the two opposing forces are equal, when the object is stationary it will not move...So we are saying when two forces acting on opposite directions and their resultant force is zero, the object is not going to move.
> The first condition is- If the object is stationary the object will stay at rest
> Different from the first case, say the cart is in motion and it is moved with 70N and an opposing force of 70N is applied. What do you think is going to happen now that the opposing forces are equal but the cart is in motion?
> S2 – The cart will stop.
> T – It will stop? That's her opinion, let's hear what others say.
> S3 – The resultant force will become zero.
> T – That is true, but we want the effect of the forces on the cart.
> S4 – It will slow the cart down
> T – It will slow down the cart? Ok let us begin it this way. The cart was moved with a forward force of 70 N, now the opposing force is 60N, now it is less than the pulling force…

From the segment, it seems that Mr M explained the resultant force by presenting students with a situation that is familiar to most of them. Discussing what happens as the whole class, Mr M further assessed students' understanding that even when balanced force is applied to the moving cart, it will continue to move, but with constant velocity. A further analysis shows that when he realised that students had an alternative understanding, Mr M used that feedback to structure further discussion.

Further assessment of the teacher and students' responses shows that, the teacher provided most of the information and decisions. The students' responses were very short, while those of the teacher were long. This characterises teacher dominance.

Experimentation

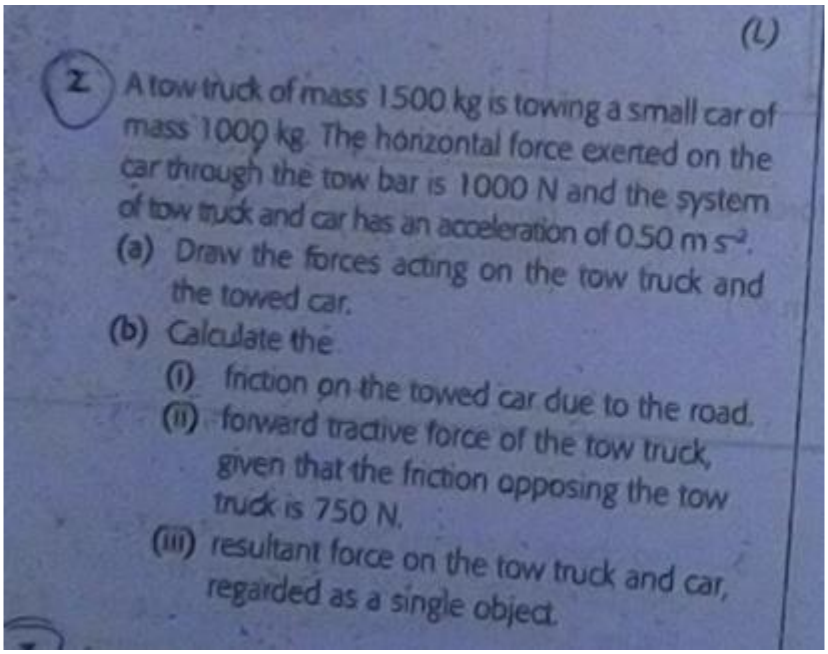
Another observed strategy was experimentation. Mr M used this strategy after discussing the effects of force on the shape and size by referring to elastic materials. He introduced the lesson this way: "*we are going to find the relationship between force applied on elastic material and extension*." He followed that by defining extension and showed students how it is calculated. Then he explained and demonstrated how to do the experiment as shown in the excerpt below:

> T - The procedure is that we are going to attach a spring on a fixed point, we are going to use a retort stand in our case, then hang the spring on the stand (shows with a diagram), after hanging the spring, we will measure its original length. We measure the part of the spring which extends, not the hanger (demonstrates with a diagram). This length is our original length. Afterwards I will supply you with objects of different masses which you are going to hang on the spring. We are not going to waste time measuring their masses because their masses are known and are written on the objects. Then if you know the mass of the object, say 50g, can you find the weight of that object?
>
> Student (In unison) – Yes
>
> T – How are you going to do it?
>
> S1 – I will change grams to kilograms and…
>
> T – That's the first step, what is the second step?

As shown, Mr M told students about the aim of the experiment. From the excerpt it seems that Mr M planned the experiment himself and then presented the finished product to the students. He provided the materials, explained the procedure and demonstrated how to do the experiment. There is no evidence of him involving students in the selection of materials, planning or even the procedure. The students seemed to be involved only when calculating the amount of force applied by the different masses. This could indicate that the teacher did not help the students to develop the competency to design investigations, thus failing to address some of the goals of science teaching.

Written work

In addition to questions and answers as a form of teacher assessment strategies, he also assessed his students through written assignments. Figure 5.8 below shows a sample of the written assignment.



(L)

(2) A tow truck of mass 1500 kg is towing a small car of mass 1000 kg. The horizontal force exerted on the car through the tow bar is 1000 N and the system of tow truck and car has an acceleration of 0.50 m s^{-2}.

(a) Draw the forces acting on the tow truck and the towed car.

(b) Calculate the

(i) friction on the towed car due to the road.

(ii) forward tractive force of the tow truck, given that the friction opposing the tow truck is 750 N.

(iii) resultant force on the tow truck and car, regarded as a single object.

Figure 5.8 Sample of Mr M's written work

Analysis of the questions in Figure 5.8 shows that the questions required students to identify the forces and to perform the calculations.

In general, Mr M seemed to have both instructional and assessment strategies in place to teach and assess students' understanding. He incorporated class discussions with lecturing and used questioning as well as written assignments as the assessment methods. On the contrary, he did not seem to assess some of the scientific skills such as inquiry. He mostly assessed factual knowledge and the ability to perform the calculations.

5.2.3.4.4. Mr M's orientation towards teaching

Characteristics of Mr M's teaching

The data presented in the preceding sections shed light on the characteristics of Mr M's instructional practices. It highlights that his instruction mainly comprised knowledge transmission. His classroom teaching was characterised by teacher statements while the students copied notes and answered his questions. This was observed despite him explaining teaching as "*…helping the learners develop…understanding of science…*" An analysis of his statements about teaching revealed that he notably used the word "deliver", which became very apparent during his actual teaching.

> …those areas should be my target areas when delivering the force concepts.
> …when you have planned it becomes very easy for you to deliver effective teaching.

This indicated that, even though he understood teaching as facilitation of learning, his preferred practice was delivering knowledge. This discord between the teacher's views and his practice could mean that there was a gap between knowing and doing. He held a knowledge facilitation view, but seemed to lack the skills to enact.

Factors determining Mr M's classroom practices

Limitations of time

The justification that Mr M put forth regarding his reliance to lecturing and less students' involvement were to save time, *"…this year is different…we are a little bit behind time*…*I am trying in so many ways to cut corners*"

It seems that Mr M agreed that he mostly lectured and he justified this by pointing out that there is insufficient time to complete the syllabus. He attributed the lack of time to the teachers' strike that had been taking place that year.

Insufficient laboratory materials

The teacher further elaborated that another reason for his expository instruction was related to insufficient laboratory materials: "*We do not have enough materials and…I am actually chasing time."* Consequently, he made classroom decisions based on the time available and availability of science laboratory materials.

Students' strengths and weaknesses

When asked to explain why he gave students classwork, he indicated: "*it is very important to give classwork, not assignments. In my view, individual class work…the teacher monitors*…"

It seems that Mr M gave his students classwork so that he could monitor them. I observed that when students did class work, he marked them as they worked and gave individual feedback. He was able to measure their understanding, identify the mistakes and difficulties they encounter and immediately provided them with the necessary help. However, he explained that homework assignments were deceiving because students sometimes copy from one another and that gives a false picture of their understanding:

> …the problem that we are facing with these students is…they are tempted to copy from their neighbours so classwork always helps, not the assignments (homework).

It seems that Mr M prefers classwork because homework assignments are deceiving as students sometimes copy from one another. As a result, homework assignments may give a false picture of their understanding. However, he was observed giving more homework than class work.

His classroom practice may be classified as mostly teacher-centred and driven by a didactic orientation. The reasons for his practice were mostly contextual and to a small extent they were motivated by students' needs. The contextual issues were related to availability of resources and time, while students' factors included minimising copying and using illustrations familiar to students.

5.2.3.4.5. Mr M's approach when teaching the concepts of force

This section presents Mr M's approach to teaching the topic force and momentum. As presented in **Section 5.3.3.3**, he prepared his lesson plan in writing. An analysis of his lesson plans shows that he was informed by the syllabus aims and objectives, including some knowledge of instructional strategies. In addition to determining the knowledge bases that informed his practice, his classroom teaching was also analysed, based on interactivity and instructional decision.

<u>Lack of in-depth planning</u>

Though Mr M had written lesson plans for some of his lessons, it was observed that he did not give himself enough time to prepare well thought out lessons. This was shown by the untidiness of his lesson plans (Figure 5.7c). There were two occasions where I observed him drafting a lesson plan few minutes before the commencement of the lesson. Moreover, during instruction, I observed him stumbling when trying to work out questions in class. The excerpt below shows how the lesson proceeded.

In the fourth lesson, Mr M discussed the following question:

> A car of mass 1000kg is pulled by a tow truck of mass 1500kg. The truck pulls the car with a horizontal force of 1000N and the whole system moves with an acceleration of $0.5 m/s^2$.
> Calculate the frictional force acting on the small car.

Calculating frictional force is not included in the LGCSE physical science syllabus, so this could mean that Mr M did not study the syllabus when he planned this assessment in order to ensure that it was relevant. The following excerpt shows part of what happened when students tried to answer the second question.

> T - Between the duster and the piece of paper, which one has the largest mass?
> S1 – The duster
> T - When I pull them along this table, which one do you think has the largest friction?
> S1 - Duster
> T – Why?
> S (in unison) – Because …

T – …friction depends on what?

S2 – Weight

S3 – Duster has more mass than the paper

T – …the duster exerts more force or more weight on this table…than the paper…that means…frictional force depends on the weight of an object. When one object has more weight and the other one small weight, if they are pulled on the same surface, the object with more weight will have more friction. <u>More weight means more friction</u>.

So, here, to find the frictional force we say frictional force will be [-*pause*-] …(inaudible) it will be the mass of this small car, meaning in short, what we are going to find here is the weight of this car [–*pause*–]

From the excerpt, it is observed that Mr M paused two times as if he was trying to figure out what to do. This could mean that Mr M did not study the question before coming to class, which is part of planning, in order to analyse the question and identify areas that might be difficult for students to do. This could also mean that he did not thoroughly plan for his teaching.

<u>Interactivity and instructional decision</u>

As presented under instructional strategies (cf. 5.3.3.4.3), Mr M used teacher-directed discussions and lecture methods. He decided on the content to be discussed and involved students through a question and answer strategy. Moreover, the students copied notes. The excerpt below is a sample of his classroom practice.

T - We learned force in secondary [school]. I need one of you to define force for me. Yes...

S1 – Force is a push or pull

T - Come again

S1 - Force is pull or push

T – …it is a push or pull.

S2 – Or twist

T – … because we know …these are the effects of force…Push an object, pull and… shear as well. So those are all the effects of force. So we have push, pull or twist, shear, though I have not written all of them.

The excerpt shows that after informing students that they learned about force in the lower grades (secondary school), he decided on what to review about force by asking oral questions. A further analysis also shows that the students mostly worked individually. That means it was the individual's responsibility to recall the facts in order to respond. Also based on the data presented about Mr M's instruction, it could be concluded that there was more teacher-student interactivity than student-student and student-teacher. Moreover, he seemed to be the only one making instructional decisions. Thus, his approach to teaching force could be categorised as traditional and teacher-centred.

5.2.3.4.6. Summary of Mr M's findings

The analysis of Mr M's instruction and documents show that his goals for teaching science and force and momentum in particularly were aligned to the syllabus goals. He explained the concepts and clarified them by using everyday examples. Though he notice when students experienced difficulties and misconceptions, he also seemed to have non-scientific views and/or misconceptions of some force concepts himself. His strategies, both instructional and assessment lacked fluidity as he used the same strategies throughout the topic. Moreover, his practices were inclined towards traditional teacher-centred practices. The way his lesson plans looked and the information as well as what happened during the classroom teaching indicated that he did not to do in-depth lesson planning. Based on his practices and goals and the purposes of his classroom actions, the core orientation which seems to direct his practice was a didactic orientation.

5.3. Chapter summary

This chapter presented the accounts of three grade 11 physical science teachers regarding their classroom practices when teaching the topic force and momentum. The qualitative data presented and interpreted in this chapter were collected through classroom observations, post-observation interviews and document analyses. In general, the accounts showed that the teachers' classroom practices were informed by their knowledge base. However, differences and similarities of their practices including the knowledge bases which dominated their classroom decisions were identified. In the next chapter (Chapter 6), the cross-case analysis and integration of both quantitative and qualitative data as well as the summary of key findings and their discussion, conclusion recommendations and significance of the study are presented.

Chapter 6.
Cross-case analysis, discussion of key findings conclusion and recommendations

6.1. Introduction

This chapter starts with a summary of how the study was conducted, A cross-case analysis, followed by discussions of the main findings, conclusions, limitations of the study, implications and recommendations, and my final remarks are presented. I felt it important to outline the framework that guided this study and to discuss how I used it, because the review of the literature indicated that researchers used it differently.

A literature search resulted in only one study that was conducted in Lesotho, which explored physical science teachers' PCK (Qhobela & Moru, 2014). Although the study also used an explanatory sequential mixed method approach, the following differences were observed: (a) the sample size of the surveyed teachers was smaller (39) than in this study–the current study has a larger sample of 92 teachers. (b) The qualitative aspect in this study was based on classroom observations, teacher interviews and analyses of syllabi and lesson plans. (c) The study used a different framework. The present study used science teachers' PCK framework as proposed by Magnusson et al. (1999), while Qhobela and Moru reported to have used a PCK framework that they adapted from An et al. (2004), which had different PCK components. This study is therefore believed to provide findings that will complement those found in the previous study.

6.2. Summary of the study

The purpose of the study was to explore science teachers' perceptions of their knowledge to teach force and momentum as well as how it shaped their practices in grade 11. To shine more light on my study, I used science teachers' PCK framework as advanced by Magnusson et al. (1999). This framework conceptualises the science teachers' PCK to comprise five components: orientations towards science teaching, knowledge of the science curriculum, how students understand science, instructional and assessment strategies specific for science teaching and assessment. I chose this framework because it allowed me to measure teachers' perceptions of each knowledge domain and to identify them during instruction. This is because each of the domains has sub-domains, which can be observed in the classroom to assist in identifying the knowledge domains that come to the fore when teachers teach. Furthermore, the framework was used as an analytical tool during both data collection and analysis. It guided me during the development of the survey questionnaire and observation protocol as well as during my analyses of both lesson plans and classroom observations.

Literature on perceptions and practice indicate contradictory findings. However, most studies found that perceptions do not always align with practice (Albergaria-Almeida, 2010; Barendsen & Henze, 2017; Moodley & Gaigher, 2019). Many things take place in the classroom, which prevent teachers from doing everything they believe they should. Consequently, they find that perceptions influence practice to a smaller extent than initially thought; rather, various factors were found to play a bigger role during decision-making.

My study employed a mixed method approach to data collection and analysis. Since the mixed method approach uses both quantitative and qualitative methods during data collection and analysis, quantitatively, I drew a holistic picture of science teachers' perceptions, while qualitative methods allowed me to get an understanding of whether perceptions actually influenced practice or not. I collected quantitative data from a sample of physical science teachers in the five districts of Lesotho, using a questionnaire, followed by qualitative data collection,analysing the physical science syllabus, lesson plans and classroom observations of four teachers. The four teachers were purposefully selected from those who participated in the survey. However, data from the fourth teacher was not used as it lacked the necessary details.

The quantitative data were analysed using the SAS program to determine the descriptive and inferential statistics. The qualitative data, in the form of audio records, were transcribed verbatim, cleaned and coded. The in-depth analysis of explicit PCK proposed by Park and Oliver (2008) was used to code the observations and the interviews.

6.3. Cross-case analysis

6.3.1. Teachers' background

Table 6.1 below presents the background information of the teachers.

Table 6.1: The teachers' background

Teacher	Gender	Qualification	Major subjects	Teaching experience	Class size	Teaching Load/periods per week
Mr L	Male	BSc Ed	Mathematics and physics	1 year	50	35
Mr C	Male	BSc and PGDE	Mathematics, computer science and physics	10 years	48	30
Mr M	Male	BSc in Chemical Technology	Applied chemistry and physics	9 years	25	32

Although the researcher used purposive sampling, the selection of all male teachers was random. This could be due to the larger number of male physical science teachers than females, as shown in Chapter 4, Figure 4.1. Table 6.1 also shows that the teaching load of the teachers was 30 periods or more. This indicates that two teachers, Mr L and

Mr M, were overloaded because their teaching loads exceeded a maximum recommended number of 30 periods (Lesotho, MoET, 2006).

6.3.2. Teachers knowledge

6.3.2.1 Knowledge of the science curriculum

This theme explores the physical science teachers' perceptions of their knowledge of the science curriculum and how they relate to practice. I examined this theme under two sub themes: knowledge of the goals and purposes of teaching science, and the purposes for the topic force and momentum in the school curriculum.

Goals and purposes for science teaching

The three teachers seem to have similar perceptions of their knowledge of goals for science teaching. The teachers explained that they strive to help the students to develop scientific skills. Collectively, the three teachers highlighted that their aim was to help students acquire the basic scientific knowledge and skills they need to further their studies. Mr C highlighted that "*…they (students) should have a thorough knowledge so that where ever they go when furthering their studies they should be able to apply what they learned*." Mr L mentioned that students should be "…*able to do manipulations…do things at home to solve such problems, also to discover* …." Mr M further pointed out that his purpose was to "…*develop a learner that will confidently address problems which are science related.*"

Notably, the teachers mentioned similar goals for science teaching and all of them referred to the competences science students are expected to develop. Since the goals and objectives of science teaching are provided in the syllabus, the similarity could be the result of using the same syllabus (ECOL, 2018).

Both quantitative and qualitative data show that, when explaining the goals for science teaching, the teachers referred to high-order cognitive skills (HOCS) (Zoller, 2012). That is, skills that enable people to participate actively in the society, which is envisioned by different nations globally (Lesotho, MoET, 2008). For the teachers to perceive science teaching as an endeavour to help the students develop HOCS is interesting, because teachers' actions are determined by many factors, including their perceptions (Wei & Li, 2017). Nevertheless, a variation was observed in relation to whether the teachers realised the perceived goals when teaching. Contrary to the articulated goals and purposes, Mr L and Mr M's practices were theoretical, as discussed in **Sections 5.2.2 and 5.2.3**. A match between Mr C's instructional practices and the articulated goals was observed. During the instruction, he engaged students in thinking and helped them to relate knowledge of force to what happens in their daily lives, as highlighted below:

> T - ...you are saying force of friction will be between two objects...moving in opposite directions...if we have frictional force between the box and the desk when the box is pushed across the desk. The desk will be stationary and the box will be moving, so do we have frictional force in that case?"

On the one hand, a match was observed between the teachers' perceptions and practice, while on the other hand a mismatch was observed. The differences could be related to the teachers' PCK and background (Moodley & Gaigher, 2019). Knowing the purposes of science teaching and how to articulate them when teaching are two distinct aspects. For teachers to realise the goals when teaching requires integration of different bodies of knowledge.

The reasons for including the concepts of force in school curriculum

The interview data indicated that the three teachers explain the purposes of teaching force and momentum differently. Mr C explained them in terms of the syllabus structure as follows:

> **…**the syllabus structure, you will see that there is a link... it means we need this topic (effects of force)...even when we go further, may be after dealing with forces we will go to topics like...magnetism, forces are still there**…**

On the other hand, Mr M explained why it was important to teach force concepts this way "...*when learners develop the concept of force it can help them even in their tertiary* *education...even when they pursue science related careers."* It seems that one of Mr M's purposes for teaching force concepts was to provide students with the background knowledge they needed as they study physics beyond high school. He based this on the knowledge of what students learn in the subsequent grades and during their further studies. This is what Magnusson et al. (1999) refer to as knowledge of the depth of the curriculum.

Both Mr C and Mr M's explanations could be interpreted to indicate that they were familiar with the syllabus structure. This indicated that they have knowledge of the vertical structure of the syllabus; that is, what students will learn in the current and subsequent grades Demirdöğen (2016).

Mr L, however, referred to force as the basis for understanding the natural environment in this manner:

> Force is very important because most of the things, such as walking, happen because of force....So when students know this they are able to explain why we are able to walk.

The same reason was echoed by Mr C who said that

> There are many things such as this issue of friction under force. They should know about friction force and air resistance. When they see a parachute they should know what is happening.

The teachers seem to view force concepts as foundational to understanding other science concepts as well as how things happen in nature. This is also a characteristic of knowledge of the breadth of the science curriculum. It seems that the teachers' knowledge of the concept of force is broad; hence, the students are able to relate it to real-life issues. This understanding is also shared by Sağlam-Arslan and Kurnaz (2009:2) who refer to the concept of force as "...the principal concepts of physics." Furthermore, they seem to share the same understanding as Carson and Rowlands (2005:474) who explain that "…mechanics is the logical point of entry for the enculturation into scientific thinking."

The qualitative results highlight why the teachers believe that force concepts are important in developing students' logical and creative skills. As Mr M and Mr C explained, when students understand the concept of force, they will be able to explain most of the natural phenomena, such as walking and the mechanism of operation of a parachute, which is logical thinking.

Explanations

The qualitative data revealed that the three teachers explained force concepts differently. Although they all referred to real-life examples when explaining most of the concepts, Mr C's explanations differed from those of the others. He presented examples with real-life situations. Then he deconstructed the content by providing a step-by-step explanation of why things happen in the way that they do. Finally, he represented the concepts with diagrams and/or a small demonstration **(Section 5.2.1.3.1)**. Mr L mostly explained the concepts theoretically and reinforced them with mathematical expressions **(Table 5.6)**. Though Mr M attempted to explain using real-life examples, he was not logical and he ran out of examples and words to explain. He even confessed his shortcomings regarding the English language "…*I am not confident in English so sometimes I feel that I use words that confuse students; so sometimes…I teach in my mother tongue.*"

The teachers' knowledge of the breadth and depth of the curriculum can be observed in how they provide explanations. In this study, the qualitative results show that even though the teachers believe that they know how to explain the concepts of force, there are differences in how they do it. One teacher provided theoretical explanations while the other two provided conceptual explanations. The teachers' use of real-life examples when explaining science concepts is linked to their level of content knowledge (Ngman-Wara, 2015). The differences in how they integrated contextual issues when teaching may be explained in terms of their content knowledge. However, Mr M attributed his limitations to his lack of fluency in English as the language of instruction.

6.3.2.2. Knowledge of how students understand science

Prior knowledge

The multiple case study analysis revealed more similarities than differences regarding the prior knowledge that the teachers reviewed as well as how they reviewed it. When introducing the lessons, all of them asked questions that required students to recall facts and definitions, for instance:

> Mr C –…what is force?
> Mr L - …what do you know force to be?
> And
> Mr M - …I need one of you to define force for me.

When explaining concepts, they provided examples or scenarios based on the situations students experience in their daily lives. Mr C **(Section 5.2.1.3.1)** and Mr L **(Section 5.2.2.4.1)** explained the concept inertia by providing an example of what one experiences when a speeding car suddenly stops. Similarly, Mr M explained the concept up-thrust force by referring students to how they would feel when they slowly push their hands in still water **(Table 5.9).** The three teachers seem to tap on students' prior knowledge of what they have experienced in their environment.

Hailikari et al. (2007) established that the types of prior knowledge affecting students' understanding are knowledge of facts and meaning, as well as integration and application of knowledge. Collectively, the teachers seem to emphasise one type of prior knowledge, knowledge of facts or declarative knowledge. This is because they asked definitions and presented scenarios from which the students' task was to recall and recognise facts as well as to define them (Binder et al., 2019).

<u>Misconceptions</u>

The qualitative data revealed that the teachers were able to recognise when students displayed misconceptions, although Mr C and Mr M were unable to express them when they were asked to. Mr C realised that students presented non-scientific views of frictional force **(Section 5.2.1.3.2**), while Mr L noticed that the definition of force that his students presented was likely to culminate in a misconception if not addressed at that point (**Section 5.2.2.4.2**). Moreover, Mr M realised that students struggled with the concept of gravitational force **(Section 5.2.3.4.2)**.

Consistent with the literature, students in this study had some misconceptions about force. This was observed during classroom instruction. Examples of misconceptions include the fact that there is active force and that frictional force is only related to motion (Develi & Namder, 2019; Hestenes et al., 1992). The teachers recognised that misconceptions were evident during the classroom instruction and that could be an indication of strong content knowledge.

Although Mr L's students did not demonstrate misconceptions during the classroom instruction, he explained that he realised, while marking some of the students' work, that they have some misconceptions about the concepts of force. He indicated that "…*most of them (students) believe that there are no forces acting on the object when it is at rest*…" Contrary to the literature, which states that some teachers do not know about students' misconceptions and that they refer to misconceptions as confusion that needs more information to dispel (Gomez-Zwiep, 2008), two teachers in this study recognised and addressed misconceptions when they became evident, while the third teacher expressed and addressed them.

Moreover, two teachers, Mr L and Mr M, occasionally used and accepted phrases that indicated non-scientific views of some force concepts. As presented in **Section 5.2.2.4.2, Table 5.8**, Mr L accepted students' responses, which displayed the view that force has a source, and which Hestenes et al. (1992) refer to as "active force". Mr M also displayed the non-scientific view that frictional force is applied only when contact objects are in motion **(Table 5.9)**. Accordingly, Develi and Namdar (2019) explain that this view is problematic, because on the one hand, friction is said to enable motion, while on the other hand, it is said to inhibit motion. For the teacher not to elaborate when friction inhibits motion and when it enables it, can confuse students.

That Mr C and Mr M were not able to express possible students' misconceptions of force could be an indication that they did not view them as aspects of science learning that teachers should know about. However, Hammer (2000) advises that it is important for teachers to know about students' preconceptions, regardless of whether they view them as barriers or building blocks towards learning. If Mr L managed to express some of them, even though he was only in his second year of teaching, it could mean that, because he had just completed teacher training when students presented misconceptions in the test, he easily remembered them from his university training. Experienced teachers have long since completed their training and they probably never took note of misconceptions since they started teaching. They may have forgotten such concepts.

6.3.2.3. Knowledge of instructional strategies

Whole-class discussions and lecturing

The teachers directed whole-class discussions were the most dominant strategy in all three classrooms. On a few occasions though, Mr C **(Table 5.2 Lesson 2)** and Mr L **(Section 5.2.2.4.2)** put some effort into engaging students in the discussion by asking them questions that required explanations. However, this did not last for long. These results are similar to those of Rahman (2018) who explained that secondary school science teachers did not use different activities, such as group work and practical work, when teaching science.

Discussions done in the three classrooms followed the same pattern: teacher question, students' response and teacher approval or rejection of the response. Consistent with the literature, this classroom discourse is said to be so dominant in teaching that Sherry (2019:28) refers to it as "the dominant discourse genre found in teaching." The teachers often evaluated the responses as either correct or wrong. In a few instances, they reflected the wrong response back to the students for them to evaluate. Asking questions is one of the most important aspects of teaching as it benefits both the teacher and students (Döş et al., 2016). However, for questioning to be effective, teachers should plan for it.

Notably, the teachers provided most of the information during the discussions as students participated by responding to low-order questions. Contrary to Mr C's classroom practice, the other two teachers provided some written notes for their students. Therefore, the students spent most of their time copying notes. The literature indicates that lecturing is not only dominant in universities, but also in secondary schools. Teachers avoid dealing with disciplinary issues (Shamsudin et al., 2013). Furthermore, the teachers often resorted to expository methods, which do not require the intense planning necessary for sourcing knowledge from other domains. That the teachers did not vary their strategies could mean that there is a knowledge-doing gap (Qhobela & Moru, 2014). The teachers in this study probably knew the various instructional strategies theoretically, but had limited knowledge of how to apply them.

Representations

When explaining the concepts of force, the teachers used different representations. They provided examples, drew illustrative diagrams and provided demonstrations, while students looked and listened passively and copied what the teachers wrote. Janík et al. (2009) explain that it does not matter whether teachers or students initiate representations. What is important is the purpose of use.

The various representations of force they used comprise scenarios, arrow diagrams and mathematics in the form of formulas and/or equations. Using representations when teaching force concepts is one strategy teachers use to make constructs more concrete (Martinez et al., 2013). Mr L used arrow diagrams and mathematical representations, while Mr C **(Section 5.2.1.3.3)** and Mr M **(Section 5.2.3.4.3)** included scenarios and demonstrations. Ngman-Wara (2015) indicates that scenario-based instruction brings what happens outside into the classroom so that students could see the relevance of science. Also, it helps teachers to present science concepts, thus reducing the cognitive overload of students.

Experimentation

Different from the other two teachers, Mr M used experimentation **(Section 5.2.3.4.3)**. However, he used it only once. Although physics is called the science of abstractions, which can be understood best when taught through experimentation, it is lacking in most science classrooms, physics included (Trna, 2012). In addition to unavailability of laboratory materials, it is indicated that some teachers do not teach through experimentation because they do not know how to use some of the laboratory materials (Gülçiçek & Kanli, 2018).

6.3.2.4. Knowledge of assessment of force and momentum

The teachers' assessment practices had more commonalities than differences. The three teachers used the same assessment methods: oral questioning and written assignments. There was no variability in terms of their assessment practices.

Oral questioning

As discussed in **Section 5.3.2.3**, except for Mr M, whose students did an experiment once, the teachers did not give students other forms of activities except responding to teacher questions and copying notes **(Mr L and Mr M)**. Particularly, Mr L did not give students any written classwork **(Section 5.2.2.4.4)** throughout the observation period. This means that his classroom teaching was predominantly through questions and answers. Döş et al. (2016:2065) indicate that "[q]uestions are stimulants which activate students' cognitive skills…" However, they should be on a level that challenges students' cognition.

From the lesson plans of Mr M **(Section 5.2.2.3)** and Mr L **(Section 5.2.3.3),** there was no evidence that they planned how the question and answer sessions would take place. Mr L simply indicated that he would assess students through questioning **(Table 5.5)** without giving examples of the questions that he intended to ask. Such behaviour has been noted by Black et al. (2004), who state that teachers often do not plan the questions to ask when teaching, hence they end up asking low-order questions only.

As evidenced by the assessment methods used and the questions asked, the teachers seemed to assess factual knowledge. Mr C's written assignments, as shown in **Figures 5.1 and 5.2**, indicated that most of the questions required students to recall definitions and formulas. Similarly, Mr L **(Figures 5.5, 5.7** and **5.8)** asked recall questions. In all three classes, the teachers assigned written assignments at the end of the lesson or when they had finished teaching particular concepts within the topic. Acar-Erdol and Yildizli (2018) explain that classroom assessment is classified according to its purpose and when it is done. It seems that the purpose of assessment, for the three teachers in this study, was to measure how much students could recall what they were taught; that is, the definitions and explanations as well as the formulas and methods to perform the calculations. Thus the teachers used summative assessment methods.

Feedback

There were differences in how the teachers gave feedback. As presented in **Sections 5.2.1.3.2** and **5.2.3.4.2**, Mr C and Mr M sometimes used the feedback from the students to shape instruction. For instance, both teachers presented scenarios when they realised that students displayed alternative conceptions of frictional and gravitational forces. Moreover, Mr C marked most of the classwork during the lesson. He emphasised that students should not wait to complete all the questions before they could be marked. He showed the students what they missed and asked them to redo the work. In the same way, Mr M marked the students' written work during the lesson. He went from student to student and checked their progress and challenges. However, he did not give the students written classwork so he was not observed giving his students feedback on any written work. The three teachers gave feedback on whether students' oral responses were correct or wrong.

6.3.2.5. Teachers' classroom practices and orientations knowledge

In this section, I compare and contrast the characteristics of the teachers' classroom practices and why they follow them. There were more commonalities in the nature of classroom discourse, the level of interactivity and the purposes of the strategies the teachers used than in how they prepared for the lessons.

Nature of classroom discourse and interactivity

It seems that the classroom discourse in all three classrooms was mostly one-way, from teacher to students. This type of discourse characterises teacher dominance. The whole-class discussions dominated all three classrooms **(Section 6.3.2.3.1)**. However, there were isolated cases in Mr C's classroom where student-teacher interactions were observed **(Table 5.4)**. The teacher and students took turns in asking questions, thus changing the pattern of the discourse and the interaction to student-teacher discourses.

The purposes for choice of strategies

The purposes of the teachers' instruction seem to be mainly to transmit knowledge. Magnusson et al.'s (1999:97) framework of science teachers' PCK, which was adopted for this study, highlights that "…it is not the use of a particular strategy but the *purpose* of employing it that distinguishes teacher's orientation to teaching science." The teachers indicated that they chose strategies that would enable them to complete the syllabus so that students could get ready for the examinations. Mr M **(Section 5.2.3.4.6)** and Mr L **(Section 5.2.2.4.5)** indicated that their decisions were motivated by the time factor. Mr M explained that since school attendance had been interrupted by the teachers' strike, he had to "cut corners". Mr M highlighted that the time factor seemed to be a concern of the HOD as he kept on inquiring about Mr M's progress **(Section 5.2.2.4.5)**. Mr L's concern seems to link to Deemer's (2004:85) observation that "…school culture, in terms of work culture that teachers perceive for themselves, relates directly to instructional approaches…." Conversely, Mr C indicated that he did not use other strategies such as group work, because not all students participate **(Section**

5.2.1.3.5). He complained about insufficient science laboratory materials, while Mr L further lamented the absence of a science laboratory at his school.

Furthermore, while comparing their purposes for representing force with arrow lines and for using scenarios, the teachers explained that they were trying to make the concept concrete so that students could understand. Mr M said that:

> …force has to be represented with an arrow as it gives direction of this force and again in calculations…I encourage students to use the signs…because they are helpful when students are calculating, for example, resultant.

This statement further supports Mr M's use of arrow diagrams to transmit the fact that force has direction. Mr C and Mr M further explained that they preferred to assess students through classwork because they can make sure that students work individually. "*…they (students) are tempted to copy from their neighbours. Therefore classwork (not the homework) always helps them."* Mr C also explained that he preferred to give homework that requires some calculations, because that is what students will be asked to do in their examinations.

Lesson planning

It seems that the three teachers planned for their lessons prior to going to class. However, the way they planned varied. Two teachers, Mr L **(Section 5.2.2.3)** and Mr M **(Section 5.3.2.2)** had written lesson plans, while Mr C did not have any. Though there was no evidence, Mr C indicated that he read the content that he intended to teach to his students. The content of Mr L and Mr M's lesson plans was similar, except for the activities and assessments. Mr L highlighted the subject matter he planned to assess as well as the assessment methods that he intended to use.

Acar-Erdol and Yildizli (2018) emphasise that assessment is an important aspect of teaching and should be planned thoroughly in order for it to serve its purpose. That is, during the lesson preparation, teachers are advised to ask themselves questions such as: What do I want my students to learn today? How will I make sure that they learn it? What resources do I need to help them? What do they already know about what they are going to learn? What do they need to know in order to understand what they are going to learn? How will I know that they know what they should know? How will I know that they have learned what they were supposed to learn today? Shulman (1987) calls this pedagogical reasoning, the thinking process that teachers undergo in their preparation to teach.

It also seems that the teachers did not give themselves enough time to plan their lessons. Some of the lesson objectives in Mr M **(Section 5.2.3.3)** and Mr L's **(Section 5.2.2.3)** lesson plans were not measurable. Moreover, it seems that when they decided on the teaching methods, they wrote down everything they knew even if they were not going to use it. For instance, Mr L included demonstrations and discovery strategies although the learner activities (both on the plan and during the instruction) were not structured to lead to any form of discovery.

Teacher orientation

As presented in **Sections 5.2.1.3.5, 5.2.2.4.5** and **5.2.3.4.6**, it seems that the teachers' instructional practices were mostly teacher-centred. They directed the discussions by asking low-order recall questions and provided most of the explanations. The justification that they put forth for classroom decisions seem to be driven by the limitations of the time that was set for them to complete the syllabus and by the unavailability of laboratory materials. Mr L further highlighted the pressure from the HOD about his coverage of the syllabus (refer to **Section 5.2.2.4.5**). Consequently, he was forced to rush through the syllabus so that he could meet the demands of his HOD. Moreover, Mr C explained that he mostly asked calculation questions because those were emphasised in the examination. Although the teachers seemed to hold the view that teaching is about facilitation of knowledge construction, their utterances and practices were not congruent. When they talked about teaching, they used the term "deliver" which portrayed their strongly held belief about teaching.

Though the characteristics of all three teachers displayed knowledge transmission, Mr C allowed his students to ask him questions and he pushed them with challenging questions (**Table 5.4**) to a limited extent. Therefore, he showed a conceptual change orientation. Based on the observed practices and their purposes for science teaching, all three teachers seemed to have didactic orientations. However, little evidence of conceptual change orientation was observed with Mr C. That the two teachers displayed a unitary orientation to teaching force and momentum is in agreement with the argument of Campbell et al. (2017) that teacher orientations are topic specific. On the other hand, that Mr C displayed more than one orientation, is also consistent with the literature. Feyzioğlu (2019) indicates that since orientations are linked to the goals and purposes one holds, teachers sometimes have different goals for different pedagogic aspects such as instructional strategies. Hence, they sometimes display more than one orientation, one main and the other peripheral.

6.4. Discussion of the key findings

The key findings of this study are based on the four sub-research questions. Thus the findings are discussed in relation to the themes emanating from the four sub-research questions in order to answer the main research question:

> What are the Lesotho science teachers' perceptions of their knowledge on the topic: force and momentum; and How does it shape practice in grade 11 classrooms?

6.4.1. Science teachers' perceptions of their knowledge base to teach force and momentum

The results of the teachers' perceptions of their knowledge to teach force and momentum were examined based on two parts. I examined perceptions of their knowledge base and of practice. In general, the study found that the teachers had positive perceptions of both their knowledge base to teach the concepts of force and practice.

Perceptions of teacher knowledge base

The teachers felt that they knew the science curriculum better than the other components of teacher knowledge, as shown by the highest average mean score on both its aspects, namely knowledge of goals for science teaching **(Table 4.2a, mean = 4.53)** and knowledge of the breadth and depth of the curriculum of force concepts **(Table 4.2b, mean 4.34)**. Although they still had positive views about the knowledge of assessment, they were not very confident, as evidenced by the smallest average mean scores of 3.37 for knowledge of the aspects of science to assess **(Table 4.5a)** and 3.44 for knowledge of assessment methods **(Table 4.5b)**. When asked why they taught physical science, the teachers mentioned that they do so in order to help students develop problem solving and manipulation skills as well as to be confident when dealing with science matters **(Section 6.3.2.1.1)**.

The fact that the teachers had positive perceptions about their knowledge base and how to teach force concepts supports views from other scholars who mention positive views on content knowledge, students' misconceptions and questioning (Albergaria, 2010; Catalano et al., 2019; Qian et al., 2019). Albergaria (2010) investigated the teachers' perceptions of their questioning and found that teachers believed that students ask more questions than they do, and that the teachers ask high-order questions. Qian et al. (2019) investigated the teachers' perceptions of students' misconceptions and found that they had low positive perceptions.

Perceptions of practice

Another important finding was that the teachers had positive perceptions that their practices were both teacher- and student-centred. Positive views about teacher-dominated practices were shown by the average mean score of 3.70 as shown in **Table 4.8a** and student-centred practices by the average mean score of 4.81 in **Table 4.8b**. These results support the observation that science teachers' practice is both teacher- and student-centred (Qhobela & Moru, 2014; Milner et al., 2012). These could mean that the teachers believe that both teacher- and student-centred practices have their own intent and benefits in teaching. Furthermore, based on their views about the nature of a particular topic or concept, they tend to believe that it can be best taught in a particular way (Campbell et al., 2017). Thus, teachers who perceive a particular topic as abstract and difficult, are likely to transmit information thinking that they are helping students comprehend it.

One of the significant contributions to this study's findings is the exploration of teachers' perceptions of knowledge of many components of science teacher knowledge, especially in Lesotho. This is because science teaching, particularly the concepts of force, requires teachers to integrate different knowledge domains (Robertson et al., 2017). With evidence that perceptions determine practice (Cheng et al., 2016; Park et al., 2016), I felt that knowing how teachers feel about their knowledge bases and competences to teach the concept of force is important, because it shows that they were confident in their abilities, which is good, because confidence is likely to increase their performance.

6.4.2. Knowledge base of science teachers when teaching force and momentum in grade 11

It was found that when science teachers taught the concepts of force, three knowledge domains became apparent. These were knowledge of the science curriculum, how students understand science and instructional strategies. However, there were variations in how knowledge of the science curriculum and how students understand science manifested during teaching.

<u>Variations in teachers' knowledge of the science curriculum</u>

The study found that the ways in which the teachers explained most of the force concepts differed. As shown by the overall mean score of 4.34 in **Table 4.3a**, the teachers showed confidence in their abilities to explain the force concepts, thus indicating that they believed they had adequate knowledge of the content of force concepts. The results of classroom observations confirmed their beliefs about the ability to explain concepts. Two of the three teachers explained force concepts by referring to students' real-life experiences, visual representations such as diagrams, and small demonstrations (**Section 6.3.2.1.3**). Mr C, in particular, provided clearer explanations than Mr M and Mr L. He talked slowly and gave step-by-step explanations by referring to students' real-life experiences and he gave visual demonstrations and/or gestures, while Mr M was not logical and ran out of examples to clarify what he was explaining. The third teacher, Mr L, provided theoretical explanations and quickly reinforced them with mathematical formulas, symbols and/or numbers. As highlighted in the literature, science teachers' explanations are mainly qualitative and they are followed by demonstrations. Most teachers move quickly to formalise their explanations with formulas, symbols and units (Cabello et al., 2019; Geelan, 2020). The fact that two teachers made an effort to use contextual issues and students' real-life examples and small demonstrations to represent force concepts, contradicts Cabello et al.'s (2019) observation that science teachers use theoretical explanations, which refer neither to nature nor to history of science and quickly move to mathematical representations. In this study, two of the three teachers referred to nature when presenting examples rooted in students' real-life examples. Nonetheless, mathematical representations cannot be avoided when teaching physics, especially in grade 11. However, for conceptual understanding; students should first be helped to develop conceptual explanations rooted in their experiences before moving to abstract mathematical representation. This is what Mr C did and to a small extent, also Mr M.

Providing explanations is central to teaching and learning; hence, Kulgemeyer and Riese (2018:7) call it "… the bread and butter of science teachers' existence." A prime purpose of teaching is to make students understand and to attain that goal, thus providing explanations that take into account the characteristic of the group of students is critical. This is because explanations become effective and plausible when they consider the characteristics of the students. More evidence of the use of knowledge of the science curriculum is apparent when teachers identify the key ideas or concepts they feel are imperative for students to understand so that they develop a conceptual understanding of the topic. Mavhunga and Rollnick (2013) refer to it as curriculum saliency. As revealed by the time he took to explain and logic to be infused, it was concluded that Mr C regarded those concepts as important for students to know. Mr C emphasised some concepts more than the others, which was then interpreted to mean that he regarded them as central to understanding.

The findings further indicated that, although the teachers made an effort to explain using real-life examples and demonstrations, their level of success differed. When providing explanations, Kulgemeyer and Riese, (2018:20) state that PCK "…played the role of transferring CK to explaining performance." This could therefore mean that the PCK of the three teachers differed, as shown by the differences in the quality and clarity of their explanations. The fact that Mr C identified and used more than one example and/or demonstration per concept is indicative of knowledge of the goals and objectives of the curriculum of force, including the breadth and depth of force concepts. By using multiple real-life examples in his explanations, he enhanced students' development of conceptual understanding and how things happen in their everyday lives. However, that there were differences in the teachers' abilities to make on the moment decisions of the examples and actions to take when explaining, is indicative of variations in their PCK-in-action strengths (Cabello et al., 2019; Kulgemeyer & Riese, 2018).

That the teachers' knowledge of the science curriculum manifested differently during science teaching explanations is significant, because it highlights areas of classroom teaching that teachers could receive support on. Science teaching explanations are inevitable in science classrooms. Kulgemeyer and Riese (2018) refer to them as the "bread and butter of science teachers' existence." Therefore, teachers should be empowered on how to make plausible and intelligible explanations.

Limited knowledge of students' understanding of science

Another finding is that the teachers' knowledge of how students understand was limited. One of the indicators of the knowledge of how students understand science is the ability to identify what they know, including misconceptions (Mazibe et al., 2018). The study revealed that the teachers had positive views about the knowledge of how students understand force concepts (**Table 4.4**). In particular, the teachers had positive views about the knowledge of students' misconceptions (**Items 15, 18 and 20**). However, during teaching, all of them started the lessons by reviewing what students had learned previously (**Section 6.3.2.2.1**). When introducing the topic, they dedicated most of the class time reviewing what students knew about the concepts of force through questions and answers, mostly low-order questions (**Section 6.3.2.4.1**). As Binder et al. (2019) posit, prior knowledge can be in the form of knowledge of facts and meaning. But all three teachers reviewed knowledge of facts higher than knowledge of meaning. Given that they asked low-order questions, students did not have more opportunities to provide explanations, thus resulting in limited opportunities for teachers to notice whether students had misconceptions or not. Although they did not purposefully attempt to solicit students' misconceptions, Mr C and Mr M identified them when they arose and they performed small-scale demonstrations to help students understand. In general, all three teachers did not purposefully reveal students' misconceptions.

However, Iona et al. (2012:349) explain that, in order for students to understand the new subject matter, they need to "…relate new concepts to knowledge they already possess…", which did not seem to be the concern of the teachers in this study. The fact that teachers did not reveal students' misconceptions of the concepts of force could mean that they had limited knowledge of what could facilitate or impede comprehension.

Barendsen and Henze (2017) explain that what teachers do in the classroom is informed by other knowledge domains and that it also involves making decisions on the spot, which they call PCK-in-action. Seeing teachers giving scientifically clear explanations and identifying misconceptions when they arose during teaching, but failing to reveal what students know by asking meaning-seeking questions, could mean that their PCK-in-action was limited. Based on the working definition of PCK that this study adopted, “the teachers’ understanding and enactment of how to help a group of students understand…” their understanding of students’ prior knowledge and misconceptions seemed limited.

The finding is significant because it highlights that the teachers recognise the abilities of students to recall the factual knowledge as an important element of science learning. This means teacher trainers should consider how best they can help teachers to reveal students’ personal understandings of science concepts and how to use them as entry points to teaching those concepts.

Lack of knowledge to plan for a lesson

Over reliance of teachers on low-order questions could also be explained in terms of their lesson planning. It was also found that the teachers’ lesson planning was superficial and lacked the details and evidence that it had been done with care and diligence (**Section 6.3.2.5.2**). Only two teachers had written lesson plans. However, they did not write them for all the lessons that I observed. The questions and classroom activities that could enable students to construct meaning and thus reveal prior knowledge, including misconceptions, should be developed before the lesson. Therefore, they need time to prepare. However, teachers had indicated that they did not have time, because of their large teaching load (**Table 6.1**) and interruption of school attendance as a result of a teachers’ strike (**Section 6.3.2.5.2**). Barendsen and Henze (2017:1142) highlight that PCK encompasses “… knowledge base used in planning for and delivery of topic-specific instruction.” Park and Oliver (2008) refer to it as knowledge-on-action or PCK-on-action; the knowledge that is developed during planning as teachers reflect about what went right or wrong in the previous lesson and how they could improve in the next lesson and so on.

Since the teachers did not seem to give themselves enough time to plan for the lessons, it implies that they created limited opportunities to reflect on practice, thus fewer chances of developing their PCK, both PCK-on-action and PCK-in-action. On the one hand, teachers might not be creating opportunities to reflect on their practice because they are not aware of the benefits of reflections, hence they regard it a waste of time. On the other hand, it could be because they lack the skills to reflect on their practice; that is, they do not know the right questions to ask themselves and to respond to them. This finding is significant because it could be pointing to one of the reasons why science teachers' PCK is not developed.

6.4.3. Approaches when teaching force and momentum

Traditional teacher-centred approaches

The study also found that although there were some elements of student-centred approaches in one classroom, they were very minimal, such that in general their approaches were teacher-centred. The teachers' perceptions of the approach to teaching the topic were both teacher-centred (**Table 4.8a**) and student-centred (**Table 4.8b**). Achor et al. (2019:97) explain that "… interaction between teacher and students is a fundamental part of the teaching-learning process used in Physics." Moreover, teacher-centred classrooms are characterised by teachers who spend most of the class time in teacher-directed behaviours (Achor, et al., 2019). The actual practice of Mr C aligned with the perceived practice in that he approached the topic through both teacher- and student-centred approaches while Mr L and Mr M's approaches were only teacher-centred. All three teachers conducted teacher-directed whole-class discussions **(Section 6.3.2.3.1)** and asked most of the questions, while students listened and copied notes. Nonetheless, Mr C occasionally allowed students to ask questions and to direct discussions **(Section 6.3.2.5.2)**. As explained, they provided explanations and teacher-initiated representations **(Section 6.3.2.3.2)**. Consequently, there was one-way interaction in all three classrooms **(Section6.3.2.5.1),** except in the few cases where Mr C' students asked questions. When inquiring about their views about teaching, the teachers portrayed a constructivist view, but when talking about teaching they used words that indicated that they had knowledge transmission views **(Section 6.3.2.5.3)**. This could mean that the teachers' views about teaching were consistent with practice, hence prevalent teacher-dominance. This finding supports the view of other scholars that science, especially physics, is taught through teacher-centred approaches (Haagen-Schützenhöfer & Joham, 2018; Karal, 2017). Even after interventions at teacher education programmes, some of the teachers did not change their perceptions of teaching, hence they begin their teaching profession with teacher-centred approaches (Karal, 2017). However, some of those with student-centred beliefs still experienced challenges putting them into practice.

That teacher-centred approaches dominated the three classrooms could be attributed to inadequate planning, and reflection-on and reflection-in teaching. Reflection is one of the competences essential for teachers to improve the quality of instruction. Through reflections, they get to realise what worked and what did not work during instruction, thereby improving the next lesson. That the teachers consistently employed teacher-centred strategies throughout the entire topic could mean that teaching was a routine to them. The finding is significant and researchers and professional development providers should focus on improving the teachers' reflection proficiency and enactment of student-centred strategies.

6.4.4. Explanation of physical science teachers' practices

This section attempts to answer the fourth research question, which states:

> How can the teachers' perceptions of their knowledge and practice be explained and/or understood?

This section discusses the relationship between the teachers' perceptions of their knowledge to teach the concepts of force to classroom practices based on the results presented in Chapters 4 and 5 and the cross-case analysis in Chapter 6. Although research on the relationship between in-service science teachers' knowledge base and perceptions is limited, what is available provided insights on their exploration. For example, a study that explored the relationship between teachers' knowledge of students' misconceptions and perceptions about teaching electric fields, found that understanding misconceptions does not always correlate to conceptual perceptions of teaching about electric fields (Moodley & Gaigher 2019). It was therefore not strange to find that, in general, the quantitative and qualitative results of this study indicated that, although the teachers had positive views about their knowledge to teach the concepts of force, these perceptions shaped their practices to a small extent. Many more occurrences happen in the teaching and learning process and the teachers' environments, which shape practice. However, it is evident from the findings that the teachers were confident about their knowledge to teach the concepts of force, which is sometimes over-estimated and thus affect their practice. This suggests that, because the teachers believe that they had enough knowledge to teach, they sometimes did not see the value of incorporating other aspects of teaching practice such as lesson planning **(Section 6.3.2.5.3)**, which provide opportunities for them to reflect-on-practice, thus impacting their knowledge base and practice. Therefore, this shows that what teachers perceive to know does not always translate into practice.

The Spearman correlation **(Section 4.5.3.1)** registered a relationship between the knowledge components although the relationships differed in strength. The MLR **(Section 4.5.3.2)** indicated that, although a relationship exists between knowledge of the science curriculum, particularly content knowledge (CK), it is negative, meaning that more CK does not necessarily mean teachers have best approaches to teaching. As shown in **Table 6.1**, two of the teachers had a bachelor's degree in science education and have specialised in physics. They supposedly have the same amount of physics CK. However, during teaching their CK informed how they provided explanations, examples and representations differently. Moreover, the clarity and logic of their explanations also differed **(Section 6.3.1.2.3)**. Although the teachers seem to have knowledge of those three aspects, there were variations in how they informed their practices. These variations were also shown by the differences in the strength of the correlations (**$0.219 \leq r \leq 0.658$**r). This further indicates that the teachers' possession of a particular knowledge domain may not necessarily mean that they possess the same amount of knowledge of the other domain. The fact that there is a small to medium relationship between the knowledge domains means that the teachers do not necessarily possess the same level of understanding of each of the knowledge bases investigated in this study. A teacher's level of understanding how students understand science may not be as strong as that of instructional strategies. This implies that during teaching, that particular teacher's knowledge of how students understand science could inform decisions more than knowledge of instructional strategies.

As indicated, teachers' perceptions and knowledge bases are not the only aspects that influence practice. Other factors, as highlighted in **Section 6.3.2.5.2**, also shape how they teach. The fact that the teachers in this study used teacher-centred approaches could be explained by the other factors that are neither perceptions nor knowledge based. Teachers are always working under time constraints. Even in this case, when justifying their instructional choices, they pointed to the limitations of time available to finish the syllabus. In particular, they highlighted that the teachers' strike, which was on-going at the time of this study, wasted most of the school time, hence they were trying to get through the curriculum as fast as they could. Even though the Lesotho General Certificate in Secondary Education (LGCSE) examination is written at the end of grade 12, the teachers felt that, if they leave much work to be done in grade 12, then that will mean more work for both teachers and students, which will have to be done within a short time.

The teachers further reiterated that their approaches were motivated by the nature of the examination **(Section 6.3.2.5.3)**. Mr C pointed out that the type of questions he asked when assessing his students were similar to those asked in the examination. Particularly, he said that it is of no use to make his students practice what they will not be asked, and therefore most of his homework assignment questions required calculations.

Mr L in particular indicated that the expectations and demands of the school administration, particularly the head of department (HOD), influenced what and how he taught. The HOD is mostly concerned about syllabus coverage, so he used strategies that helped him to cover the material as expected by the HOD. The availability of science laboratory space and materials also influenced the teachers' practice. Mr C highlighted unavailability of science laboratory materials in his school. His students thus did not conduct experiments. While Mr L pointed out unavailability of both a science laboratory and materials, to improvise takes time, hence he taught the concepts theoretically. Although Mr M had both laboratory space and materials, his students did an experiment only once and they did not investigate; rather, they followed a predetermined procedure with the aim of confirming what the teacher had already taught them. The fact that a mismatch was observed between the teachers' perceptions of knowledge and practice does not necessarily mean that they did not know; rather, they experienced challenges due to other factors as found in this study (Cheng et al., 2016; Gess-Newsome & Lederman, 1995).

That the teachers did not fully translate their perceived knowledge and skills to effect strategies to increase students' participation and comprehension while still incorporating the issues of time and resources availability, could mean that their PCK was not fully developed. This argument is consistent with Barendsen and Henze's (2017) contention that there are other psychosocial factors that play a role in classroom decision-making hence, teachers realise their PCK.

6.5. Contribution to knowledge

Literature reviewed in Chapter 2 Section 2.4 indicated that in-service science teachers have both positive and negative perceptions about different aspects of the knowledge base for science teaching (Moodley & Gaigher, 2019; Sadoglu & Durukan, 2018; Wei & Li, 2017). However, the teachers' perceptions did not match with their practices (Barendsen & Henze, 2017; Qhobela & Moru, 2014; Savasci & Berlin, 2012). The mismatch between their perceptions and practices is explained in terms of the teachers limited PCK. That is, teachers displayed limitations regarding how to enact instruction that aligns with their perceptions while working within different constraints due to limitations of time, demotivated students and unavailability of laboratory space and materials (Pimentel & Mcneill, 2013; Qhobela & Moru, 2014).

From the researcher's perspective, one of the significant contributions of this study was the investigation of physics teachers' perceptions of their knowledge of force and momentum, and how they shape their practices, especially in the context of Lesotho. The study investigated teachers' perceptions of knowledge of five domains of teacher knowledge base. This is an important contribution because PCK entails teachers' ability to use knowledge from different domains during teaching. Therefore the study revealed that the teachers' inability to integrated different knowledge domains while working within different contextual factors results from, among others, lack of/or insufficient lesson planning. This is because thorough lesson planning gives teachers the opportunity to reflect-on their practices. As they reflect-on practice, they identify areas that need attention and thus simultaneously develop their PCK. The study therefore contributes that in addition to other factors, teachers' limited PCK and inability to teach the way they believe they should results from their lack of/or insufficient lesson planning.

6.6. Conclusions

In this study, I investigated the physical science teachers' knowledge to teach force and momentum and how it shaped their classroom practices, if at all. I conducted a survey intended to capture the physical science teachers' perceptions of their knowledge to teach the concepts of force, followed by classroom observations and post-observation semi-structured interviews to ascertain if the perceptions shaped practice or not. After a survey of 92 physical science teachers in schools within five districts in the lowlands of Lesotho and observations of lessons of three teachers, statistical analysis concluded that the teachers had positive perceptions of their knowledge base. Analyses of classroom observations, interviews and lesson plans indicated that when teaching, some of the components of the knowledge base emerged more than the others, which indicated that their practices were not completely informed by their perceptions of knowledge, but that there were other factors that influenced practice.

Although the findings of this study confirmed those from previous studies on teachers' perceptions and practice, this is significant in the context of Lesotho where literature reviewed in this study did not find studies of this nature. That the teachers' perceptions did not match their practices could be attributed to many things such as the contextual factors as found in other studies by Qhobela and Moru (2014). However, this study adds to this finding a different dimension of lack of in-depth lesson planning. The study highlighted that when teachers do not diligently plan for their lessons, they deprive themselves the opportunity to reflect-on and in their practices hence develop their PCK. This study has therefore put to the fore that, one possible reason why teachers' perceptions of their knowledge base did not match their practices is the underdeveloped PCK, which is a result of lack of in-depth planning.

Previous studies that explored relationships between teachers' perceptions and practice produced conflicting findings. In this study, I used a mixed method approach as opposed to the single approach used in the previous studies (Cheng et al., 2016; Moodley & Gaigher, 2019). It is possible that the results will vary, because actual practice, as opposed to reported practice, was observed. The approach made it possible to map what the teachers said they know and do against what they actually did.

This study used the PCK conceptual framework as framed by Magnusson et al. (1999). The framework helped to delineate the components of teacher knowledge to focus on. The components that form this framework are orientations towards science teaching, knowledge of the science curriculum, knowledge of how students understand science, and knowledge of instructional and assessment strategies used when teaching science. Since each of the components has sub-components, I used it to develop the questionnaire, and as an analysis framework for classroom observations and lesson plans. While different studies used Magnusson et al.'s framework mostly as an analysis tool, I used it to guide me during data collection and analysis. This study therefore contends that using this framework to guide both data collection and analysis can assist in obtaining a comprehensive view of the teachers' PCK and practice.

6.7. Limitations of the study

There are limitations with regard to data collected. Data were collected from teachers who were teaching in five districts in the lowlands instead of ten districts across the country. The challenge with this data is that the characteristics of the schools and students in these five districts were similar; as a result, the data lacked diversity in terms of school and student contexts. Both quantitative and qualitative data were collected at a demanding time for the teachers. Quantitative data were collected from August to October when they were preparing students for final examinations and qualitative data were collected from April to June. In the same way, teachers were finishing off teaching and getting students ready for mid-year examinations. Therefore, this might be a limitation, because it is possible that they did not give enough thought when responding to the questionnaires; even during observations they were “cutting corners”, as one teacher had explained.

Another limitation is that the second phase of data collection (qualitative) was done when teachers were on strike. The classroom observations were done at a time when the strike had been suspended for three months. This was a limitation for the study because it could have impacted on the collected data. That is, teachers were working under pressure due to time constraints. However, different methods of data collection were used (classroom observation, semi-structured post-observation interviews as well as analysis of lesson plans and the syllabus). Although each of the methods used has its own innate errors and limitations, which cumulatively may affect a few results and conclusions made, the different approaches were complementary when triangulated, thereby improving confidence in the findings.

The study was also limited in terms of the number of cases followed for classroom observations, which were small and comprised physical science teachers. This means that the results cannot be generalised to other physical science teachers. Although they may apply to them, caution must be taken when doing so. A large study could be done to ascertain if these results are applicable to other teachers or not.

Moreover, only male teacher participated in the qualitative part of the study. Even though the quantitative data showed that there were more male physical science teachers than females that only males participated in the qualitative phase is a limitation. This is because the results may raise gender issues. However, another study could be done and thus guard against gender issues.

6.8. Implications and recommendations for practice and research

6.8.1. Implications and recommendations for practice

As highlighted in **Table 6.1** that the teachers' teaching loads exceeded the recommended number, it was not surprising that the challenge of lack of sufficient time to do most of their activities was a concern for all teachers observed. Therefore, this was found to be one of the factors that impeded them from doing thorough planning of the lessons before going to the classroom. As indicated, lesson planning is one of the tools that is supposed to help teachers to reflect on their knowledge and teaching, therefore, if teachers are not provided the environment to support them in engaging in effective and quality practice, then the quality of education is compromised. This study therefore recommends that teachers should be provided with school environments that afford them enough time to engage in reflective activities such as lesson planning. Moreover, there should be professional development opportunities that focus on assisting teachers to reflect on all aspects of teaching.

6.8.2. Implications and recommendations for future research

This study's focus was on establishing teachers' perceptions of their knowledge base to teach concepts of force and how it shapes practice; not on the actual knowledge that they have. Whether they possess the knowledge they believe they had was deduced from the observations. However, it was possible to make wrong deductions. So future research could focus on investigating their knowledge, not perceptions, and whether and how that shapes practice.

In order to aid teachers to develop PCK that will help them work within the contextual factors, some of which are not easy to do away with, future research could also target developing one aspect of PCK such as PCK-on-action. That is, a larger group of teachers may be helped to develop content representations (CoRes) of the concepts of force and assess whether it can impact practice. This is because previous research found that developing topic specific CoRes does not only develop PCK but also content knowledge.

The study also found that teachers who are the least experienced use a variety of strategies compared to more experienced teachers. This implies that, because experienced teachers have been in the field for a long time, they have long stopped to engage and reflect on teaching as they no longer do lesson planning. That is, they teach through experience. They teach the same way probably because they are used to getting the required results. So future research could focus specifically on more experienced teachers to determine how they teach and what shaped their practice.

6.9. Final remarks

More research on science teaching focused on exploring teacher knowledge and to track how it is translated into teaching. This study has therefore tracked the physical science teachers' perceptions of their knowledge to teach the concepts of force, their teaching practice as well as the teachers' purposes for observed practice, primarily to ascertain whether there is a relationship between teachers' perceptions of knowledge and practice or not. This purpose called for the identification of areas of teachers' knowledge of what to focus on. In this regard, the study adopted the model of science teachers' PCK as coined by Magnusson et al. (1999).

The study has shown that teachers' perception of their knowledge is to a limited extent related to practice. This means that what happens during teaching, though it might be influenced by what teachers regard as important to do, is also determined by other factors.

In concluding this research study, it is worth highlighting what I have learned throughout this research process. As a physics teacher and inspector, I have learned that what happens during classroom teaching is not dependent solely on the teachers' perceptions of their knowledge base. Rather, it depends on other factors, such as the limitations of time and unavailability of resources. However, of utmost importance is the realisation that the teachers' insufficient lesson planning deprive them the opportunity to develop their PCK because they do not reflect-on their practice. Furthermore, there is a need to provide teachers with professional development activities meant to assist them to engage in to reflection activities and to realise the importance of lesson planning.

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Appendix A: Survey

SCIENCE TEACHERS' KNOWLEDGE BASE FOR TEACHING

Thank you for your time to participate in this study. Please take your time to think about the questions and give thoughtful and genuine responses. Your responses to this questionnaire will be highly appreciated.

SECTION A: DEMOGRAPHIC INFORMATION

Questions 1 up to 4, tick with X in the appropriate box

1. Gender

Male	
Female	

2. Age in Years

21-30	
31-40	
41-50	
51-60	
61+	

3. Highest Qualification

STC	
Dip Sec Ed	
Degree	
Post graduate Degree	

4. Teaching experience

1-5	
6-10	

11-15	
16-20	
21+	

5. Subject Specialisation

Physics and Maths	
Maths and Chemistry	
Chemistry and Biology	

If you have not specialized in any of those given, please write yours here ______________________________

SECTION B: KNOWLEDGE BASE FOR TEACHING

For items 6 up to 79 please tick the best option with an X

A. KNOWLEDGE OF SCIENCE CURRICULUM					
To what extend do you agree or disagree with the following statements	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
6. I can clearly explain science concepts in the topic force.					
7. I am familiar with the topic force which I am teaching in grades 11 or 12.					
8. I have sufficient knowledge of the force concepts to answer students' questions in learning.					
9. I am familiar with the whole structure and directions of grades 11 and 12 physics syllabus concerned with the topic force.					
Rate how important the following are to students when you teach science topics such as force	**Not very important**	**Not important**	**Not sure**	**Important**	**Very important**
10. Students should think in a sequential and procedural manner when learning science concepts such as force.					
11. Students should understand science concepts, principles, and strategies.					
12. When learning force concepts, students should be able to think creatively.					

13. Students should be able to provide reasons to support their conclusions.					
B. KNOWLEDGE OF STUDENTS' UNDERSTANDING OF SCIENCE					
Please rate how much you agree or disagree with the following statements	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
14. Before I teach the topic force, I anticipate difficulties that students might have about the force concepts (e.g. Moment of force).					
15. I begin every topic by giving students test to determine what they know.					
16. I use a variety of teaching approaches or strategies to develop students' understanding of the topic force.					
17. Before I teach the topic force, I find out what students already know about it.					
18. I am aware of the misconceptions students have about force concepts.					
19. I realize the errors students make when solving problems related to force concepts (e.g. identifying forces acting on objects).					
20. I know that students sometimes confuse force with other concepts.					
21. I know some of the possible sources of students' difficulties to learn force concepts.					
22. I know what students need to know before learning force concepts in grades 11 or 12.					
23. I know how to plan activities which are interesting to students when I teach the topic force.					
24. I give students activities similar to those that are in their real life.					
C. KNOWLEDGE OF INSTRUCTIONAL STRATEGIES					
Please indicate how often do you do the following	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
25. When I teach the topic force, I relate force concepts to students' daily life experiences.					
26. As I teach force I ask students to explain their understanding to other students.					
27. I ask students to complete challenging exercises that require them to go beyond the instruction they got on force concepts.					
28. I encourage classroom discussions among students as they learn the topic force.					
29. I engage students in the whole class discussions.					

30. I link new content about force to students' prior knowledge.					
31. I ask students to decide on their own problem solving procedures.					
32. I encourage students to express their ideas about force in class.					
33. I have students work in small groups as they learn about force.					
34. I give students chance to make formal presentations to the rest of the class (e.g. on individual or group assignments, projects).					
35. When I teach force I give students activities in which they represent data using tables, charts, graphs etc.					
36. When I teach force, I present students with a series of force diagrams for them to analyse.					
37. I ask students to complete exercises on force before instruction.					
D. KNOWLEDGE OF ASSESSMENT OF SCIENCE LEARNING					
How often do you do the following?	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
38. I use standardized tests produced outside the school when I assess students learning of force.					
39. I give students teacher-made short answer or essay tests that require students to describe or explain their reasoning.					
40. I use teacher-made multiple choice or true-false or matching tests to assess students learning of force concepts.					
41. I assess how well students do on homework assignments.					
42. I assess how well students do on practical or laboratory exercises.					
43. I observe students as they do experiments or practical work to assess their experimental skills.					
Rate how often you do the following when you assign homework on the topic force.	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
44. I asses students' ability to write definitions or other short writing assignment about force concepts.					
45. I give students small investigation(s) or data gathering assignments related to the topic force.					
46. I assign students' individual work on experiments of force concepts.					

47. I assign students work in small groups on experiments of force concepts.					
48. I assign students work to find the uses of the content covered under the topic force.					
49. I ask students to prepare oral reports of the investigations they did.					
E. ORIENTATIONS TOWARDS TEACHING					
Rate how you agree or disagree with the following statements	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
50. When I teach the topic force, I pay more focus on students' ability to make observations.					
51. I emphasize that students draw their own conclusions of experiments.					
52. When I teach the topic force I emphasize that students should know definitions.					
53. I make sure that students know scientific facts.					
54. When teaching force concepts, I give students situations for them to explain.					
55. I give students challenging questions and probe them for answers.					
56. I give students activities which help them discover science concepts related to the topic force (e.g. elastic limit, moments of force).					
57. When I teach the topic force, I ask students to work in small groups.					
58. I engage students in determining what to investigate.					
59. When teaching about force, I give students hands-on activities (e.g. Draw diagrams, do experiments etc.).					
60. When teaching the topic force, I give students activities from which they solve real life problems.					
61. A quiet classroom is generally needed for effective learning.					
62. Students are not ready for "meaningful" learning until they have acquired basic reading and scientific skills.					
63. It is better when the teacher not the students decides what activities are to be done.					
64. Students' projects often result in students learning all sorts of wrong "knowledge."					
65. How much students learn depends on how much background knowledge they have.					

F. CLASSROOM PRACTICES/APPROACHES TO TEACHING FORCE					
When teaching the topic force, how often do you do the following?	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
66. I ask students to listen as I explain to the whole class.					
67. I ask students to keep quiet and listen as I teach.					
68. I ask students to watch as I demonstrate an experiment (e.g. verification of Hooke's law).					
69. I begin the lesson by explaining the concepts.					
70. I ask students to make predictions based on the action of force.					
71. I ask students to explain their predictions.					
72. I ask students to observe natural phenomena, such as force, and explain what they see.					
73. I ask students to design experiments about force.					
74. I ask students to conduct experiments or investigation related to force.					
75. I ask students to present data from experiments or investigations.					
76. I ask students to interpret data from experiments.					
77. I ask students to use evidence from experiments and investigations to support conclusions.					
78. I begin the lesson by giving an activity which needs students to use their prior knowledge.					
79. I give activities from which students will be able to explain concepts on their own.					

Appendix B: Classroom Observation Protocol

Name of Teacher ____

Class ____ **Duration** _________ **Date** ________ **Topic** _______________________________

GENERAL TEACHING BEHAVIOURS	
1. STUDENTS	
The teacher…	
a. Gives activities which tap on students' prior knowledge	
b. Highlights students' difficulties	
c. Activities/problems enable application of new knowledge.	
d. Individual/group work	
e. Students present own ideas	
2. INSTRUCTIONAL STRATEGIES	
The teacher …	
1. Provides opportunities for independent or group learning to promote depth in understanding content.	
2. Encourages students to express their thoughts.	
3. Concepts represented differently	
4. Refers students to examples/incidences found in their environment	
5. Gives students opportunities to suggest what to investigate and how to do it	
3. ASSESSMENT	
The teacher …	
1. Asks questions that need understanding	
2. Emphasises students' ability to conduct experiment (set up materials, record etc.	
3. Asks questions that need memorised facts and formulae	
4. Assesses students' ability to solve problems	
5. Asks oral questions only	
6. Gives written work only	
4. CURRICULUM	
The teacher …	
Gives rationale for teaching the topic	
a. Ensures students work collaboratively and share ideas (development of communication, working together etc.)	
b. Refers to work done in earlier grades	

c. Deviates/stick to syllabus	

Appendix C: Interview Protocol

POST OBSERVATION INTERVIEW PROTOCOL FOR PHYSICS TEACHERS

Teacher code: __________ **Date:** ___________ **Time:** __________

Type of interview: face-to-face interview held at the end of a three week classroom observations

INSTRUCTIONS:

1. You are asked to respond to these questions to the best of your knowledge.
2. You are allowed to ask questions if you feel some questions are not clear.
3. You are kindly informed that the conversation will be recorded, however it will be used for the purposes of this study only. After the study is completed it will be destroyed.

TEACHER BACKGROUND:

Name of teacher: ____

Qualifications: _____________________ Major Subjects: ______________________________________

Teaching experience: ________________________

Knowledge of science curriculum

1. What do you intent your students to achieve by teaching them LGCSE physical science syllabus?
2. What are you intending your students to achieve by teaching them the topic force?
3. What is the importance of this topic within the whole curriculum?
4. By making reference to any of the concepts, e.g. inertia, Hooke's law, Newton's laws,
   What is it that you feel students should know at this level? Why?
   What is it that they should not know at this level? Why?
5. What is your understanding of science teaching and learning?
6. Why is it important for students to learn these concepts?
7. You discussed many types of force; can you explain what you based yourself on when deciding on how many types of force to talk about?

Knowledge of students' understanding of science

1. What difficulties/limitations are connected with teaching this topic, force? How did you address those difficulties?
2. From your experience as a physics teacher, what do students find difficult to understand under this topic?
   Why do you think they find it difficult?
   What did you do to ascertain whether your students encounter those difficulties?
3. In the past weeks as you taught the topic force, which concepts did your students misinterpret?
   Did you deliberately reveal those misinterpretations? N/Y
   If YES, what did you do?
   If NO, why?

Knowledge of instructional strategies

5. You gave students written class and homework and discussions, why did you do it?
   Were there other activities you could have given them other than written assignments and discussions? Yes/no
   If YES, why did you choose these ones not those other ones?
   What are their strengths in helping students understand force as compared to other activities?
6. I realised that your students did class work individually, is it you who emphasise this behaviour? Why?

7. You explained concepts (friction and resultant force inertia, etc.) by giving examples and by making illustrations such as, diagrams, can you explain what motivated these decisions.
8. By reflecting on the approach you took when teaching elastic deformation, can you explain what motivated your decision to use the approach you took.

   If you have a chance, how can you change and why?
9. In what ways have your teaching helped students develop the knowledge and skills which you wanted them to have?
10. I realised that you sometimes gave information and sometimes you gave students chance to ask questions, what informs you to make those decisions?

Knowledge of assessment of science

1. For a physics student, which aspects of physics or science should they be assessed on? (You said one of the goals of science is ...)
2. Most of the questions in the assignments were mainly calculations, why was that the case?
3. Under the topic force, what else should students be assessed on? Did you assess them? Why?
4. Why do you think it is important to assess students on those aspects?
5. You mostly asked oral questions, why?

Classroom practices

1. Can you take me through your lesson preparation? (What is your focus, what do you do, why do you do that?) Notes taking
2. What do you base your self on when answering students' questions? (you did not answer the question about people falling to space when on one side of the globe/earth)
3. Before and as you plan, what informs your decisions regarding your lesson plan?
4. How did you introduce the topic force? Why?

Appendix D: Document Analysis Protocol

ASPECTS ANALYSED	DOCUMENTS ANALYSED	
	LGCSE PHYSICAL SCIENCE SYLLABUS	**TEACHERS' LESSON PLANS**
AIMS (worthwhile experience, acquire sufficient knowledge and understanding, develop abilities and skills, develop attitudes relevant to physical science, stimulate interest, promote awareness about scientific process)	What are the aims of the syllabus?	Which aims do teachers plan to achieve?
OBJECTIVES **(**demonstrate scientific knowledge and understanding, handle information and problem solving, make scientific investigations)	What are the objectives of the syllabus?	Which objectives do the teachers plan to achieve?
SKILLS (Observation, recording, measuring, analyzing, interpreting, designing experiments, etc.)	Which scientific skills does the syllabus envision?	Which skills do teachers plan to develop?
INSTRUCTIONAL STRATEGIES (Question and answer, whole class discussion, exposition, group/pair work, demonstration, experimentation, etc.)		Which instructional strategies do teachers plan?
ACTIVITIES **(**Hands-on, discussions, experiments, note taking, calculations etc.)	Which forms of classroom activities does the syllabus encourage?	Which activities do teachers plan?
ASSESSMENT **(**Facts, skills, etc.)	Which aspects of science does the syllabus assess?	What do teachers assess?
(Written, oral, observation)	Which assessment methods does the syllabus encourage?	Which assessment methods do the teachers use?

Appendix E: Data Analysis Grid

Research questions	Themes	Sub-Themes	Categories
What is the knowledge base of science teachers in Lesotho on the topic of force and momentum?	1. Knowledge of curriculum of force and momentum	1.1 Goals of teaching force and momentum	1.1.1 Goals
		1.2 Content knowledge of force and momentum	1.2.1 Content knowledge
	2. Knowledge of how students learn force and momentum	2.1Knowledge of requirements for learning	2.1.1 Students' prior knowledge
		2.2 Knowledge of students' difficulties when learning	2.2.1 Misconceptions about force
			2.2.2 Ways of addressing misconceptions
	3. Knowledge of instructional strategies used to teach force and momentum	3.1 Teacher-centred strategies	3.1.1 Teacher directed discussion
			3.1.2 Lecturing
			3.1.3 Representations of force
	4. Knowledge of assessment of force and momentum	4.1 Assessment methods	4.1.1 Written work
			4.1.2 Oral questioning
		4.2 Dimensions to assess	4.2.1 Knowledge with understanding
			4.2.2 Handling information
How do science teachers approach the topic force and momentum in their teaching in grades 11 and 12 classrooms?	5. Classroom practices when teaching force and momentum	5.1 Traditional classroom practices	5.1.1Knowledge transmission
			5.2.1 Interactivity
			5.2.2 Instructional decision

		5.3 Lesson preparation	5.3.1 Lesson planning
How can the teachers' knowledge base and classroom practices be understood and/or explained?	6. Science Teachers' orientations towards teach force and momentum	6.1 Traditional orientations	6.1.1 Didactic

Appendix F: Ethical Clearance Letter 1 (2017)

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
EDUCATION
OPVOEDKUNDE

Faculty of Education

21-Aug-2017

Dear **Mrs Maphole Marake**

Ethics Clearance: **Mapping Science Teachers' Knowledge of Force and Momentum to Classroom Practices in Selected Schools in Lesotho**

Principal Investigator: **Mrs Maphole Marake**

Department: **Curriculum Studies (Bloemfontein Campus)**

APPLICATION APPROVED

With reference to you application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2017/0962**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours faithfully

Prof. MM Mokhele
Chairperson: Ethics Committee

Education Ethics Committee
Office of the Dean: Education
T: +27 (0)51 401 9683| F: +27 (0)86 546 1113 | E: NkoaneMM@ufs.ac.za
Winkie Direko Building | P.O. Box/Posbus 339 | Bloemfontein 9300 | South Africa
www.ufs.ac.za

Appendix G: Ethical Clearance Letter 2 (2018)

UFS·UV
EDUCATION

Faculty of Education

23-Aug-2018

Dear **Mrs 'Maphole Marake**

Ethics Clearance: **Mapping Science Teachers' Knowledge of Force and Momentum to Classroom Practices in Selected Schools in Lesotho**

Principal Investigator: **Mrs 'Maphole Marake**

Department: **Curriculum Studies Department (Bloemfontein Campus)**

APPLICATION APPROVED

With reference to you application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2018/1115**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours faithfully

Prof. MM Mokhele Makgalwa
Chairperson: Ethics Committee

Education Ethics Committee
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Appendix H:CEO Secondary Letter of Permission

THE KINGDOM OF LESOTHO
MINISTRY OF EDUCATION AND TRAINING

26th October 2017

REF: ED/1/10

Mrs. 'Maphole Marake
P. O. Box 368
Morija 190
Lesotho

Dear Mrs. Marake

RE: REQUEST FOR PERMISSION TO CONDUCT A RESEARCH STUDY

Your letter on the above subject dated 28th September 2017 refers.

The MOET has no objection to you conducting your research study in high schools in Lesotho, as requested. Nevertheless, the onus to solicit consent and permission from the authorities and teachers in your sample schools shall remain with you.

Good luck in your studies.
Yours sincerely

Paramente Phamotse (Mr.)
Chief Education Officer – Secondary (For the Principal Secretary)

Cc. Regional Inspector – South

P.O. BOX 47 MASERU 100 LESOTHO TEL.: (+266) 22 322862 ceo2.moet@gmail.com

Appendix I: Language Editing Letter

TRANSLATUM

Mrs H C Lombard
B.A. (Bibl)
B.Bibl (Hons) – (Cum Laude)
M. Inf. (Cum Laude)
M.A. (Language Practice) – (Cum Laude)

P.O. Box 12122
BRANDHOF
9324

TO WHOM IT MAY CONCERN

I, Huibrecht Christiana Lombard, hereby confirm that I have edited the under mentioned document to the best of my ability.

Mapping Science Teachers' Knowledge of Force and Momentum to Classroom Practices in Selected Schools in Lesotho

by

Marake, 'Maphole Georgina

Although I always strive to consistently maintain the highest quality in respect of document editing I have no way of ensuring that source documents are indeed replaced with my edited version. I also do not have control over changes subsequently made to documents. The final responsibility for documents therefore always rests with the commissioning author.

HCLombard

Mrs H C Lombard
MA (Language Practice) (*Cum Laude*)
SATI membership nr: 1001718

Appendix J: Turnitin Report

Thesis

ORIGINALITY REPORT

6%	5%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	repository.up.ac.za Internet Source	<1%
2	scholar.ufs.ac.za:8080 Internet Source	<1%
3	www.saarmste.org Internet Source	<1%
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8	etd.lib.metu.edu.tr Internet Source	<1%
9	mafiadoc.com Internet Source	<1%