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SCIENCE TEACHERS' PERCEPTIONS OF THEIR KNOWLEDGE BASE FOR TEACHING FORCE CONCEPTS

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Abstract. *It is important for students to understand force concepts because they are central to learning physics and other sciences; however, students find it difficult to understand. There are calls for teachers to tap into their professional knowledge and develop beliefs that help them assist students comprehend the topic. To meet this challenge, teachers' perceptions of their knowledge base for teaching force concepts should be probed because perceptions act as windows into teachers' practices. This study, therefore, explored physics teachers' perceptions of their knowledge base for teaching force concepts. Science teachers' pedagogical content knowledge (PCK) frameworks were used to develop a questionnaire based on a 5-point Likert scale administered to 100 physical science teachers who were randomly selected from 54 schools in five districts in Lesotho. Data were analysed using descriptive statistics. The results suggest that, even though teachers reported positive views about their knowledge base, there is no correlation between sub-components of curricular knowledge. It is concluded that teachers should build the curricular knowledge by participating in collaborative activities. It is, therefore, recommended that studies that probe teachers' actual knowledge of PCK constructs are executed, so that appropriate information is available when planning professional development activities targeting teachers' PCK.*

Keywords: *force concepts, pedagogical content knowledge, teacher knowledge, teachers' perceptions of knowledge*

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Introduction

Understanding force concepts is one of the basic competences that students need to develop in order to understand most of the science topics, particularly physics. This notion is supported by Carson and Rowlands (2005) who expounded that Mechanics, of which force concepts are constituents, is a domain of physics that is fundamental to learning science and understanding natural phenomena. It provides skills needed to understand other science topics and the natural environment (Singh & Schunn, 2016). For instance, people do not experience force rather; they feel and see its effects such as change of speed and size. Therefore, for students to understand why objects of different mass and size that fall from the same height reach the ground at the same time, they should understand force and be able to engage in imaginative thinking, which is one of the competences needed to understand and advance in science related fields (Carson & Rowlands, 2005). It is therefore important for students to understand force concepts correctly as it provides basic tools for understanding science (Sadoglu & Durukan, 2018).

Teaching force concepts proved to be problematic because most students seem to have preconceptions of force that are not scientifically correct. Handhika et al. (2016) have indicated that students believe that no forces act on stationary objects while Khandagale and Chavan (2017) explained that students hold the view that a continuous force is needed for continuous motion to take place. Nonetheless, these are non-scientific views because, for all stationary objects, there are balanced forces acting on them and moving objects eventually stop because of friction (Singh & Chunn, 2016). For instance, a ball rolling on the ground eventually stops because of frictional force between the ball and the ground. If there was no friction, the object would continue moving. Students' alternative conceptions arise through their encounter with force in their daily experiences. They engage in imaginative thinking and try to make sense of what they see happening in their natural world (Carson & Rowlands, 2005; Nasri et al., 2020). Consequently, they develop alternative conceptions that do not align with scientific knowledge. This in turn creates problems when learning about the concepts in school. That students have different conceptions of the force most of which contradict scientific knowledge has implications for teaching and teacher knowledge.

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Teachers play a critical role of being catalysts in teaching and learning (Margot & Kettler, 2019). They are responsible for creating the environment that is conducive for all learners to learn effectively. For this to happen, teachers should have solid knowledge base for teaching among which pedagogical content knowledge (PCK) is the most essential (Shulman, 1987). PCK is the knowledge base that enables teachers to plan and teach in the manner that the subject matter is comprehensible to all students. Nonetheless, how teachers enact their teaching depends on many factors including their perceptions.

Perceptions are people's personal understandings about a phenomenon, such as knowing how to teach and one's content knowledge of force (Cheng et al., 2016). Understanding teachers' perceptions of their knowledge base provides windows into their classrooms, because they decide on which knowledge base to enact based their perceptions (Liepertz & Borowski, 2018; Şen & Sarı, 2017). However, there are conflicting views regarding teachers' perceptions and practice. On the one hand, Anagün (2018) highlighted a connection between teachers' perceptions of constructivist learning environment and 21st Century skills. On the other hand, Park et al. (2016) expounded that although teachers had positive views about teaching approaches such as Science, Technology, Engineering, Arts and Mathematics (STEAM) education, they had challenges implementing it. Nonetheless, van Schaik et al. (2018) indicated that teachers' perceptions and attitudes towards their knowledge base often serve as a barrier towards its utilisation. In this study therefore, physics teachers' perceptions of their knowledge base were measured so that a window into their educational practice could be understood.

Research about the teaching of concepts related to force indicated that physics teaching is inclined to rely on traditional teacher-centred strategies, in which teachers transmit most of the information (Mazibe et al., 2018; Melo- Niño, 2017; Qhobela & Moru, 2014). Mazibe et al. (2018) compared the reported and enacted PCK of four physics teachers in South Africa when they taught graphs of motion, while Melo-Niño (2017) examined the initial characterization of four Colombian in-service teachers' PCK while they taught electric field. Both studies found that teachers were teaching using more teacher-centred strategies. In a study done in Lesotho, Qhobela and Moru (2014) explored areas where physics teachers may need professional development, and teachers' views about science teaching, and found that their actual practices were based on teacher-centred strategies.

Research Problem

Research about science teachers' perceptions generally focused on their views about particular educational strategies (Anagün, 2018; Feyzioğlu, 2019), implementation of approaches such as Science, Technology, Engineering, Arts and Mathematics (STEAM), integrated teaching and learner-centred strategies (Du Plessis, 2020; Park et al, 2016; Tudor, 2015) and the teaching of science in general (Qhobela & Moru, 2014). The topic of forces is very important in the physics curriculum because it is part of the curriculum for students who will pursue STEM careers, such as engineering (Canu et al., 2017). However, it has been found that the way it is taught is not helpful in helping students correct their misconceptions such as "continuous force is needed for continuous motion to take place" (Khandagale & Chavan, 2017, p. 202).

It is in this regard that it is imperative for teachers to understand that the way they perceive different aspects of teacher knowledge have a bearing on how they enact teaching. Consequently, this study explores the perceptions of physics teachers about their knowledge base to teach concepts of force.

Research Focus

This study is grounded on the premise that teachers' educational practices are dependent on their perceptions about their knowledge to teach. Educational practices in this study refer to the teaching and assessment strategies that teachers use when teaching force concepts. It also relates to teachers' knowledge of how students learn the concepts, including how the importance of force concepts in the school curriculum and in students' lives can be discerned. This study seeks to understand the perceptions of science teachers about their knowledge to teach the concepts of force to Grade 11 students. The quality of educational practices depends on the teachers' specialised knowledge (Gul et al., 2021). However, how teachers enact their professional knowledge depends on different factors, such as their perceptions and beliefs about their abilities. Teachers' perceptions about their abilities to teach are imperative as they serve as guides that determine and shape what teachers learn and can do (Gess-Newsome, 2015).

What teachers do in the classroom is directed by what they know and what they believe they know and can do

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(Anagün, 2018; Cavendish et al., 2019). Within the landscape of teachers' knowledge base, Shulman (1987) pointed to PCK as the most prominent component of teacher knowledge that is essential for teaching. PCK refers to teachers' knowledge and skills as it relates to representing particular scientific concepts, by using powerful representations and illustrations so that it becomes easy for students to understand (Azam, 2020; Fischer et al., 2012; Morrison & Luttenegger, 2015). Azam (2020) referred to this conception as topic-specific pedagogical construction (TSPC). Therefore, PCK is a collection of TSPCs that a teacher develops during teaching of a particular topic, such as force concepts, over a long time. In summary, PCK is the knowledge to teach.

Park and Oliver (2008) referred to PCK as "both an internal and external construct" (p. 263); in particular, teachers realise their PCK during planning and actual teaching. It is a construct that is held personally by teachers as they think about what to teach, how to teach it, and what they do, mainly during planning. Consequently, recent debates about PCK referred to it as personal PCK (pPCK) and enacted PCK (ePCK) (Azam, 2020). However, it is worth noting that as teachers develop TSPCs and consequently PCK, there is a knowledge exchange that takes place between various aspects in the teaching and learning situation (Carlson & Daehler, 2019). For instance, using a particular analogy to represent a type of force may not be as helpful as the teacher initially thought it would be. As a result, that particular teacher may develop a negative view about the representation, and hence reject it as part of their PCK. Subsequently, teachers' beliefs and perceptions are also shaped by their experiences when enacting each of the TSPCs. PCK is therefore experiential and embedded in values and practice (Azam, 2020). The framework that is used to delineate teacher knowledge bases that this study is concerned with is explained in Table 1. These are the teacher knowledge components that science teachers are expected to possess in order to teach effectively.

Studies concerning teachers' perceptions about their knowledge to teach, particularly PCK, were mostly qualitative (Barendsen & Henze, 2017; Mazibe et al., 2018; Nilsson & Vikström, 2015). Barendsen and Henze (2017) probed how teachers' articulated knowledge and classroom practice shape each other, while Mazibe et al. (2018) focused on how reported and enacted PCK relate to each other. The authors found a mismatch between reported and enacted PCK. That is, teachers' enacted PCK did not match the reported PCK in some of the aspects of PCK.

Table 1
Components of Science Teachers' PCK

Knowledge base component	Definition
Teacher orientations	These refer to what teachers believe to be the reason why they teach science. Particularly, orientations develop and are developed by what teachers know. Just like the conception of PCK as either subject- or topic-specific, so is the conception of teacher orientations.
Knowledge of the science curriculum	It refers to what teachers know about the breadth and depth of each topic they teach, such as concepts of force. This relates to their ability to relate that topic to others and their familiarity with issues that students previously learned and those they are learning in the present and higher grades. Moreover, it refers to knowing which topics to teach at a particular grade and their importance. In other words, why it is important for students to learn it and what value it has in relation to the entire curriculum that students are learning.
Knowledge of students' understanding	This is the knowledge of the requirements for students' understanding. If teachers' purposes and beliefs regarding students' learning of force concepts is to engage them in inquiry activities, they should know the skills and knowledge that students need. In this way, the students can do effective inquiry activities (Magnusson et al., 1999).
Knowledge of educational strategies	This constitutes knowledge of activities that provide evidence of targeted topics, such as force, and representations that help students visualize ideas that cannot be directly observed (Smith & Banilower, 2015).
Knowledge of assessment strategies	This points to teachers' ability to assess. It includes "any planned method or strategy used in the classroom to establish the level of difficulties or understanding of a particular concept or idea with the purpose of helping students to succeed in learning" (Rahman, 2018, p. 274).

Research Aim and Research Questions

As the literature reviewed in this study indicated, the studies that focused on teachers' perceptions about their knowledge to teach were qualitative. Teachers' perceptions about their knowledge base were captured through teacher interviews and content representations (CoRes). Nonetheless, qualitative studies are concerned with few participants whose results cannot be generalised. For instance, CoRes were used with small number of participants,

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mostly pre-service teachers, with the purpose of capturing their PCK so that professional development activities, for that particular group, can be planned and provided (Williams, 2012). Furthermore, CoRes take time to complete (Bertram, 2012) and require teachers to willingly express themselves. To bridge this gap, this study used a quantitative method. This minimised the errors that might have been brought about by unwillingness of respondents to express themselves and their lack or limited ability to use written language to express themselves. This study therefore aspired to determine teachers' perceptions on the five components of science teachers' PCK for teaching force concepts. Accordingly, the study was guided by the following questions:

1. What are science teachers' perceptions of the five components of teacher knowledge base?
2. What is the correlation among the components of teacher knowledge base?

Research Methodology

General Background

A quantitative survey design was used to measure Lesotho physics teachers' perceptions of their knowledge to teach concepts of force. Mainly, the survey measured the teachers' perceptions of the knowledge base for science teachers which have been described by Magnusson et al. (1999) as the components of science teachers' PCK (Table 1). Data were gathered for four months (August to November 2018) among physics teachers who taught grade 11 classrooms. The questionnaires (100) were distributed to schools by the first researcher. The questionnaire was suitable to collect data about the teachers' perception and to describe the perceptions of their knowledge base to teach force concepts (Creswell, 2012).

Sample Selection

The participants were selected from 54 upper secondary schools (offering grades 8 to 12) in the five districts located in the lowlands of Lesotho. The five districts did not have equal numbers of upper secondary schools; therefore, proportional clustered sampling was used. In order to make sure that the sample was spread equitably, the ratios were worked out as follows (Bordens & Abbott, 2011; Creswell, 2012, p. 145):

$$\frac{Number\ of\ schools\ per\ district}{Total\ number\ of\ schools\ in\ the\ five\ districts} \times population$$

For instance, the district that had 51 upper secondary schools, 37 schools (teachers) $(\frac{51}{136} \times 100 = 37.5)$ were identified. Since some schools had more than one physics teacher, all were asked to participate, because they all taught physics.

Instrument and Procedures

This study aimed at determining the perceptions of physics teachers in the following components of teachers' PCK: 1) orientations towards teaching, 2) science curricular knowledge, 3) knowing how students understand physics, 4) knowing educational and 5) assessment strategies. A closed-ended questionnaire was used to determine what physics teachers perceived they know about teaching force concepts. Some of the questions in the questionnaire were developed by the researchers, while others were adopted from the 1999 and 2015 Trends in International Mathematics and Science Study (TIMSS, 1999, 2015). Table 2 presents a sample of question items adapted from TIMSS while Table 3 shows sample questions in the questionnaire.

The questionnaire contained 65 question items which were all answered on a 5-point Likert scale. The questionnaire included five items that sought to determine the demographics of the respondents. It was divided into five sections pertaining to the five knowledge components. Knowledge of the science curriculum was divided into two parts: knowledge of the breadth and depth of force concepts, and knowledge of their importance. The scales of the two parts were 1 = strongly disagree to 5 = strongly agree and 1 = not important to 5 = very important, respectively. A different scale, ranging from 1 = never to 5 = always, was used for knowledge of educational and assessment strategies.

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Table 2
Sample of Original and Adapted Questionnaire Items

Wording in 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.

Table 3
Sample Questions from PCK Domains

Knowledge domains	Sample items
Knowledge of the science curriculum	I can clearly explain science concepts in the topic force
	Students should think in a sequential and procedural manner when learning science concepts such as force
Knowledge of students' understanding	Before I teach the topic force, I anticipate difficulties that students might have about the force concepts (e.g., Moment of force)
Knowledge of educational strategies	I ask students to complete challenging exercises that require them to go beyond the teaching that they receive on force concepts
Knowledge of assessment strategies	I use standardised tests produced outside the school when I assess students' learning of force
	I assess students' ability to write definitions or other short writing assignments about force concepts
Orientations towards science teaching	When I teach the topic force, I pay more focus on students' ability to make observations

Validity and Reliability of the Questionnaire

The questionnaire was piloted with 23 physics teachers who attended a three-week workshop in March 2018. The piloted questionnaire had 83 items from which 18 were removed. When conducting the main study, the first researcher hand delivered the questionnaires to schools and asked to meet with the teacher respondents where possible. The purpose of meeting with the respondents was to explain the purpose of the survey and to help build the rapport. The effects of these meetings were evidenced by the high return rate of 92%.

Measures were also taken to check the reliability and internal consistency of the questionnaire. First, the questions were grouped so that those that sought for teachers' views about a particular theme were given a matching heading, such as their knowledge about students' understanding. This helped respondents to know what information each item was intended to elicit from them. Secondly, the researchers calculated the Cronbach's alpha coefficients for the separate themes and the whole questionnaire. The reliability estimates of the final questionnaire ranged from .784 to .918, suggesting that the instrument is reliable and could be used with confidence (Taber, 2018).

Data Analysis

In order to describe the teachers' perceptions and to answer the research questions, the following was done:

1. The mean and standard deviations for all 60 items and the five knowledge components were calculated.
2. The correlations among the components were determined using Spearman correlation coefficients.

During data analysis, responses in the range 1 to 2.9 were considered to be in disagreement with the concept. Responses with a value of 3 represented neutral views, serving as a decision point. Responses that fell in the range 3.1 to 5 were considered to be in agreement with the concept. The means and standard deviations were also calculated. The mean signifies the respondents' general response to a specific question and domain whereas

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the standard deviation designated the width of the variation of responses.

Research Results

Table 4 shows the means and standard deviations of each of the components of physics teachers' PCK used in this study.

Table 4
Summary of Mean and Standard Deviations of Components of Knowledge

	KSC		KSU	KIS	KAS		OT
	Breadth and depth	Importance of force concepts			Methods	What to assess	
M	4.34	4.53	4.11	4.05	3.44	3.37	3.78
SD	0.775	0.68	0.75	1.9	1.03	1.01	0.91

Note: KSC = knowledge of science curriculum; KSU = knowledge of student understanding; KIS = knowledge of educational strategies; KAS = knowledge of assessment strategies; OT = orientations towards teaching

In general, the respondents seemed to have positive views about the knowledge to teach force concepts. Especially, they seemed to be confident about their knowledge of the importance of force concepts, indicated by this topic having the highest mean 4.53 and the lowest standard deviation 0.68. However, the respondents did not seem as confident about their knowledge of the aspects of force concepts for assessment, as highlighted by the lowest mean score 3.37.

Teachers' Perceptions of their Knowledge of the Science Curriculum

Teachers' perceptions on the science curricular knowledge have been categorized into two subcomponents: the breadth and depth of the curriculum, and the importance of force concepts in the school curriculum. Results showed that the respondents perceived themselves to be knowledgeable about the breadth and depth of force concepts with the mean of 4.34 (0.775) and the importance of force concepts in the school science curriculum with mean 4.53 (0.68). The respondents believed that they knew how to clearly explain force concepts. Furthermore, the respondents believed they were conversant with the force concepts taught in grade 11 as well as how the concepts were organised and the goals and purposes of teaching the topic. As evidenced by the lowest standard deviation (0.68), there was agreement among the respondents regarding why students must learn force concepts, including the skills students should develop as they learn science.

Teachers' Perceptions of their Knowledge of Students' Understanding

As indicated by the mean scores 4.11 (0.75), the respondents had positive perceptions about their knowledge of how students learn science. The respondents agreed that they knew what improves students' understanding of the topics of force concepts. In order to say a teacher knows how students learn, they are expected to understand students' prior knowledge both scientific and non-scientific including knowing the aspects of the topic that are difficult for students to comprehend. Likewise, teachers are expected to know prerequisite skills students should possess to comprehend concepts such as force, including what they find interesting and boring. The average mean score also highlighted that the respondents agreed that they considered the characteristics of students that enhance learning in their teaching of force concepts. The respondents perceived themselves as being able to assess what students already know before teaching force concepts.

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Teachers' Perceptions of their Knowledge of Educational Strategies

The overall mean of 4.05 (0.9) for this component indicates that the respondents believed that they knew and varied the strategies when teaching the concepts of force. The strategies that they believed they used included small-group and whole-class discussions, presentations, using multiple representations of force, doing exercises about force, and ensuring that they connect what students already know to what is to be learned. The standard deviation indicates that the respondents' views on the use of different strategies were fairly homogeneous.

Teachers' Perceptions of their Knowledge of Assessment Strategies

The results (Table 4) showed that respondents perceived themselves to know different assessment methods as evidenced by the mean score 3.44 (1.03). The results indicated that the teachers believed that they used different assessment methods in their classrooms. The standard deviation, however, shows that the responses were not consistent. It can be said that the respondents' perceptions about the assessment methods they used were different and, perhaps, inconsistent. The assessment methods that the respondents believed they used were written tests, assignments, and homework assignments.

Furthermore, Table 4 shows that the respondents held positive views about their knowledge of the facets of the concepts of force to assess. This is highlighted by the mean score 3.37 (1.01). The respondents indicated that they assessed the recall of facts; definitions; experimental skills; identification and uses of force concepts; and oral communication. However, the standard deviation was greater than 1, which designates variations of the responses. Nonetheless, the respondents perceived that they knew the facets of force concepts that students are expected to learn, because they indicated that they assessed them, although not always.

Teachers' Perceptions of their Orientations towards Teaching

Table 4 indicates that the respondents ranked themselves high with respect to the purpose of science teaching and learning as shown by the mean of 3.78 (0.91). In general, respondents believed that they involved students when teaching and they created environment that enhanced meaningful learning. In other words, they had positive perceptions that they engaged students in both knowledge construction and transmission. The respondents' responses were homogeneous, as indicated by the standard deviation being less than 1.

Correlations between the Knowledge Components

The correlations between the knowledge components were ascertained by doing Spearman's correlation test (Table 5). The correlation test was applied to highlight the connection available amongst the five domains of knowledge in the questionnaire. The null hypothesis was that "there is no correlation among the domains of knowledge".

Table 5
Correlations between Knowledge Components

Spearman correlation coefficients (N = 92) Prob > **Irl under H0: Rho= 0**							
	KSC		KSU	KIS	KAS		OT
	Breadth and depth	Importance of force concepts			Methods	What to assess	
Breadth and depth	1	.088 .4066	.316 .0022	.051 .6317	.150 .1549	-.002 .9869	-.015 .8899
Importance of force concepts	.088 .4066	1	.211 .0436	.14 .185	-.014 .8929	.256 .0138	.229 .0285
KSU	.316 .0022	.211 .0436	1	.47 < .0001	.337 .001	.395 < .0001	.384 .0002

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Spearman correlation coefficients (N = 92)
Prob > **Irl under H0: Rho= 0**

	KSC		KSU	KIS	KAS		OT
	Breadth and depth	Importance of force concepts			Methods	What to assess	
KIS	.051 .6317	.14 .185	.470 < .0001	1	.47 < .0001	.658 < .0001	.375 .0002
Methods	.15 .1549	-.014 .8929	.337 .001	.47 < .0001	1	.595 < .0001	.457 < .0001
What to assess	-.002 .9869	.256 .0138	.395 < .0001	.658 < .0001	.595 < .0001	1	.427 < .0001
OT	-.015 .8899	.229 .0285	.384 .0002	.375 .0002	.457 < .0001	.427 < .0001	1

Note: KSC = knowledge of science curriculum; KSU = knowledge of student understanding; KIS = knowledge of educational strategies; KAS = knowledge of assessment strategies; OT = orientations towards teaching

Table 3 shows that there is a weak ($0 < r < .4$; $p < .05$) and moderate ($.39 < r < .7$; $p < .05$) positive correlations among the different domains of knowledge. Knowledge of the science curriculum, constituting knowing the importance of the concepts of force and the breadth and depth of the curriculum, correlated with a few other domains. On the one hand, the respondents' perceptions about the knowledge of the breadth and depth of force concepts showed a weak correlation only with the knowledge of how students understand force concepts (.316). This means that when teachers believe they have more knowledge of science content, they tend to be more confidence that they know how students learn science. On the other hand, knowledge of the importance of force concepts had a weak correlation with knowledge of students' understanding (.211), assessment of scientific literacy (.256), and teacher orientations (.229). It was unexpected that curricular knowledge correlated only with the knowledge of how students learn. The highest correlation was between the respondents' perceptions of the knowledge of educational strategies and knowledge of what to assess ($r = .658$; $p = .0001$). This is a moderate correlation.

Discussion

The study explored physics teachers' perceptions about their knowledge base for teaching concepts of force. Based on the premise that teachers' PCK is topic specific (Azam, 2020; Mazibe et al., 2018), the results of this study contribute to literature about teachers' perceptions of PCK on the topic of force. Studying teachers' perceptions is important, because beliefs, attitudes, and perceptions influence teachers' practices (Feyzioğlu, 2019; Meschede et al., 2017). Moreover, the results add to existing literature about how teachers' knowledge of the breadth and depth of the science curriculum relates with its importance to students' learning.

The results revealed that respondents believed that they had the appropriate knowledge for teaching force concepts. In other words, respondents believed that they know how to teach force concepts. These results reaffirm those of other scholars who studied teachers' perceptions about their knowledge base and PCK in particular (Drits-Esser & Stark, 2015; Gul et al., 2021). Nisperuza et al. (2019) indicated that teachers perceived that they know how students think, including educational and assessment strategies. Similar to results in this study, they highlighted that teachers had differing views about their orientations towards teaching force concepts. That teachers had differing views about their orientations could be because they used both teacher- and learner-centred orientations when teaching.

It was also found that respondents were mostly confident about their science curricular knowledge, particularly the importance of force concepts in the science curriculum and the breadth and depth of the curriculum. Concerning this, the respondents believed that they know the force concepts that are core, and that they can modify activities based on the nature of students they are teaching and the level of difficulty of the concepts. Because this subcomponent of curricular knowledge is more linked to content knowledge, it is understandable why respondents strongly believed that they know it. This finding is in accord with that of Catalano et al. (2019), who indicated that pre- and in-service teachers were positive about their knowledge of content. It can be implied

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that teachers believe they know the topic of force concepts because they have experience teaching it and their students' performance in the topic is good.

One interesting finding worth noting is that the respondents' knowledge of the subcomponents of curricular knowledge, breadth and depth of force concepts and their importance in the science curriculum, did not correlate with each other. On the one hand, knowing the importance of the topic indicates understanding its significance in relation to the entire curriculum and the goals for students' learning of the topic. It also makes it possible for teachers to identify main concepts, adapt activities, and target conceptual understanding. On the other hand, knowledge of the breadth and depth of the curriculum relates to knowing what students learned in lower grades, what they should learn in the present grade, and what they will learn in higher grades within a particular topic (Ball et al., 2008; Park & Oliver, 2008). Having found that there is no correlation between the two subdomains of knowledge of the science curriculum is surprising because one would expect that knowing the core concepts to teach in a particular topic, such as force concepts, requires one to know what students learned and know in that topic. This is because teachers can modify activities and integrate students' prior knowledge when teaching new content in the present grade so that they can develop conceptual understanding.

That there was no correlation between the two components could mean that knowing one component does not have an effect on the other. That is, whether teachers know the importance of why students should learn force concepts in upper secondary school does not necessarily mean that they know what students learn under the topic throughout their school years. Therefore, knowledge of one subcomponent does not necessarily translate to knowledge of the other. For one to gain knowledge of the subcomponents, that is the breadth and depth and importance of force concepts in the school science curriculum, teachers should make an effort by studying curriculum materials and collaborating with peers. As indicated by Drits-Esser and Stark (2015), when teachers collaborate to develop curriculum materials, they get opportunities to learn from peers. They thus gain a deeper understanding of some of the professional knowledge that they were not familiar with and those that did not cross their minds as being important.

Another possible explanation for why there was no correlation between teachers' knowledge of the importance and the breadth and depth of the concepts of force is that teachers often do not bother to find out what their students learned in lower grades and what they will learn in the future grades. That is, teachers do not often study the syllabi of the different grades and other curriculum materials with the purpose of identifying what might be similar and/or different. Moreover, most of the curriculum knowledge is gained through experience and collaborative activities. Teachers should know this information, because even if they had learned it during teacher training, it keeps on changing because of the ongoing curriculum reforms in most countries. Therefore, teachers should always update their knowledge. For instance, Kavanagh and Sneider (2007) highlighted that in elementary school, students learn that "things just fall". However, in middle and upper secondary school, the concept of gravitational force is taught, and students are expected to learn that things fall due to gravitational pull. When teachers do not make an effort to find out what was taught and accepted at lower grades, they may not know how to connect the two and help students to change and/or improve the preconception developed in lower grades. This is therefore an important finding because it points to the need for teachers to be part of communities of practice where they discuss their professional knowledge and practice.

Conclusions and Recommendations

The study explored physics teachers' perceptions of the knowledge base needed to teach the concepts of force to grade 11 students, particularly the PCK components. The teachers had positive perceptions about the PCK components, mainly knowledge of the science curriculum. Since curricular knowledge is linked to content knowledge, it seems that physics teachers were confident about their knowledge of force concepts taught in school including their importance as well as the scope at which these concepts are taught. However, of importance to note is that, knowing one aspect of curriculum knowledge does not necessarily translate to knowing the other component. This was highlighted by the lack of correlation between knowledge of the breadth and depth and the importance of force concepts in school science curriculum. However, to help teachers develop integrated curricular knowledge, school- or centre-based collaborative activities among teachers who teach different levels and/or grades should be planned. Mainly to facilitate discussions that will culminate into all groups understanding the scope at which concepts are taught at different grades, what is accepted as correct and not correct, including the purpose of teaching them at those different levels.

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This study focused on teachers' perceptions not the actual practice. This approach has some limitations as the actual practice may not align with what teachers believe they know and do. It is therefore recommended that future studies i) explore the interplay between teachers' knowledge of the importance of the concepts of force and knowledge of the breadth and depth of the concepts when teaching force concepts, ii) design professional development activities that help teachers deepen their understanding of curricular knowledge and relate it to classroom practices. This study also recommends collaboration between the local university and Ministry of Education to provide large scale professional development activities for teachers that target improvement of specific categories of teachers' PCK.

Declaration of Interest

The authors declare no competing interest.

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