The effect of a professional development programme on subject advisors' PCK of the energy concept

by

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Submitted in partial fulfilment of the requirements of the degree

MASTER OF EDUCATION

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Declaration

I declare that the thesis, which I hereby submit for the degree Master of Education at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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The author, whose name appears on the title page of this dissertation, has obtained, for the research described in this work, the applicable research ethics approval. The author declares that he has observed the ethical standards required in terms of the University of Pretoria's *code of ethics for researchers and the Policy guidelines for responsible research.*

Dedication

This academic work is dedicated to my parents Paul and Eva Munyurwa for their immense contribution towards my educational journey leading to the person I am today. I sincerely appreciate the sacrifices they made to ensure I succeed in my endeavours.

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My sincere gratitude and appreciation go to the following whose contributions enabled me to achieve this academic goal:

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Abstract

Teacher effectiveness is argued to depend on sound pedagogical content knowledge (PCK) at topic level referred to as topic specific (PCK). The development of sound content knowledge for in-service science teachers through professional development (PTD) workshops has been a focus for the South African department of education over the years. The aim of the study was to explore the effect of a PTD programme on the development of subject advisors' PCK of the energy concept. The rationale for the selection of the energy concept was based on the central role played by the energy concept as a cross-cutting concept in science. The study sought to provide answers to the following main research question: *How does a PTD workshop develop the quality of physical science subject advisors' TSPCK of the energy concept?*

The study followed a qualitative research approach, based on the post-positivist paradigm and a case study design. A conceptual framework adapted from Mavhunga (2014) and Gess-Newsome (2015) was used which links PCK to five components through which transformation emerges. A sample of fifteen physical science subject advisors from a province in South Africa was conveniently sampled and they completed the pre- and post-assessment CoRes. The participants' written CoRes were then scored using an expert CoRe and rubric that were designed by the researcher. The validity of the expert CoRe and the rubric were aided by the use of the Rasch model. The model indicated reversed thresholds for some prompts and the researcher had to adjust the rubric until all the prompts indicated ordered thresholds before the final scoring process. To aid to the trustworthiness of the data collected, the researcher employed triangulation, data collection involved a semi-structured interview, document analysis of the workshop study manual and data from the CoRes. Data was interpreted and analysed using content analysis and the results suggested that the subject advisors' PCK of the energy concept improved after the PTD workshop. The improvement was more noticeable in the TSPCK components that were addressed during the workshop. It is however apparent from the analysis and interpretation that teachers' TSPCK of the energy concept may be improved through PTD workshops.

KEYWORDS

Topic specific pedagogical knowledge; content knowledge; professional teacher development; subject advisor; energy concept; content representations (CoRes).

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TO WHOM IT MAY CONCERN

This is to confirm that the thesis titled ***" THE EFFECT OF A PROFESSIONAL DEVELOPMENT PROGRAMME ON SUBJECT ADVISORS' PCK ON THE ENERGY CONCEPT"*** by WESTON MUNYURWA was proof read and edited by me in respect of language.

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Kind regards

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List of Abbreviations

ACE	: Advance Certificate in Education
CAPS	: Curriculum Assessment Policy Statement
CK	: Content Knowledge
DoBE	: Department of Basic Education
DoE	: Department of Education
ELRC	: Education Labour Relations Council
FET	: Further Education and Training
KC	: Knowledge of Context
PCK	: Pedagogical Content Knowledge
PK	: Pedagogical Knowledge
PTD	: Professional Teacher Development
SAs	: Subject advisors
SMK	: Subject Matter Knowledge
STEM	: Science, Technology, Engineering and Maths
TIMSS	: Trends in International Mathematics and Science Study
TSPCK	: Topic Specific Pedagogical Content Knowledge

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CHAPTER 1

INTRODUCTION AND ORIENTATION

1.0 CHAPTER 1 INTRODUCTION AND ORIENTATION

1.1 INTRODUCTION

In the past two decades following the inception of a new political dispensation in 1994, the South African education system has undergone a number of educational reforms aimed at rationalising educational equality and quality (Reddy, 2006). Among these reforms is the government's deliberate drive towards improved science education in response to the national and global demands for scientific literacy and competitiveness in Science, Technology, Engineering and Mathematics (STEM). However, the performance of South African learners in science, though with significant increases over the years is still among the lowest (Reddy et al., 2013). This poor performance is quite evident in the physical science matric results (DoBE[1], 2011). Scholars (Mavhunga 2014; Mavhunga & Rollnick, 2013, 2014; Rollnick, Bennet, Rhemtula, Dharsey & Ndlovu I., 2008; Shulman, 1987) have argued that the performance of learners in science and in any discipline is a reflection of the subject teachers' pedagogical content knowledge (PCK). When teachers lack the ability to teach science content to learners in understandable constructs, it becomes difficult for learners to understand the subject on a conceptual level (Grossman 1990; Marks 1990; Shulman 1986, 1987). It is argued by these scholars that this inability to realise conceptual change in learners has resulted in the learners performing poorly in science globally. Researchers (Brickhouse & Bodner, 1992; Mellado, 1998) have investigated novice teachers' conceptions of teaching and learning science and the content knowledge (CK) of pre-service science teachers in the context of learning the art of teaching. They concluded that for teachers to have requisite content knowledge alone is not sufficient to bring about understanding in learners but a combination of both content knowledge and the ability to teach the content to learners is required (Gess-Newsome, 1999; Haidar, 1997). Research is needed to find ways to develop teachers' PCK. In South Africa, it may be fruitful to investigate PCK of Subject Advisors as they are in a position to support teachers. The

[1]DoBE refers to the Department of Basic Education, a government ministry responsible for primary and secondary education in South Africa.

following paragraph describes the subject advisor in the context of the South African education system and explains their role pertaining to in-service teacher development.

1.2 BACKGROUND

The South African education system is structured in such a way that science, like all subjects, has a subject advisor in every district of each province **(**ELRC, 2003) The subject advisor is a former teacher who is employed by the provincial DoBE as a subject specialist and is assigned to a specific district within the province. One of the roles of the physical science subject advisor, is to ensure that effective teaching and learning of physical science are taking place in schools (ELRC, 2003). This is achieved by monitoring teacher performance and providing support where necessary in terms of professional teacher development through workshops. Professional teacher development is one key role of subject advisors, considering that South African science teachers are among the least qualified in terms of degrees in science education (Reddy et al., 2013; Rollnick et al., 2008). For the few who have degrees, the qualification is usually in educational psychology, management, law and policy and not necessarily in science education (Rollnick et al., 2008).

The South African government introduced intervention programmes to try and improve the teachers' qualifications in science, such as the Advanced Certificate in Education (ACE[2]). However, the science content covered in these programs is still inadequate to sufficiently improve content knowledge and confidence to teach the content (Mavhunga, 2014; Rollnick et al., 2008; Reddy et al. 2013). Several researchers have investigated the cause of learner poor performance in science, generally focusing on instructional methods and educational theories rather than subject matter knowledge of the teachers (Mavhunga, 2014). She further argued that deliberate efforts need to be put into the development of the science teachers' PCK in teaching science with a particular focus on content knowledge pertaining to specific topics.

Each science topic with its specific content has a unique type of teacher knowledge that is required in translating that content into understandable constructs which are referred to as topic specific pedagogical content knowledge (TSPCK) (Mavhunga, 2014; Rollnick

[2]ACE refers to Advanced Certificate in Education, a qualification offered to teachers whose original qualifications were not in science education per se, aimed at bridging the content gap.

et al., 2008). According to Mavhunga (2014), the development of a science teacher's TSPCK is the critical function of any pre-service or in-service teacher training programme. However, developing a teacher's PCK requires a method of capturing and measuring the levels of PCK prior to any attempt to develop it. Mavhunga (2014) adapted a tool originally developed by Loughran, Mulhall and Berry, (2004) to capture and measure a teacher's PCK. This tool is referred to as the content representations (CoRe) tool.

1.3 PROBLEM STATEMENT AND RESEARCH QUESTIONS

1.3.1 Problem statement

The Trends in International Mathematics and Science Study (TIMSS) report of 2011 revealed that South African learners, though with some improvements over the years, are still lagging behind learners from the developed countries and some African countries such as Ghana in science performance. This poor performance in science at Grade 8 has been a worrying issue for the South African Department of Basic Education (DoBE) since 1994 (Reddy et al., 2013). Reddy et al., (2013) further argued that this poor performance is also evident in the Further Education and Training (FET[3]) band.

According to the physical science national chief examiner's annual reports for the physics paper, learners generally perform poorly in answering questions from the physical science curriculum section on work, energy and power (DoBE, 2011; 2013). The problems learners have in this section contribute significantly to their overall poor performance in science, since this section constitutes about 27% of the physics paper (DoBE, 2011b). It must also be noted that understanding the energy concept is critical to the understanding of other topics as energy is a crosscutting concept running through all science topics and disciplines (Bybee, 2011b).

The poor performance in work, energy and power can be attributed to a number of factors that generally affect the teaching and learning of science. Teaching physics concepts to learners all over the world is not an easy task (Thomas, 2013). Thomas further argued that this task is even more complex to less experienced science

[3]FET refers to the secondary school level in the South African education system which starts from Grade 10 to Grade 12.

teachers, owing to their lack of knowledge in terms of the content, how they structure and pace the content and lack of knowledge of appropriate instructional strategies. Mavhunga (2014) pointed out that effective teaching of science concepts is an indication of sound content knowledge (CK) and pedagogical knowledge (PK) which form part of a professional teacher's pedagogical content knowledge (PCK). Rollnick et al., (2008) in their case study of South African teachers, investigated the role played by content knowledge in PCK, and realised that many teachers lacked the ability to illuminate the interrelatedness of concepts because they do not have an in depth understanding of the concepts. The DoBE mandates education districts to utilise subject advisors to conduct workshops. In the workshops the subject advisors are responsible for the development of teachers' PCK, this responsibility requires that the subject advisors' PCK should be well developed too. Among a range of studies on PCK in teacher professional development, literature seems not to show any study on the effects of a professional teacher development (PTD) workshop on the development of PCK of physical science subject advisors in the teaching of work, energy and power.

1.3.2 Rationale

I have been involved in the teaching of science for the past fourteen years and have worked in two different education systems. I obtained my initial science education qualification in Zimbabwe and worked as a science teacher for six years before joining the South African education system. My experience as a teacher in the South African system has revealed that learners generally do not do well in science, and I have also realised that some of the science teachers themselves lack the necessary content knowledge and they seem to hold serious misconceptions in the topics they teach. I have also observed that some of the teachers struggle in comprehending science concepts, which makes it difficult for them to effectively teach these concepts to learners.

Physical science subject advisors conduct teacher development workshops in the hope that developing the science teacher's professional knowledge will make the teachers better professionals who have sufficient pedagogical content knowledge. However, despite these programmes, learners' performance is still comparatively very low (Reddy et al., 2013). According to scholars such as Mavhunga, (2014) and Rollnick et al.,

(2008) this is because most of the developmental programs are in general pedagogy per se and not necessarily in science content. This is consistent with my experience. As a physical science teacher I have attended a number of teacher development workshops organised and facilitated by the district physical science subject advisor. Generally, the workshops were focusing on methods of teaching and few were on content or how to teach specific content. I have observed that content workshops are generally conducted when a new topic is introduced, as was the case during the training workshops in 2011 when the new CAPS curriculum was introduced. However, the time allocated for the training sessions is usually not enough for the training to be effective. It is also possible that subject advisors who facilitate teacher training sessions may lack content knowledge and/or TSPCK, contributing to a cycle of inadequate teaching and learning.

An investigation into the PCK of subject advisors may be a starting point to improve teaching and learning in schools. An opportunity to conduct such a study presented itself when a week long content workshop for teachers and subject advisors was organised by the DoBE in one of the provinces in South Africa. The workshop was presented by staff from a South African university. The purpose of the workshop was to improve the content knowledge of subject advisors and science teachers, trusting that it would result into improved physical science matric results in the province. Fifteen subject advisors and 150 science teachers attended the five-day workshop.

I was afforded the opportunity to utilise the workshop as an intervention needed in the research for my Masters' study. As the workshop explicitly addressed content, I was able to investigate the effect of a content workshop on the development of PCK of physical science subject advisors. The results may be of interest in the sense that PCK was not the focus of the workshop. The subject advisors agreed to participate in the collection of data to assess their PCK before and after the workshop. The workshop was planned to address problematic topics in the curriculum. The subject advisors identified the topics in the FET science curriculum that learners find difficult. The list comprised of the following physical science topics:

- Electricity
- Work, energy and power

- Electrodynamics
- Chemical equilibrium
- Acids and bases

From the list of topics, I have made a choice to investigate TSPCK about the energy concept based on the South African Grade 12 physics topic ‘work, energy and power’. This choice was based on the experience that many teachers and learners perceive the topic to be very abstract and difficult. This perception is also consistent with my own observation as a science teacher. Another justification for the selection of the topic is that, most topics in science involve the concept of energy in one form or the other; it is a central theme for the understanding of science in general.

1.3.3 Statement of purpose

The aim of the study is to explore the effect of a professional teacher development (PTD) workshop on the development of physical science subject advisors’ PCK in the teaching of the energy concept. The significance of the study is that its findings can be used to inform the planning of content specific workshops geared at improving the TSPCK of novice and experienced physical science teachers. A well-developed PCK may improve learner performance in science (Mavhunga, 2014), and may result in an increased number of learners qualifying to study science programmes at universities, thereby helping in reducing the skills shortages the country has in Science Technology Engineering and Mathematics (STEM). Furthermore, the findings can be used by teacher education institutions in developing teacher training programmes aimed at the development of PCK in the teaching of work, energy and power. The study will be guided by the following research questions.

1.3.4 Research questions

The research seeks to provide an answer to the following main research question.

How does a professional teacher development (PTD) workshop on work, energy and power develop the quality of physical science subject advisors’ TSPCK?

The main research question will be addressed by answering the following research sub-questions.

- What was the quality of the subject advisors' TSPCK before the PTD workshop on the teaching of work, energy and power?
- What was the quality of the subject advisors' TSPCK after the PTD workshop in the teaching of work, energy and power?
- In which ways were the subject advisors' TSPCK influenced by the workshop?

1.3.5 Working assumptions

- It is assumed that developing physical science subject advisors' content knowledge can support the development of their TSPCK.
- It is envisaged that subject advisors with well-developed TSPCK can transfer their newly acquired skills in developing science teachers' TSPCK through workshops.
- It is assumed that the improvement of TSPCK of teachers will improve learner performance in science.
- In spite of the tacit nature of PCK, it is assumed that TSPCK can be captured in a written format and evaluated to assess PCK.
- It is assumed that content knowledge is the only factor that would contribute to possible changes in PCK during the workshop.

1.3.6 Concept clarification

- **Subject advisor:** A subject advisor is a former teacher who is employed by the provincial education department as a subject specialist and is assigned to a specific district (DoBE, 2011). The role of the subject advisor as a subject specialist is to monitor the process of teaching and learning in schools assigned to him/her and to provide developmental support for teachers where necessary. The support can be provided to the teachers in terms of teacher development workshops within the district or within a cluster.
- **Work, Energy and Power**

  Work, energy and power are physics topics covered in Grade 12 in the South African physical sciences curriculum. It addresses concepts related to external forces acting on objects and energy possessed by the objects as they undergo some displacement as a result of the force, hence doing work (DoBE, 2011).

- **PTD (Professional teacher development) programmes**

  These programmes are aimed at in-service training for teachers with the hope of improving teacher effectiveness and efficiency in teaching their subjects; it is provided for teachers already in the field and it focuses on content, instructional methods and other developmental aspects of teacher professionalism necessary for specific topics to enhance better understanding by learners (Ngobeni, 2002).

- **FET curriculum**

  Further Education and Training (FET) curriculum refers to the curriculum of a subject, in this case a science curriculum from Grade 10 to Grade 12 within the South African education system.

1.4 DISSEMENATION OF FINDINGS

The findings from this study will be kept in an open depository of the University and will be available for public and academic use.

1.5 STRUCTURE OF THE DISSERTATION

Chapter 1 presented an introduction to the study to familiarise the reader with the aim and scope of the research. Chapter 2 is the literature review and contains some of the literature by other scholars that is relevant to the study, it also includes the conceptual framework upon which the study is imbedded. Chapter 3 is the methodology chapter; it gives a detailed account of the philosophical approach and the general methodology that was followed in answering the main research question. Chapter 4 presents the pre-CoRe data that was recorded before the PTD workshop. Chapter 5includes the post-CoRe data, interview data and the data from the document analysis of the workshop study manual. Chapter 6 is the analysis and interpretation chapter, in this chapter the researcher made sense of the data collected in chapters four and five by giving meaning and interpretations to the data. The thesis was then concluded with Chapter 7 which provides recommendations to the education community based on the findings from the study.

CHAPTER 2
LITERATURE STUDY

2.1 INTRODUCTION

Chapter 2 focuses on the existing literature that relates to general PCK and TSPCK about the teaching and learning of the energy concept. There seems to be a paucity in literature on the development of TSPCK in the teaching of the energy concept in the FET phase in the Grade 12 South African physical sciences curriculum. Literature by such scholars as Gess-Newsome (2015), Loughran et al., (2004), Mavhunga (2014), Rollnick et al., (2008) has shed some light in terms of general PCK and TSPCK in the teaching of other science topics. Literature was reviewed on the teaching of energy and other related concepts including work and power. In addition, literature on the role and mandate of the physical science subject advisors in their respective education districts, as facilitators of in-service teacher development, was also studied. The nature of the South African education system in terms of science and the impact of learner performance locally and globally was also discussed. The key role played by 'work, energy and power' as a curriculum concept in learner achievement, as well as literature on PTD[4]workshops and their critical roles as intervention strategies aimed at improving Grade Twelve results, were also studied in this chapter.

2.2 LITERATURE REVIEW

2.2.1 Introducing pedagogical content knowledge

A number of definitions for PCK have been presented by many scholars, however establishing a universally acceptable working definition has proven difficult (Borko, Bellamy & Sanders, 1992; Geddis & Wood, 1997; Grossman, 1990). PCK is defined as that critical knowledge necessary for the transformation of subject knowledge into understandable units more intelligible to learners (Geddis, Onslow, Beynon & Oesch 1993; Grossman 1990; Marks 1990; Mavhunga 2014; Shulman 1986, 1987). According to Shulman (1986, p. 9), PCK involves and comprises of "the ways of representing and

[4]PTD refers to Professional teacher development.

formulating the subject that make it comprehensible to others". What consistently appears in all definitions and conceptualisations of PCK is that it is inherent in teacher knowledge and that teacher knowledge is an amalgam of knowledge bases referred to as teacher knowledge domains by Rollnick et al., (2008). According to Berliner (1988) teaching aimed at promoting understanding is based on genuine scholarship of practice, it involves the teacher's content knowledge coupled with the ability to transfer this knowledge in a way better understood by learners. This ability is what usually distinguishes novices from experienced teachers and bad from good teachers (Loughran, Mulhall & Berry, 2008). Shulman's (1986, 1987) suggestion that teachers need strong PCK to be good teachers gave rise to many studies into the development of PCK of pre-service science teachers. In recent years, studies about middle and high school learners' conceptualisation and their teachers' instructional approaches to the energy concept has increased (Kind, 2009). Much vigour and focus are accorded to the energy concept owing to its central role in the general teaching and learning of broader science (Trumper, 1998).

2.2.2 PCK and Knowledge Domains

According to scholars (Gess-Newsome, 1999; Magnusson, Krajcik & Borko, 1999; Rollnick et al., 2008; Van Driel & De Jong, 1999;) teacher professional knowledge comprises of knowledge bases referred to as knowledge domains by Mavhunga and Rollnick (2013). These knowledge domains are the same set Gess-Newsome (1999) referred to as knowledge bases and are as follows:

- Knowledge of context (KC)
- Knowledge of students
- Content knowledge (CK)
- Pedagogical knowledge (PK)
- Pedagogical content knowledge (PCK)

Park and Oliver (2007) noted that certain scholars and researchers regard some of the knowledge bases as components of PCK while others regard them as distinct knowledge bases for teaching outside PCK. What is evident is that most scholars view the synergy between content knowledge and pedagogical knowledge as pivotal in developing PCK. Park & Oliver (2008) in their multiple case study of the conceptualisation of PCK as a tool to understand teachers as professionals, centred on these knowledge domains and their study was seeking answers to how this conceptualisation can help novice teachers in developing effective synergy between content knowledge, pedagogy and PCK. It is argued that trying to understand the complexity of the teachers' knowledge, that is, what the teacher knows, what they do, how and why, is actually trying to understand one's PCK (Baxter & Lederman, 1999; Kagan, 1990;). An analysis of the data from the study by Park and Oliver (2008) exposed five significant characteristics of PCK. These characteristics of PCK included the development of PCK as a result of reflections related to knowledge-in-action and knowledge-on-action, the effectiveness of teacher efficacy as an affiliate of PCK, students' influence on PCK development, teachers' understanding of students' misconceptions and its impact on PCK development and finally the idiosyncrasy in the enactment of PCK. Park & Oliver's (2008) findings are useful in the conceptualisation and understanding of PCK development for the study, mainly by focusing on teacher effectiveness and teachers' understanding of students' misconceptions. However, their study did not focus on the development of PCK of a specific science topic in line with the identified knowledge domains, unlike this study that is focusing on the development of PCK of a specific topic.

2.2.3 Capturing and measuring teachers' PCK

According to Loughran et al. (2008, p. 1304) many scholars have described "the nature of PCK as being 'fuzzy'", owing to the tacit nature of teacher professional knowledge which leads to difficulties associated with the portrayal and capturing of a teacher's PCK. Many teachers find it hard to articulate their teaching orientations and teaching philosophies that govern everything that they do when they teach (Loughran et al., 2004, 2008). In order to understand the development of teachers' PCK, it is necessary to carefully articulate and portray their PCK. Loughran et al., (2004) argued that the personal nature of teacher knowledge further complicates the articulation and documentation of PCK. Loughran et al., (2004) set out to investigate and develop ways of capturing science teachers' PCK by developing a tool which they named content representations (CoRes).

According to Loughran et al., (2004) the CoRe-tool is both a research instrument for assessing science teachers' understanding of content as well as a way of representing teacher professional knowledge. It is a tool designed to elicit teacher understanding of the important aspects of the topic under discussion (Ndlovu, 2014). In the study the subject advisors' TSPCK was captured and measured in the context of planning to teach, referred to as planned TSPCK by Mavhunga and Rollnick (2013). The CoRe-tool is designed to capture teacher professional knowledge by letting the teacher identify the main ideas of the content, and then link them to the prompts of the CoRe as shown in Table 1 below as adapted by Mavhunga (2014).

Table 1: The CoRe instrument (Mavhunga, 2014)

A1	What do you intend the learners to learn about the idea?
A2	Why it is important for learners to know this.
A3	What concepts need to be taught first before teaching this idea?
A4	What else do you know about this idea (that you do not intend learners to know yet)?
B1	What are the difficulties/limitations connected with teaching this idea?
C1	What is your knowledge about learners' thinking which influences your teaching of this idea?
C2	Are there other factors that influence your teaching of these ideas?
D1	What are your teaching procedures (and particular reasons) for using these to engage with the idea?
D2	Specific ways of ascertaining learners' understanding or confusion around this idea.
E1	What ways would you use to support learners' understanding?
E2	What ways would you use to assess understanding?

The main findings of the study by Loughran et al., (2004) included the realisation of the difficulty and complexity of trying to study, understand and capture science teachers'

PCK using data collection techniques such as interviews alone. The results revealed that the CoRes are a useful and appropriate tool for capturing science teachers' professional knowledge and practice. Loughran et al., (2004) argued that through the use of CoRes experienced science teachers' PCK can be captured and be used by novice teachers to improve their PCK or can also be used in teacher education programs.

2.2.4 Topic specific pedagogical content knowledge (TSPCK)

Mavhunga & Rollnick (2013) introduced the concept of topic specific pedagogical knowledge (TSPCK), which refers to the PCK of a teacher to teach a specific topic. Earlier Veal and MaKinster (1999, p. 9) noted that "the most specific and novel level of the general taxonomy [of PCK] is topic specific PCK". Teachers should have well developed PCK that speaks to a specific topic. Each topic has its unique content which has its own specific and appropriate instructional methods needed in its transformation into units better understood by learners and each topic is also situated in its own context and therefore demands unique knowledge to address it (Mavhunga, 2012). The transformations of CK about a specific topic into teachable units is what Mavhunga (2012) viewed as the core of any teacher education programme. She identified five knowledge components from which the transformations of CK emerge and these are regarded as key in the development of PCK. According to Mavhunga (2014, p. 32) these components are: 'students' prior knowledge including misconceptions, curricular saliency, what makes a topic easy or difficult to understand, representations including analogies, and conceptual teaching strategies'. The components are briefly explained below.

- Learner prior knowledge refers to the information a learner has about a specific scientific concept before being taught in class. When learners are confronted by new concepts, the way they reason around them and interact with the new concept is based on their prior understanding about the concept and this could be consistent with correct scientific reasoning or can be misconceptions.
- Curricular saliency refers to the knowledge teachers have in selecting the order in which topics are taught, it involves the identification of topics that are central to

the understanding of the concept and those that are peripheral. This enables the teacher to determine the depth and time required for each topic.

- What is difficult and what is easy? This refers to the knowledge the teacher has in identifying key concepts in a topic that are very difficult to understand thereby providing a dedicated conscious awareness when teaching them.
- Representations refers to the knowledge the teacher has about a number of subject matter representations useful in their teaching, such as analogies, illustrations, examples, models and simulations that increase comprehension of a concept.
- Conceptual teaching strategies refer to the knowledge teachers have about a variety of instructional methods they employ as they teach particular concepts. The choice of a conceptual teaching strategy is based on a number of aspects which include the nature of content, type of misconceptions, relevance of the topic, known areas of difficulty and how the representations can be utilised.

These content specific components are argued by Mavhunga (2014) to be linked to each other and the quality of TSPCK is said to be influenced by knowledge of the content-specific PCK components and how they relate to each other. The findings from the study by Mavhunga (2014) indicated that pre-service chemistry teachers have basic chemistry content but lack the skills necessary to make the content understandable for learners. The study also highlighted that content knowledge on its own as a separate knowledge domain is inadequate in achieving and promoting the development of TSPCK. The study showed that after exposure to a training module on a topic that clearly talked about the pedagogical transformation of the topic, the quality of the pre-service chemistry teachers' PCK and their conceptual understanding significantly improved (Mavhunga, 2014). The current study draws strongly from the study by Mavhunga (2014), and the PCK models presented by such researchers as Davidowitz and Rollnick (2011), Mavhunga (2014), and Rollnick et al., (2008) have provided a theoretical framework from which the current study can be operationalised.

2.2.5 Work, energy and power

The South African physical science Grade 12 curriculum is divided into six knowledge areas of which three belong to the physics section and three to the chemistry part of the curriculum. The physics section comprises of the topics mechanics; waves, sound and light; electricity and magnetism; and part of matter and materials while the chemistry section contains chemical change, chemical systems and the remaining part of matter and materials. Mechanics constitutes 42%, 63 marks from the 150 marks available for the physics paper (DoBE, 2011) and 'Work, energy and power' is a topic in this section of the physics curriculum. According to the national chief examiner's reports, learners are doing poorly in this section in their final Grade 12 paper one (the physics paper) examinations, resulting in learners performing badly in the physical science examinations (DoBE, 2013). In CAPS work, energy and power are treated as a topic with the rationale that work is done when energy is transferred and the rate of transfer of that energy indicates the amount of power dissipated by a system. The poor performance of learners on this energy based topic can be traced back to lack of teacher competence in terms of content mastery and ability to transform that content into understandable units better understood by the learners (Mavhunga, 2014). The obvious question that emerges is; do the science teachers have the requisite content knowledge to teach effectively?

The teaching of energy is central to the understanding and future learning of physics by the learners. Energy is one of the most critical crosscutting and unifying themes in science education, yet its conceptualisation is highly context dependent (Trumper, 1998; Nordine, Krajcik & Fortus, 2010). A study by Trumper, Raviolo and Shnersch (1999) about pre-service elementary science teachers revealed that about 32% of the pre-service teachers do not really understand the concept of energy. These students did not hold correct scientific views to enable them to instruct their future pupils. They further produced one of the most interesting findings in science education, namely the realisation that teachers hold strong misconceptions or alternative conceptions about energy. The abstract nature of the phenomenon of energy and its deep rootedness in context has made its conceptualisation extremely difficult to teachers and students alike despite its central role in science (Nordine et al., 2011).

Results of a study by Rollnick et al., (2008) have shown that even though some teachers have qualifications and experience required to teach a certain level of science, they still teach concepts at a superficial level, not addressing the interrelatedness of concepts. ‘Teachers are constrained in their teaching by the limitations of their understanding of the concept’ (Rollnick et al., 2008). As a result of these constraints teachers resort to algorithms and rote teaching that do not result in any meaningful conceptual change (Gess-Newsome, 1999). Realising conceptual change in high school learners regarding energy needs effective instruction, which unfortunately is not promoted by many high school sciences textbooks (Hestenes, 2003). Many textbooks take an approach based on energy calculations without giving learners a clear cognitive understanding based on energy transformations and energy transfer (Nordine et al., 2010).

2.2.6 Effective teaching of the concept of energy

Instruction as it pertains to the actual teaching of a concept, plays a vital role in learners’ cognitive and conceptual development (Nordine et al., 2010). A number of alternative approaches to instruction of the energy concept exists, but the question is how effective is the instruction in bringing about a change in the learners’ prior thinking. Energy is a unifying concept of science, yet general approaches to energy instruction in high school have indicated limited success in helping learners modify their alternative conceptions about energy into more plausible scientific understanding (Trumper, 1990). Owing to the central and pivotal role of the concept of energy as it relates to objects and their interactions in space and time, the conceptualisation of energy is essential (Trumper, 1998). A complete understanding of the concept of energy at high school and elementary physics classes at universities cannot be over emphasised, as this has a direct impact on the understanding of a number of science topics (Swackhamer & Hestenes, 2003; Watts, 1983). However, teaching this concept is not easy, it presents serious challenges even to the experts in the field of physics education. These challenges are mainly due to the abstract nature of the concept and learners’ inadequate or incorrect prior understanding of energy (Hestenes, 2003).

Nordine et al., (2011) proposed an instructional approach that acknowledges learners’ prior knowledge or alternative conceptions of energy, logical sequencing of integrated ideas in energy, use of context based illustrations and examples and the general understanding of energy based on its transformations. These aspects relate closely to the TSPCK components. When learners come to a physics class they bring along their own alternative conceptions of energy (Watts, 1983). According to Watts (1983, p. 673) alternative conceptions learners have about energy can be classified into seven alternative frameworks which are: -

> …*anthropocentric (energy is mainly associated with human beings), depository (some objects have energy whereas others need energy), ingredient (energy is dormant within some objects and can be released by some trigger), activity (energy is identified by overt displays – the display itself is energy), product (energy is a relatively short lived by-product of some situation), functional (energy is a very general kind of fuel for technical devices), and flow-transfer (energy is a physical fluid that is transferred in certain processes)(Watts, 1983).*

Trumper (1990) later substantiated Watts' original energy frameworks and added by splitting the depository framework into two frameworks, passive depository and active depository. Trumper furthermore added the transformation framework (when a process takes place, energy is transformed from one type to another). Based on these frameworks, it becomes apparent how learners differ in their understanding of energy as that understanding is based on their informal encounter with the idea of energy. If a learner's initial encounter with energy is based on the product framework, or activity framework or the depository framework their conceptualisation of energy then becomes limited to the underlying framework and negates other frameworks.

Trumper's transformation framework agrees well with the Nordine et al., (2010) instructional approach to the energy concept, which speaks of the need for the teacher to explicitly explain the fundamentals of energy transformations with regard to the law of conservation of energy. Nordine at al., (2010) strongly contends that when learners fully understand the energy transformations that take place as objects interact the understanding of the conservation law becomes much easier. Nordine et al., (2010) further argued that learners find it much simpler to understand work and power relations once they have grasped the type, nature and effects of energy within a closed system. Erlichson (1977) and Sherwood & Bernard (1984) argue that the main problem in understanding the concept of energy as it relates to work and power in physics education resides in the conservation law and on the interpretation and application of the all familiar but poorly understood 'work – kinetic energy theorem'[5]which is a derivative of Newton's second law.

The work-kinetic energy theorem describes the relationship between the amount of work done by a resultant force on an object with the object's change in kinetic energy. The theorem speaks to the fact that when a resultant force acts on an object, the object's kinetic energy changes, in other words the object accelerates in the direction of the resultant force. This acceleration is directly proportional to the resultant force.

Without a clear conceptual understanding of the conservation of energy and the transformations of energy as objects interact, the understanding of the theorem remains muddled in deep misconceptions. Sherwood and Bernard (1984) further argued that understanding the concept of energy begins with a complete appreciation of the effects of resultant internal and external forces on objects. The relationship of internal and external forces on the motion and displacement of objects gives rise to resultant internal and external work being done on the object (Sherwood & Bernard, 1984). This relationship between work-done and amount of energy transferred in doing that work is a complex construct to many learners as they usually have their own conceptions of energy and work based on the other energy alternative frameworks (Watts, 1983).

Teachers are confronted daily with learners who hold multiple alternative conceptions of the concept of energy with regard to work and power. The learners' incorrect prior knowledge results in cognitive conflict as new and correct information is presented. In resolving such cognitive conflict, the teacher must provide plausible correct scientific knowledge regarding the concept of energy that stimulates and develops conceptual change in learners. That demands the teacher's complete understanding of the concept of energy (Nussbaum & Novick, 1982). Teachers need to have the correct conceptual understanding of the concept if they are to effectively teach the concept (Rollnick et al., 2008).

[5]Work-energy theorem: - It is a theorem which states that the amount of work done on an object by a net force is equal to the change in kinetic energy of the object.

2.2.7 Typical misconceptions of the energy concept

In many school science textbooks, energy as a physical quantity is often introduced from a conceptualisation of its ability to do work and this more or less limits the concept to mechanics (Duit, 1984). The role of such an approach in developing understanding of the energy concept is quite limited as it does not cater for other key areas where energy transformations are evident such as heat, light and electricity. A limited view of the energy concept brings with it a number of misconceptions that learners struggle with in understanding other physics concepts since energy is a cross-cutting concept in science education (Bybee, 2011b). According to Duit (1984) misconceptions about the energy concept emanate from four key aspects. These are; (1) *energy transfer, (2) energy conversion, (3) energy conservation and (4) energy 'degradation'* in systems. Understanding energy in accordance to aspect one, which refers to energy as a quantity that can be transferred from one system to the other and from place to place, is consistent with correct scientific understanding of the energy concept. However, how much is transferred and from which system is where misconceptions occur. One fundamental misconception that I have observed as a science teacher is that learners think energy is only transferred from bigger objects and that objects at rest or at thermal equilibrium possess no energy. This observation is consistent with results from a study by Duit (1984). Viewing energy in accordance with aspect two, 'energy conversion', which refers to the fact that energy can be transformed from one type to the other is quite simple to comprehend, at Grade 12 level, however it becomes complex to learners when associated with aspect one and three Energy can be transformed during energy transfer and energy can be transferred during transformation. Learners find it confusing that during transfer and or transformation the total energy of that system remains conserved which is in line with aspect three. As a science teacher I have also observed that learners can identify the changes in the amount of a particular type of energy but fail to realise that this change also results in the change of another type of energy within the system. Learners tend to conceptualise energy conservation only in terms of one type of energy and not during transformations and this leads to the misconception that energy is 'lost'. Energy 'degradation', which is aspect four, refers to the idea that a particular type of energy decreases while another type within the system increases in magnitude, which is consistent with the conservation aspect. However, if the transformations involve the dispersion of thermal energy to the immediate environment some learners tend to think the energy is completely lost, not realising the change in ambient temperature and that energy is conserved in a bigger system which includes the environment.

In the South African curriculum, the concept of energy is viewed in accordance with aspect three, and forms part of early instruction in science classes. The natural sciences curriculum (Grade 4 to 9) has a section on conservation of energy; however, the content is limited to the general recall of the law of conservation of energy and basic energy transfers such as electrical potential energy in a battery to light energy in a glowing bulb without explicitly mentioning thermal dispersion. As a result, learners may progress to higher grades with their understanding of the concept of conservation of energy limited to conservation of a specific type of energy. This may give rise to a misconception that there is no conservation in transformations. It is very important for learners to understand the energy concept based on the amalgamation of the aspects and the realisation that as work is done on an object, energy is transferred and transformed and during transformation one type of energy decreases as the other increases in magnitude (Duit, 1984).

2.2.8 Professional Teacher Development (PTD) programmes

Teacher efficiency is at the centre of any education system (Boaduo & Babitseng, 2007); however, attainment of this efficiency does not only depend on the initial qualifications of a teacher but on professional teacher development (Ngobeni, 2002). According to Ngobeni (2002, p. 4) teacher development is categorised as follows:

- School-based in-service: to help teachers improve the quality of education in their schools.
- Job-related in-service: to help teachers to be more effective in their own post; and to derive job satisfaction.
- Career-orientated in-service: to prepare teachers for promotion.
- Qualification-orientated in-service: to provide teachers with further qualifications.

All of these categories are vital to teacher development; but this study focuses on the ‘job-related in-service-type of development’. This category of in-service teacher training is aimed at improving teacher effectiveness and efficiency in teaching their subject. It is provided for teachers already in the field and it focuses on, among others, the development of teacher professionalism and teaching strategies necessary for specific topics to enhance learner understanding (Ngobeni, 2002). Job-related in-service training in South Africa is usually conducted as developmental workshops organised by the DBE and conducted by subject advisors or any assigned personnel who are specialists in the field. These workshops are generally conducted as a response to teacher support needs or at the introduction of a new topic in the curriculum, as in the case with the CAPS training workshops that were conducted throughout South Africa in 2011.

2.3 CONCEPTUAL FRAMEWORK

The conceptual framework for the study is adapted from Mavhunga (2014) and part of Gess-Newsome's (2015) models on TSPCK. These models have been selected as being the most appropriate because both Mavhunga's (2014) and Gess-Newsome's (2015) models include the four knowledge domains that have consistently featured in a number of PCK models and also includes the five components through which the transformation and manifestation of CK can be seen as discussed earlier in the literature.

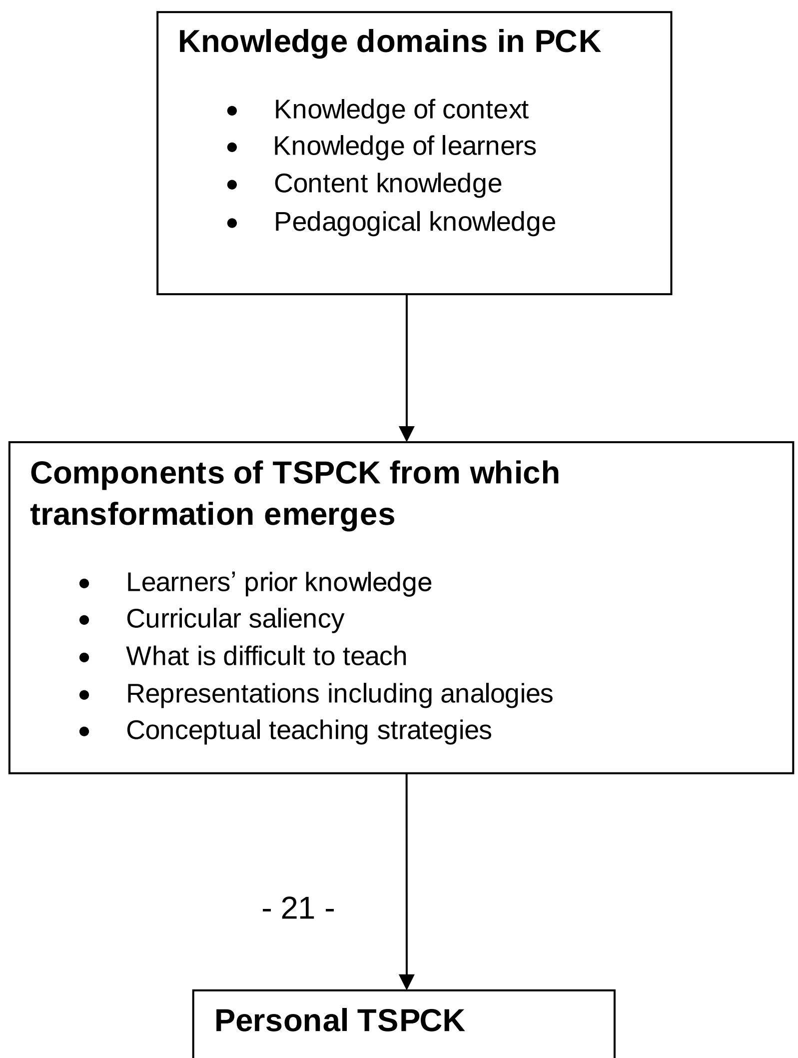

Figure 1: Conceptual framework (Adapted from Mavhunga (2014) and Gess-Newsome (2015).)

The knowledge domains and the components of TSPCK identified in the conceptual framework are linked by arrows that show how knowledge domains are transformed through the components of TSPCK into an individual's TSPCK. According to Mavhunga (2014) the five components of TSPCK as shown in the diagrammatic representation of the conceptual framework contribute to what is referred to as a teacher's professional knowledge. Professional teacher knowledge[6] might be the distinction between successful teachers and unsuccessful teachers (Rollnick et al., 2008). The components of TSPCK from which transformation emerges are linked by an arrow with revealed personal TSPCK. It is this revealed TSPCK that can be captured and measured by a tool such as the CoRe.

2.4 SUMMARY

The study is grounded on Shulman's (1986, 1987) conceptualisation of pedagogical content knowledge (PCK) and draws from Grossman's (1990) conceptualisation of PCK, which includes distinct knowledge bases for teaching. Literature has shown that many scholars have developed PCK models that have consistently shown four commonalities, and these include pedagogical knowledge (PK), subject matter knowledge (SMK) or referred to as content knowledge (CK) by other scholars, pedagogical content knowledge (PCK) and knowledge of context (Park & Oliver, 2008; Rollnick et al., 2008). Rollnick et al., (2008) developed a model that regards PCK as a separate knowledge base, where the other domains link and contribute to the overall development of an individual's PCK. These authors placed emphasis on PCK and argued that CK is a critical component inside TSPCK and that CK is an issue in the South African context where teacher efficiency and learner performance are still very

[6] The type of knowledge that distinguishes teachers from other professionals and provides a framework within which teachers operate as professionals

low (Rollnick et al., 2008). Mavhunga's (2014) topic specific pedagogical content knowledge (TSPCK) model was based on Shulman's (1987, p. 16) foundational statement that "comprehended ideas must be transformed in some manner if they are to be taught". Mavhunga & Rollnick's 2013 TSPCK model which draws significantly from work by Davidowitz and Rollnick (2011) also acknowledges the role of four knowledge domains that include knowledge of context, CK, PK and knowledge of students. According to Veal and MaKinster (1999, p. 9) "the most specific and novel level of the general taxonomy [of PCK] is topic specific PCK". Teacher knowledge is content specific and content is topic specific (Abell, 2008). Work, energy and power are specific topics in the physical science curriculum, therefore Mavhunga's TSPCK model provides a framework from which the determination of the physical science subject advisors' TSPCK about this topic can best be understood.

Literature also has shown that the teaching of the concept of energy and the work – kinetic energy theorem is not easy owing to the abstract nature of the concept and the fact that it is highly context dependent. Despite the difficulties in teaching the concept it remains critical that learners understand the concept of energy as it is fundamental to future learning of other concepts in science. Energy is a cross cutting concept in science education (Bybee, 2011b). It has also been reviewed in the literature that learners' misconceptions make the teaching and learning of the concept of energy as it relates to work and power very difficult. Nordine et al., (2010) identified seven energy concept frameworks upon which learner misconceptions can be categorised, and they argued that learners' initial understanding of the concept of energy is based on one or two of these frameworks. Instruction provided to learners should develop conceptual change by providing learners with clear conceptual understanding of energy transformations during unfolding of a process or interaction of bodies (Nordine et al., 2010).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the overall research methodology that was followed when carrying out the study. It addresses such issues as the philosophical lens that was used in view of the ontological, epistemological and methodological position of the researcher. The chapter also looks at the research design, sample and sampling techniques used and the rationale behind selection. In answering the research questions, the study adopted a qualitative approach based on the interpretive paradigm, with a case-study as the research design.

3.2 RESEARCH QUESTIONS

The research methodology employed in the study seeks to provide answers to the following main research question.

How does a professional teacher development (PTD) workshop on work, energy and power develop the quality of physical science subject advisors' TSPCK?

The main research question will be supported by the following research sub-questions

- What was the quality of the subject advisors' TSPCK before the PTD workshop on the teaching of work, energy and power?
- What was the quality of the subject advisors' TSPCK after the PTD workshop in the teaching of work, energy and power?
- In which ways were the components of TSPCK influenced by the workshop?

3.3 PARADIGMATIC PERSPECTIVES

The core of any form of enquiry in research is to understand the world around us, and this understanding of the phenomena that confronts mankind is informed by how we as individuals view the world. How we view the world is guided by a number of philosophical questions, such as what individuals perceive understanding and knowing to be, what is regarded as the purpose of understanding and finally what is viewed as valuable (Cohen, Manion & Morrison, 2011). In giving answers to the raised philosophical questions on the nature of enquiry a researcher has to adopt a particular philosophical stance or school of thought, and each school of thought has its own different ontological and epistemological assumptions (Cohen et al., 2011; Maree, 2007).

3.3.1 Ontological assumptions

Ontological assumptions are concerned with the basic nature of the phenomena under investigation, thus one can ask, what is reality and is social reality external to individuals or is it a result of individual perception? Is the nature of reality objective or subjective? The objective nature of reality referred to as realism contends that knowledge exists independent of the knower, whereas the subjective nature of reality (nominalism) contends that reality is a product of individual consciousness (Burrel & Morgan, 1979). Owing to the subjective nature of human beings involved in this study the researcher adopted the subjective nature of reality (nominalism), which entails the realisation that individuals create, modify and assign meaning to words in interpreting phenomena. In the study the researcher made interpretations and assigned meaning to the written CoRes and also to the interview transcript from a nominalist viewpoint. The obvious bias associated with the subjective nature of this worldview of reality, was minimised by having multiple interpreters of the same data. In the study the researcher, supervisor and co-supervisor were involved in the interpretation process. Subject advisors (SAs) were expected to articulate their TSPCK, in terms of content knowledge, teaching instructions and what they think is important for learners to know from their perceptions of reality. Ontological assumptions about the nature of reality and the nature of things give rise to epistemological assumptions (Cohen et al., 2011).

3.3.2 Epistemological assumptions

According to Cohen et al. (2011, p. 6), epistemological assumptions “concern the very basis of knowledge - its nature and form, how it can be acquired, and how it can be communicated to other human beings”. How an individual understands knowledge and how one goes on to uncover and acquire this knowledge demands that one should adopt a particular philosophical stance. Owing to the nature of enquiry in the study, a post-positivist paradigm was followed. Capturing, interpreting and making sense of the PCK about work, energy and power of physical science subject advisors can best be done from a subjective approach. The post-positivist paradigm, requires a subjective approach to research and allows the researcher to gain insight and understanding into the meanings and interpretations individuals give to phenomena (Beck, 1979; Creswell, 2009; Denzin & Lincoln, 2005; Maree, 2007).

In the study the researcher interacted with the participants' written CoRes and also the interview transcript and drew meaning and provided interpretations to the participants' responses. Knowledge within the interpretive paradigm is viewed as a direct product of the people's experiences in specific contexts and social reality is explained through the eyes of the participants (Cohen et al., 2011; Creswell, 2009). Post-positivism strives to understand how individuals in everyday settings construct meaning and explain the events of the world (Creswell, 2009; Denzin, 2008). Subject advisors, like every other person, understand and acquire scientific concepts differently as individuals. Since teacher professional knowledge is very subjective and highly individualistic (Loughran et al., 2004; Rollnick et al 2008), the post-positivist paradigm was a more appropriate epistemological stance, as it focuses on an individual's experiences in a specific context as a single case and not as a collective. Subject advisors articulated their TSPCK in different ways, and what individual teachers view as important key concepts (key ideas) in teaching work, energy and power, varied from one teacher to another.

However, the use of post-positivism as a research paradigm is not without flaws. Cohen et al. (2011) argued that the focus and greater emphasis given to the individual as the main actor submerged in a particular phenomenon brings forth the inherent biases associated with the subjective nature of human beings. Interpretations and meanings assigned to reality and knowledge by individuals are strongly linked to one's axiological standpoint, meaning the values assigned to meanings and interpretations differ from one individual to the other (Cohen et al., 2011). Another criticism of the interpretivist research paradigm is its inability to generalise findings outside the studied situation (Maree, 2007). However, for this study the focus is not to generalise the findings towards the broader population but to provide an understanding of the fundamental issues affecting the teaching and learning of the energy concept in the target province.

3.3.3 Methodological paradigm

According to Myers (2013) research methodology refers to strategies of enquiry that include the philosophy behind the selection of the research design process and data collection instruments. While there are overlaps of research methodologies arising from differing epistemological stances adopted by researchers, qualitative and quantitative approaches emerge as the main distinct classifications of research methods. Inferring from the nature of this study, a qualitative research approach was used, with a bit of quantitative research aspects in data collection. However, the inclusion of this aspect of quantitative approach does not make the research approach a complete mixed methods research. Qualitative research attempts to study people as individuals, as groups or communities in their natural settings (Creswell, 1998). Qualitative researchers contend that people are different, and have different beliefs and values and their ways of interpreting reality are different and can only be understood by exploring their experiences regarding certain phenomena from within. The researcher assumes an active participatory role and is not detached from the phenomena under investigation as in the case with quantitative research (Maree, 2007). Nominalism, the ontological assumption to reality adopted for this study, contends that reality is a product of individual consciousness. Post-positivism, which is the adopted epistemological stance, strives to give meaning to words in interpreting phenomena.

It is further argued by Maree (2007) that human experiences can be explored through interviews aimed at understanding how individuals in everyday settings construct meaning and explain the events of the world (Burrel& Morgan, 1979; Creswell, 2009; Denzin, 2008). According to Burrel and Morgan (1979) nominalism entails that individuals create, modify and assign, questionnaires, written opinions and public documents and that qualitative research is concerned with textual interpretations different from the statistical analysis employed by quantitative research methodology. In this study an interview with the staff member of the Faculty of Education who conducted the workshop, helped shed some light and brought the researcher closer to the participants and what happened during the workshop.

However, when using the qualitative research approach which actually acknowledges the researcher's subjectivity, one has to be wary of an apparent bias which can enter the data collection process. The interpretations of the written CoRes that the researcher made were based on the quality of his personal TSPCK in teaching ‘work, energy and power’ and even though a rubric was used, its design can also give room for subjectivity. How this apparent bias will be dealt with, will be discussed clearly under data analysis. Another point of criticism raised against the qualitative approach is that participants may not necessarily be credible, or that the group under investigation may not be representative enough of the larger group (Denzin and Lincoln, 2005).

In this study the credibility and representativeness of the participants were not issues since all the participants had a university qualification in science education and were all former physical science teachers appointed as subject advisors of different regions in the same province and were thus a credible representation of the population.

3.4 Research design

The research design for the study was a case study-design; this research method is seen by Cohen et al. (2011) as satisfying the main tenets of the qualitative approach: describing, interpreting, understanding and explaining an event or phenomenon. In this study an attempt was made to describe an event, which is the actual development programme and to explore the effect of the programme on the subject advisors’ TSPCK in the teaching of work, energy and power. This was achieved through in-depth analysis and careful interpretation of the subject advisors’ written CoRes. According to Robson (2002), case study research could be an individual case study, or a set of individual cases. Investigating the development of TSPCK for an individual subject advisor would constitute a single case study. In criticising a single case study, Campbell (1975) suggested that involving two or more cases for comparative purposes increases the validity and trustworthiness of the study, and this, he argued could be referred to as multiple-case study design. Campbell (1975) pointed out that multiple cases reinforce the results by replicating pattern-matching, thereby increasing confidence in the data. However, since this study is not focused on individual cases it cannot be referred to as a multiple case design.

There are multiple advantages to case studies. Case study research, whether single or multiple case designs, stands to portray, analyse and interpret the exceptionality and uniqueness of real persons and situations through accessible accounts (Cohen et al., 2011). According to Maree (2007) case study research is characterised by in-depth, detailed data and it involves the holistic treatment of phenomena. The strength of case study research is in the significance and quality rather than quantity of data that can be obtained. Other advantages of case study research include the fact that the results are easy to understand and are quite intelligible even to non-academics, the results speak for themselves (Cohen et al., 2011). Case studies provide realistic results of a study and this is due to their down to earth and attention-holding nature (Nisbet & Watt, 1984). They further agree with Cohen et al., (2011) that case studies can be undertaken by a single researcher thereby not requiring a team of researchers to conduct, and are less expensive compared to large scale surveys.

However, case studies have their own limitations, even though Campbell (1975) suggested an increase in the number of cases to improve validity and trustworthiness of data, Yin (1984, 1993) strongly argued that the relative size of a sample does not transform a multiple case design into a macroscopic study to enable generalisation of the results. Therefore, like Cohen et al. (2011), Yin (1993) contends that one of the major drawbacks of case study research is the lack of generalisation of results to a larger population. However, Cohen et al. (2011) argue that the purpose of a case study is not to generalise findings towards a population but towards a theory. Case studies are prone to researcher bias, due to the subjective and personal interpretations given by the researcher in trying to understand and give meaning to data (Creswell, 1998; Cohen et al., 2011; Maree, 2007; Yin, 1993).

In minimising bias in interpretations and in drawing conclusions in the study, a rubric was used in scoring the CoRe and employed reflexivity, which according to Cohen et al. (2011) is a process whereby data, inferences and interpretations are checked by other external reviewers, in this case the researcher’s supervisors, before final conclusions were drawn.

3.5 SAMPLE AND SAMPLING TECHNIQUE

The population in the study was physical science subject advisors in South Africa and a convenient sampling technique was used. A university in South Africa was commissioned to present a workshop for subject advisors and teachers in a specific province. The fifteen Subject advisors that attended the workshop formed the sample for this study as they were easy to access. Convenient sampling is a qualitative sampling technique (Creswell, 1998; Cohen et al., 2011; Maree, 2007). This sampling technique refers to situations when population elements are selected based on the fact that they are easily and conveniently available (Maree, 2007, p. 177). According to Cohen et al. (2011) convenient sampling is not only limited to proximity but to general ease of access.

Convenient sampling techniques are usually criticised due to the fact that information drawn from such samples might not be generalised, however Creswell (1998) contends that the primary concern of convenient sampling is not on generalising the results to a larger population, but on ease of access and in-depth information that can be obtained from the sampled experts.

3.6 DATA COLLECTION

3.6.1 Research steps

In this study, data collection was characterised by a chronological order of events and processes. Initially subject advisors completed the pre-CoRe before the PTD workshop. The workshop was conducted over five days covering some physics topics including work, energy and power. The CAPS document was the guideline for the selection of content that was included in the workshop manual. Work, energy and power was allocated one and a half hours of tutoring by the presenter. Immediately after the PTD workshop and without any interaction with any personnel other than members of the sample and the presenter of the workshop, the subject advisors wrote the post-CoRe. During the scoring process the pre- and post-CoRes were initially scored and based on the actual responses by the participants. The rubric had to be refined to align categories and their descriptors. The Rasch analysis was then done using the RUMM programme. Initially the CoRe data for both pre- and post-assessment revealed disordered or reverse thresholds for some CoRe prompts and that necessitated further refinement of the rubric and rescoring. An interview was conducted with the presenter of the PTD workshop and an analysis of the workshop manual was done.

Understanding the development of the physical science subject advisors' TSPCK is challenging owing to the difficulties associated with capturing and portraying an individual's TSPCK which is often constructed tacitly and personally (Loughran et al, 2004; Rollnick et al, 2008; Mavhunga, 2014). Many science teachers find it difficult to articulate their TSPCK, which further makes it problematic to interpret and understand its development.

To aid the trustworthiness of the collected data the study employed triangulation, which according to Maree (2007) refers to the use of three data collection strategies. In the study the CoRes instrument, interview and document analysis were used to collect data. The main research question required a data collection instrument that probed the subject advisors to clearly articulate their TSPCK through answering questions stemming from the components of TSPCK as discussed in the literature review and under the conceptual framework.

Loughran et al., (2004) designed a tool which could help capture and portray the science teachers' TSPCK. The tool consisted of a number of prompts that encouraged teachers to reveal their thinking about aspects of their teaching. The tool is referred to as content representations (CoRe). It aligned with the TSPCK framework by which science teachers' TSPCK could be captured and portrayed (Loughran et al., 2004). Rollnick et al, (2008) and Mavhunga (2014) made use of the CoRe in their respective studies and in both cases the CoRe was found to be an appropriate and effective data collection instrument. The instruments used to collect data and the reasoning behind the implementation of these instruments will be discussed below.

3.6.2 The CoRe-tool

A CoRe is a tool that can capture and portray a teacher's knowledge about how to teach the content of a particular topic (Loughran et al., 2004). It is a useful tool for research focused on PCK as it effectively links with the TSPCK framework. In this study the CoRe represented the subject advisors' knowledge about how to teach the topic, 'work, energy and power'. The CoRe did that by probing the subject advisors to identify the "key ideas" of the topic or key aspects. According to Loughran (2004) these "key ideas" are essential aspects of the content intended for learners to learn, and "key ideas" form the column headings of the CoRes table. The CoRe-tool is an instrument that links well with the framework of this study. It consists of prompts which link with the TSPCK components from the framework, that reveal the physical science subject advisors' reasoning behind their pedagogical choices, knowledge of their learners (misconceptions and difficulties and areas of confusion) and their teaching strategies (*See Appendix 1*). These components, as discussed earlier, include curriculum saliency, what is difficult to teach, learners' prior knowledge, conceptual teaching strategies and finally analogies and representations.

The physical science subject advisors completed pre-assessment CoRes before the workshop and an analysis of that show the quality of their TSPCK before intervention. Then they completed the post-assessment CoRes again after the workshop to determine the quality of their TSPCK after the workshop. An assessment rubric designed by Mavhunga and Rollnick (2013) and further refined by Ndlovu (2014) formed the framework upon which the specific rubric for work, energy and power was developed and used. The assessment rubric consists of four descriptors which range from limited to basic, developing and finally exemplary; where the descriptor 'limited' refers to poorly developed TSPCK and 'exemplary' refers to well-developed TSPCK (Zimmerman, 2015). The CoRes instrument and its assessment rubric were appropriate in answering the main research question together with the first and second sub-questions. A comparison between the written CoRes before and after the workshop helped answer the main research question, which sought to explore the effect of the PTD workshop, while an analysis of the pre-assessment written CoRes highlighted the physical science subject advisors' TSPCK levels in teaching the topic 'work, energy and power' before the workshop. Finally, an analysis of the post-assessment written CoRes indicated the TSPCK levels of the subject advisors after the development programme. Validity of both the CoRes and its rubric has been established in earlier studies such as Mavhunga and Rollnick (2013) and Ndlovu (2014). The rubric was further refined by an experienced physics educator to further enhance validity. Possible challenges that can affect the validity of the rubric are discussed under trustworthiness. Table 2 below indicates the relationship between the CoRe prompts and TSPCK components.

Table 2 The relationship between CoRes prompts and TSPCK components

Content Representation prompts	**TSPCK components from conceptual framework**
What do you intend the learners to learn about this idea?	Curricular saliency.
Why is it important for learners to know this?	Curricular saliency.
What concepts need to be taught before teaching this idea?	Curricular saliency.
What else do you know about this idea that you do not intend learners to know yet?	Curricular saliency
What are the difficulties/limitations connected with teaching this idea?	What is difficult to teach?
What are typical learners' misconceptions about this idea?	Learners' prior knowledge.
What effective teaching strategies would you use to teach this key idea?	Conceptual teaching strategies
What questions would you consider important to ask in your teaching strategy?	Conceptual teaching strategies
What ways would you use to support learners' understanding?	Representations and analogies

3.6.2 Interview

The person who presented the workshop was interviewed. The purpose of the interview was to explore what was taught in the workshop, as well as the presenter's ideas in a bid to provide the answer to research sub-question 3. The interview gave perspective and enhanced the researcher's understanding as to what was communicated in the CoRes. According to Maree (2007, p. 87). "An interview is a two-way conversation in which an interviewer asks the participant questions to collect data and to learn about the ideas, views, opinions and behaviours of the participant". A qualitative in-depth structured interview was conducted with the presenter of the PTD workshop and the interview schedule consisted of questions that stem from the components of TSPCK and started by asking such questions as the purpose and duration of the PTD workshop. According to Cohen et al., (2011) structured interviews are commonly used in case studies and contain questions that are meticulous and developed in advance. However, Maree (2007) argued that if the questions are overly structured they would limit the researcher's ability to probe. An interview schedule was designed soon after the scoring of the subject advisors' written CoRes and a voice recorder was used during the interview session rather than writing down responses since this was seen by Maree (2007) as a disturbance to the flow of the interview.

3.6.3 Document analysis

Document analysis refers to a conscious scrutiny of an article for purposes of understanding the context, deeper meaning, purpose and methodology used by the author of the document (Creswell, 1998). An initial document analysis of the workshop training manual was conducted; the purpose was to check how the presenters addressed the components of TSPCK when they designed the manual on work, energy and power. Even though the PTD training manual was not specifically designed to explicitly focus on the TSPCK components, an analysis of the document revealed that the presenter structured the training manual in a manner that addressed aspects of the TSPCK components. The sequencing of the concepts provided evidence of curricular saliency, while a deliberate focus on misconceptions is an indication of an attempt to enhance teachers' knowledge of learner thinking.

The diagram below (Figure 2) indicates the link between data collection instruments, intervention and the conceptual framework. The subject advisors' knowledge about teaching the energy concept was assessed before the PTD workshop using the CoRe tool based on the TSPCK components from which an individual's knowledge emerges. The intervention (PTD workshop) was then conducted and afterwards the post-CoRe assessment was conducted using the same CoRe tool. The scoring of both the pre- and post-CoRes was done using a rubric and expert CoRe. After the scoring process an interview with the presenter of the PTD workshop was conducted with questions stemming from the TSPCK components from the conceptual framework (see Figure 2).

3.7 LINK BETWEEN DATA COLLECTION AND CONCEPTUAL FRAMEWORK

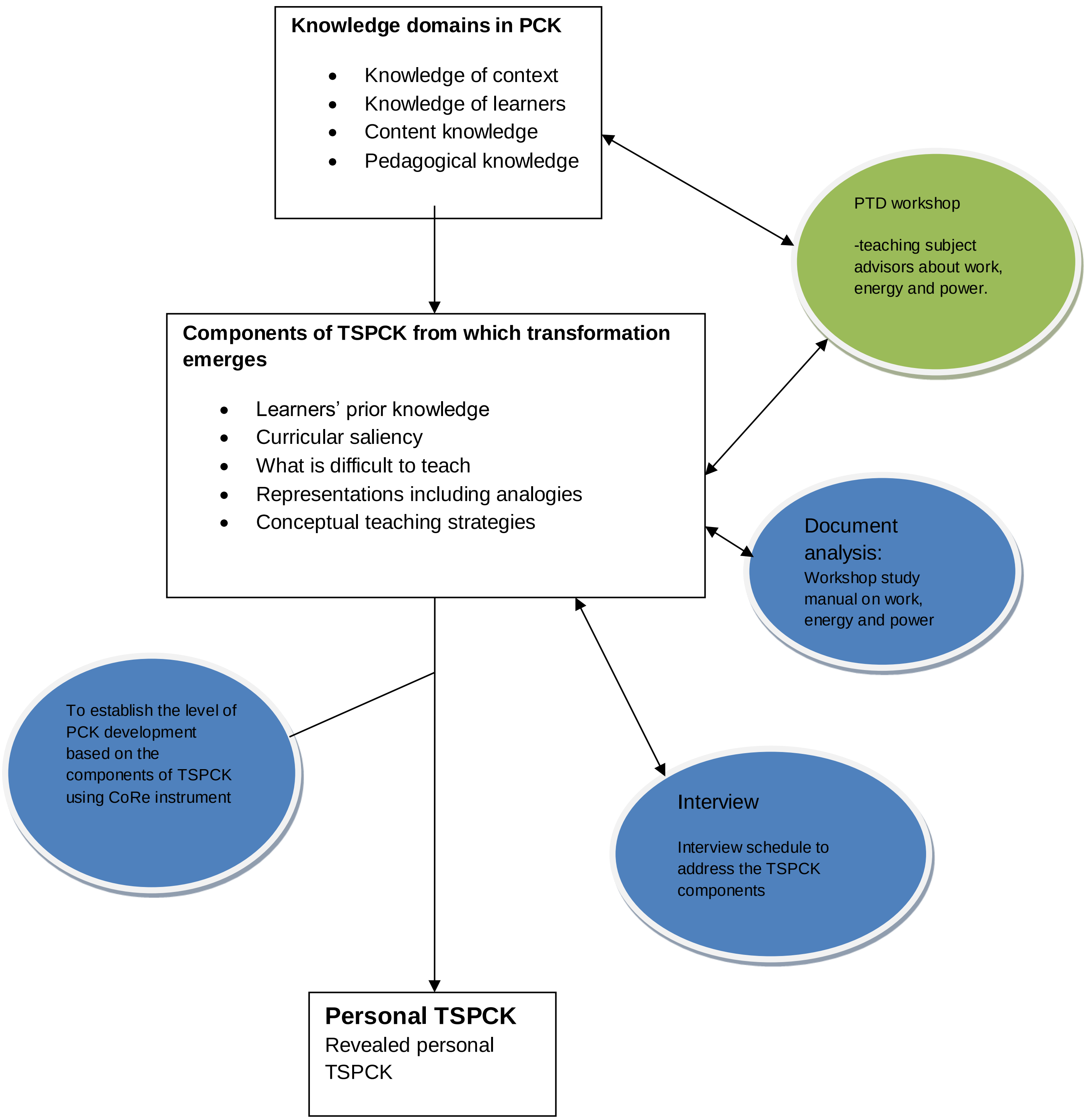

Figure 2 Diagrammatic representation of the link between data collection instruments, intervention and the conceptual framework.

3.8 DATA ANALYSIS

This section of the dissertation discusses the data analysis plan and provides the rationale for the selection and suitability of the data analysis strategy. The data analysis plan is in line with the data collection strategy discussed earlier, and links well with the research design thereby providing sufficient grounds for answering the research question and sub-questions. According to Creswell (1998) there should be a perfect link between the research design, data collection strategy, data analysis plan and research questions to aid the trustworthiness of research results.

3.8.1 Data analysis and interpretation

Based on the data collection instrument and what the study sought to achieve, content analysis was used as the data analysis technique. According to Schilling (2006) content analysis is a qualitative and interpretive technique that involves analysis of text. Content analysis focuses on describing communicated textual message or content to bring out understanding of action, based on who said what, why and to what extent what was communicated had an effect (Borg & Gall, 1989). Central to content analysis is making sense of data through the participant's world view from text (Cohen et al, 2011). In the study the subject advisors' written CoRes, which form part of the data collection instruments discussed previously, were analysed in a manner that brought meaning to the content through careful interpretation of the text. The CoRes were scored using the refined rubric *(see Appendix 2)* that corresponds to the following five components; (i) Curricular Saliency, (ii) What is difficult to teach, (iii) Students' Prior Knowledge, (iv) Conceptual teaching strategies and (v) Representations (Zimmerman, 2015).

However, even though content analysis was the appropriate technique for the primary interpretation of the data, its use still posed some drawbacks, associated with the subjective nature of the researcher owing to its focus on personal interpretations one gives to textual message (Cohen et al 2011; Schilling, 2006). The challenge of researcher subjectivity and bias was minimised by making use of a number of data analysts, aimed at achieving consensus on interpretations (Cohen et al., 2011; Mavhunga & Rollnick, 2013). In the study the researcher's supervisor and co-supervisor were involved in the scoring of the CoRes based on an agreed upon expert CoRes and rubric until consensus was established.

When using content analysis, it is very important to be clear what exactly one is looking for (Maree, 2007). The researcher compared the subject advisors' completed CoRes with the expert CoRes through textual analysis and assigned scores in terms of the TSPCK components of the rubric.

Transcribed interview data was analysed on the basis of the themes of the five components of TSPCK. The researcher explored how the workshop was presented in terms of how the content was sequenced, what teaching strategies were used, what misconceptions were identified, whether the presenter involved the participants or not and what the presenter considered was difficult to teach. For a comprehensive and correct analysis to be made and valid interpretations to be arrived at, the expert CoRes, rubric and interview transcriptions must conform to some acceptable standards of correctness.

3.8.2 Development of the expert CoRe and rubric

The design and development of the expert CoRes and the rubric were not easy, the process was rigorous and yet very critical to the scoring process. Ascertaining the appropriateness of the expert CoRes involved thorough literature study and consultations with some experts in the field of science education, particularly those involved in high school sciences, and the researcher's supervisor who specialises in physics education. The scoring process depended on the expert CoRes and rubric. The design of the rubric for the scoring process was started by first completing the researcher's own CoRes, herein referred to as the expert CoRes *(see Appendix 3*), which became the basis for scoring. The expert CoRe provided exemplary responses to the prompts. During the scoring process if for instance the rubric requires two or more misconceptions for an exemplary score, the expert CoRe would then show the actual expected misconceptions. The actual scoring was done using the designed rubric while the expert CoRe provided responses regarded as exemplary. The expert CoRes was presented to the supervisor for verification in terms of its validity. According to Creswell (1998) validity refers to whether an instrument is measuring exactly what it is intended to measure. After the expert CoRe was accepted as valid and appropriate by the supervisor, the instrument was then used in designing the rubric. The rubric was designed based on TSPCK components discussed in Section 2.2.4 and each component was rated using a four-point scale indicating the level and quality of TSPCK. Zimmerman (2015) also made use of a similar rating, where the level of one's TSPCK was assigned a score of one for 'Limited', a score of two for 'Basic', a score of three for 'Developing' and a score of four for 'Exemplary'. The entire process for the development of the expert CoRes and the rubric as it pertains to validity and trustworthiness is explained under the sub-topic 'trustworthiness' that follows.

3.8.3 Trustworthiness

Trustworthiness refers to having consistency checks done on the data and according to Maree (2007) this can be achieved by making use of multiple coders or raters to avoid researcher bias. To ensure trustworthiness of the results of the study, the conceptual correctness of the expert CoRes and the validity of the rubric had to be ascertained beyond doubt. To achieve the desired correctness of the expert CoRes and validity of the rubric, the researcher made use of two colleagues with whom he was involved in a science project in one of the provincial education districts, and who volunteered to assist in the development of the expert CoRes and were not part of the study beyond what they had volunteered for. The two colleagues are both teaching Grade 12 physical sciences at their respective schools and each holds a masters degree in physics education from the University of Zimbabwe. Their knowledge in physics education and experience in teaching the topic in question 'work, energy and power' proved vital in reflexivity[7], which according to Cohen et al (2011) supports validity. The developed expert CoRes was then scrutinised and approved by my supervisor and co-supervisor in terms of appropriateness, before it could be used. In ensuring trustworthiness of the scoring process and refining the rubric and the expert CoRes, the first three participants were scored by the researcher and his supervisor and co-supervisor. We then compared the scores and adjusted where necessary and aligned the rubric perfectly with the expert CoRes to provide for uniformity and consensus in scoring, a process argued by Maree (2007) to increase inter-rater reliability. Even though the approach to the entire study was qualitative, Rasch analysis, a quantitative data analysis technique, was employed as a way of further refining and validating the rubric. According to Davidowitz and Potgieter (2016) Rasch analysis can provide empirical evidence for

[7]A process that improves validity where data, inferences and interpretations by one researcher are checked by external reviewers in achieving unanimous and conceptually correct response (Cohen et al. 2011).

validity, reliability and unidimensionality of instruments. The Rasch model is used to validate an assessment based on the numerical scores assigned to a population on each item of assessment (Tennant & Conaghan, 2007). In this study, calibration and measurement of the Rasch model was based on two expectations: a more able person have greater probability of success on items than a less able person and any person should always be more likely to perform better in an easier item than in a harder one.

At this stage all the pre- and post-CoRes were scored and the raw numerical data was fed into the Rasch analysis program called RUMM. The program converts raw score data into interval measures which are produced as ordered thresholds indicating alignment of the categories of measurement and descriptors on the rubric. The Rasch model clearly indicated that the category descriptors on the rubric still required further refining as initially the data could not fit the model. After several category and descriptor adjustments on the rubric it was then possible to fit the data on the Rasch model. It was only after this exercise that the final scoring of the participants was continued.

The CoRe-tool as a data gathering instrument has been used by other scholars (Mavhunga & Rollnick, 2013; Zimmerman, 2015) and was verified to be credible, it is therefore expected that in this study the CoRe-tool would provide credible data upon which conclusions can be made. In terms of the interview for the faculty member who conducted the workshop, the interview schedule was verified by my supervisor to ensure that it covers all the aspects necessary in bringing out what was observed during the workshop.

Section 3.8.4 below indicates a diagram that shows how three data collection strategies where linked and used in collecting data for this study. Triangulation refers to the use of multiple methods of collecting data as a way of corroborating findings and as a test for validity (Creswell, 2009). The interview and data from the document analysis and data from the CoRe tool should corroborate each other, indicating validity of the instruments.

3.8.4 Triangulation

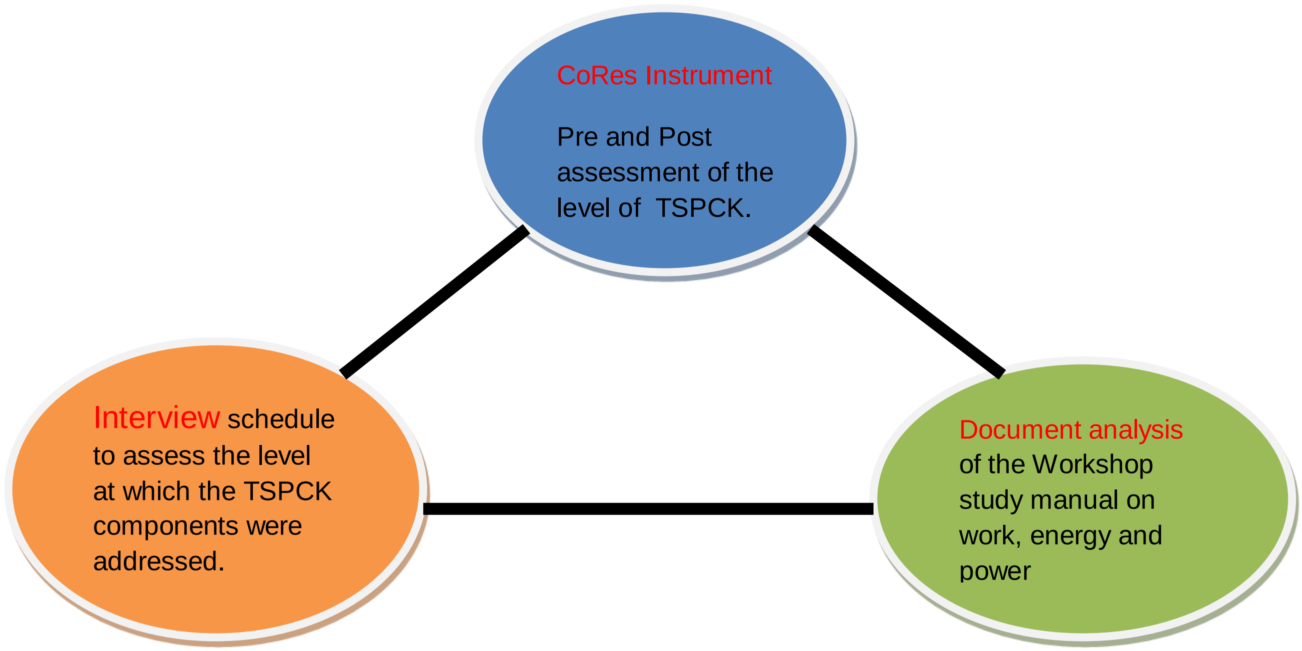

Figure 3: Triangulation.

Table 3: Research design summary

Research strategy	Multiple Case Study		
Participants	Physical science subject advisors who attended a professional teacher development workshop on the teaching of work, energy and power.		
Research main question	What is the effect of a professional teacher development (PTD) workshop on the development of PCK of physical science subject advisors on the teaching of work, energy and power?		
Research sub-question	1. What is the quality of the subject advisors' TSPCK before the PTD workshop on the teaching of work, energy and power?	2. What is the quality of the subject advisors' TSPCK after the PTD workshop in the teaching of work, energy and power?	3. In which ways were the subject advisors' TSPCK influenced by the workshop?
Objectives of the sub-questions	To determine the quality of subject advisors' TSPCK before the PTD workshop	To determine the quality of subject advisors' TSPCK after the PTD workshop	To determine the effect of the PTD workshop on subject advisors' TSPCK.
Data collection instruments	Pre-assessment using the CoRes	Post assessment using the CoRes	Interview schedule and document analysis of the workshop manual
Data analysis	Content analysis of the pre-assessment completed CoRes and Rasch analysis	Content analysis of the post-assessment completed CoRes, Rasch analysis and analysis of the workshop manual.	Content analysis of the transcribed interview data according to the themes of the five TSPCK components and analysis of the workshop manual.

3.9 ETHICAL CONSIDERATIONS

The ultimate credibility of any study is ensured when the study is carried out within a frame work of ethical norms (Thomas, 2013), hence the researcher complied with the necessary ethical requirements. It is imperative to obtain clearance from an ethics committee when conducting a study that involves human participants before the study can be carried out (Maree, 2007). Permission to use the data collected for the Department of Education of the province where the content workshop for subject advisors and teachers was presented, was obtained from the Head of Department (HOD). Ethics clearance was also obtained from the University ethics committee. Owing to the low sensitivity nature of the data involved in the study, permission from the University ethics committee and the province was sufficient. The participants were not required to sign a voluntary informed consent form since they were already willing participants to the workshop, however I undertook to maintain confidentiality of the results and findings of the study. The Faculty of Education member who conducted the workshop was requested to sign the voluntary informed consent form, and the interview recordings and transcriptions would be kept by my supervisor within the department.

3.9 SUMMARY

In this chapter the overall research design process was presented, highlighting the philosophical and paradigmatic approach to the study. The sample and sampling technique, the data collection instruments, data analysis techniques and the development of the expert CoRes and the rubric were highlighted. I also mentioned in detail how I dealt with validity of the data collection instruments and issues of bias associated with qualitative research approach in terms of interpretation of data. In the following chapter the results obtained using the research methodology explained in this chapter were presented.

CHAPTER 4

Pre-CoRe results

4.1 INTRODUCTION

In this chapter and the subsequent chapters five and six the data is presented that was collected using the data collection strategies discussed in chapter three, which were:

- Pre- and Post-CoRes completed by physical science subject advisors who attended the PTD workshop.
- A semi-structured interview with the presenter of the PTD workshop.
- Document analysis of the workshop manual used during the presentation of the PTD workshop.

Chapter 4 focuses on data that was collected using the pre-CoRe and an analysis and interpretation of this data can provide answers to the first research sub-question which sought to determine the quality of subject advisors' PCK before the PTD workshop. Chapter five centres on data collected using the post-CoRes together with data from the interview and the document analysis of the PTD workshop study manual. Analysis of chapter five data can provide answers to the second research sub-question, which sought to determine the level of subject advisors' PCK after the workshop. A qualitative comparison of the data collected in chapter four and that collected in chapter five will constitute chapter six. The qualitative analysis and interpretation in chapter six will provide answers to research sub-question three which sought to find out how the knowledge of the subject advisors of the components of TSPCK were influenced by the PTD workshop. Data collected by these instruments when fully analysed will provide answers to the main research question, which sought to find out how a PTD workshop on work, energy and power develop the quality of the physical science subject advisors' TSPCK.

Table 4 Chapter Lay-out

Analysis of data from instruments	Research question addressed	Chapter
Pre-CoRe	Research sub-question 1	Four
Post-CoRe	Research sub-question 2	Five
Interview	Research sub-question 3	Six
Document analysis of PTD workshop manual		
Quantitative and qualitative comparison of the two CoRes		

4.2 Data presentation

In presenting data, a coding system was developed for the subject advisors where SA abbreviates *subject advisor* and the other three characters identify the participant such as SA-M01. Data obtained from the CoRe instrument is presented per participant according to the CoRe prompts as they appear under each TSPCK component. These components are presented in the following order; *Curricular Saliency, What is difficult to teach, Learners' prior knowledge, Conceptual teaching strategies and Representations or analogies*. Prompt A0 is the response to a question where the subject advisors had to identify a number of key ideas related to the topic and afterwards had to select two ideas to elaborate on in the rest of the CoRe. Prompts A1 to A4 provide evidence of a participant's knowledge about *curricular saliency*, while B1 and C1 provide evidence of knowledge about what is *difficult to teach* and *learners' prior knowledge* respectively. Prompts D1 and D2 provides evidence of a participant's knowledge about *conceptual teaching strategies*, while prompt E1 shows a participant's knowledge about *representations and analogies (see CoRe template Appendix 1)*. Prompt E2 indicates a participant's knowledge about assessment techniques, however, this prompt does not belong to any specific TSPCK component but provides valuable information on a participant's general knowledge about all five the TSPCK components. The sample size was fourteen however one participant did not complete both the pre and the post assessment CoRes which reduced the sample size to thirteen.

4.3 PARTICIPANTS' RESPONSES WHEN ENGAGING IN THE FIVE TSPCK COMPONENTS

4.3.1 Development of the rubric to score the CoRes

In the scoring process use was made of two instruments that were designed and explained in the methodology chapter under the sub-topic '*development and design of the expert CoRes and the rubric'*. These instruments are the rubric and the expert CoRes *(see Appendices 2 and 3)*. The rubric is designed specifically for assessing a teacher's TSPCK in teaching work, energy and power using the CoRe-tool. The participants' pre and post-assessment responses were compared with the expert CoRes and, using the rubric, each participant's response was assigned a level based on a scale that ranges from limited (L), basic (B) and developing (D) to exemplary (E) (Park, Jang, Chen & Jung, 2011). This rating scale is further expressed as numerical values where a limited rating has a score of one, basic a score of two, developing a score of three and exemplary a score of four. The scores were expressed as numerical values for the purposes of the quantitative aspect of data analysis using the Rasch model. The rationale for using the Rasch model, as discussed earlier under trustworthiness in chapter three (see 3.7.3), was to further develop the rubric in terms of refinement of the descriptors. In Chapter 3 the origins of the first version of the rubric that it was based on, as used by Mavhunga and Rollnick (2013), was discussed. During my first scoring of the CoRes the actual responses by the subject advisors prompted me to add descriptors to my categories and further refinement of the existing categories. Then the scoring by two external raters and discussion led to yet another version of the rubric and overall rescoring. Finally, data expressed as numerical values were fed into a Rasch analysis program called RUMM. The Rasch output indicated the necessity to further revise the rubric as the output presented reversed thresholds for some prompts. A reverse threshold means that it is more likely for a person with higher ability to score lower than a person with lower ability (see Figure 4). The red coloured bars indicate persons whose knowledge about a particular prompt was rated as 'limited', while the green bars show a rating of 'basic' and purple indicates knowledge rated as 'developing'. It must be noted that on the Rasch maps below there is a rating scale of 0-3 instead of 1-4 as mentioned earlier. Since no subject advisor's knowledge about all prompts was rated as 'exemplary', a numerical rating of four, it was then not necessary to include a four on the map. The zero on the maps indicates a no-response.

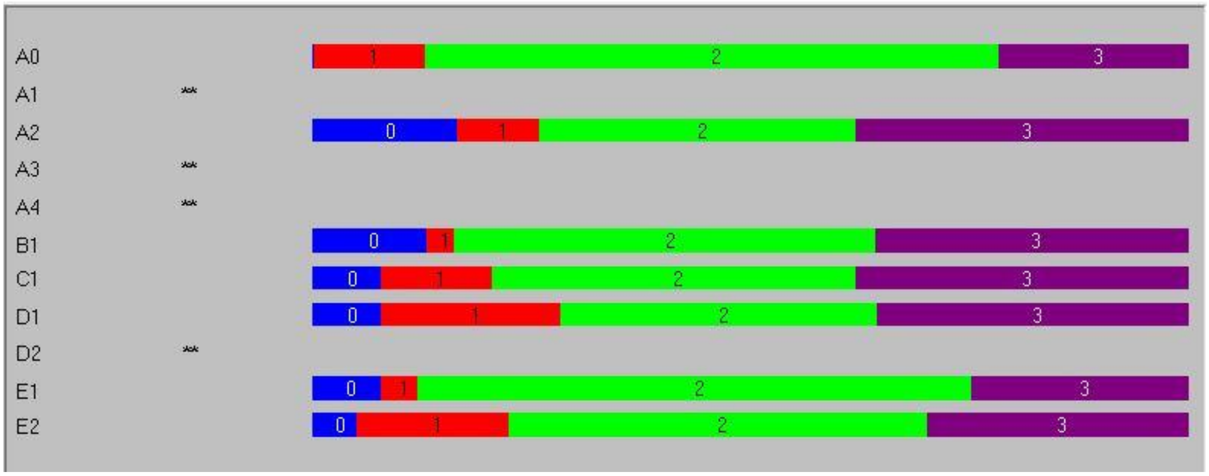

Figure 4: First Threshold Map

Prompt A1, A3, A4 and D2 did not fit the Rasch model, these prompts indicated disordered thresholds. This was a clear indication that the categories in the rubric were not clearly defined and did not distinguish effectively between the categories and needed refinement. (*See the Table 5 example of rubric categories and descriptors for prompt A1 that indicated a reverse threshold).*

Table 5: Example of rubric categories and descriptors

Limited	Basic	Developing	Exemplary
Curricular saliency			
- Not all key ideas have subordinate ideas or no subordinate ideas provided. - Identified subordinate ideas mainly incorrect and / or are repetitions of key ideas. - Identified subordinate ideas are from the designated topic and from other topics.	- Not all key ideas have subordinate ideas. However those identified are mainly correct. - Subordinate ideas are limited to being aware of the equations and their standardized definitions. - Subordinate ideas are limited to being aware of standardized definitions of terms in that topic.	- Identify correct subordinate ideas and shows links to key ideas with no additional explanations. - Identified subordinate ideas account for the application of equations / definitions, that is manipulation of equations and reproducing the definitions.	- Identify correct subordinate ideas and explain links to key ideas. - Identified subordinate ideas focus on understanding the concepts underlying the equations / definitions in the current topic.
Prompt A1 before refinement			

When revisiting the first rubric, it was noticed that for prompt A1 and other prompts, there was no clear distinction between limited, basic and developing and, as such, a person with higher ability could easily be scored 'limited' and a person with lower ability could as well be easily scored a higher 'developing' or even 'exemplary'.

The descriptors were then refined by assigning the minimum key ideas and sub-ordinate ideas for each category, for example if only one key idea and no sub-ordinate ideas are provided the participant is rated 'limited'. A participant is scored 'basic' only if at least two relevant key ideas and at least two sub-ordinate ideas are provided. For 'developing', at least three relevant key ideas and three sub-ordinate ideas are provided. A participant is rated 'exemplary' if more than three key ideas and at least four sub-ordinate ideas are provided. (See Table 6)

Table 6: TSPCK component one: Curriculum Saliency.

TSPCK component 1: Curriculum saliency			
(Evidence to score this component is found in participants' selection of key ideas and responses to prompts A1 to A4 in the CoRe-tool)			
Limited	**Basic**	**Developing**	**Exemplary**
-No key ideas or only one key idea selected - No subordinate ideas provided for the identified key ideas. - Subordinate ideas identified but mostly incorrect and not linked to work, energy and power.	-Selected at least two relevant key ideas for work, energy and power. -Identified at least two correct subordinate ideas and included equations and standardised definitions of terms under work, energy and power.	-Identified at least three relevant key ideas for work, energy and power. -Identified more than three correct subordinate ideas for teaching the selected key ideas on work, energy and power including equations and definition of terms but did not provide additional explanations to link concepts. -The identified subordinate ideas revolve around manipulation of equations and reproducing definitions.	-Identified more than three key ideas appropriate for work, energy and power. - Identified at least four correct subordinate ideas and explain links to key ideas focusing on understanding the concepts underlying the equations and definitions in work, energy and power.

Prompt A1 refined after Rasch analysis

Similarly, the categories for other prompts that had indicated reverse thresholds were refined. The researcher then rescored and the new data was fed into the Rasch analysis programme again and another threshold map was obtained (*see Figure 5, threshold map 'B'*). With the exception of prompt E2 all the other prompts indicated ordered thresholds, indicating the credibility and validity of the rubric.

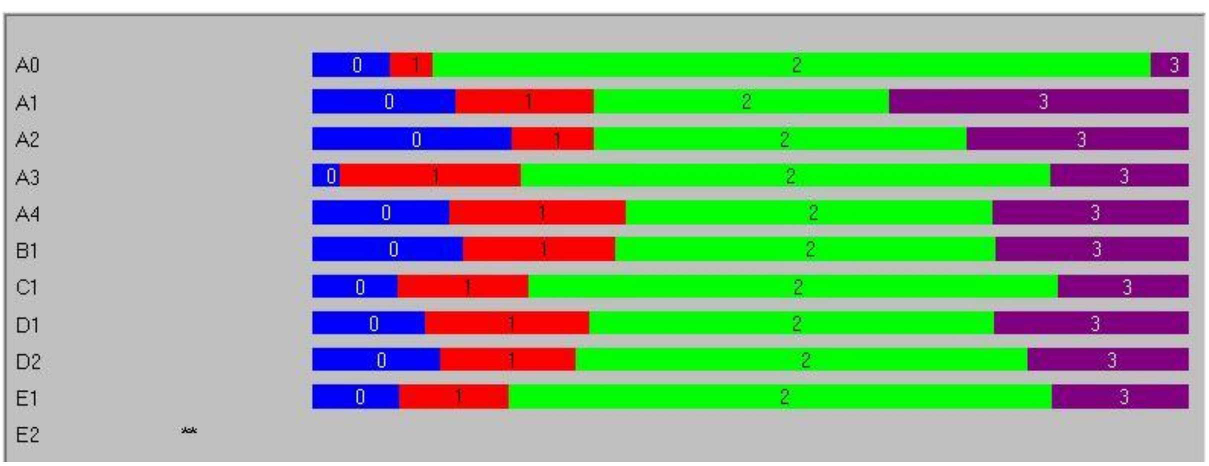

Figure 5: Threshold map 'B' after refining of descriptors and rescoring

In threshold map 'B', E2 is now disordered, but since prompt E2 does not link with the framework, this is then not a serious issue. It must also be noted that the sample effectively consisted of only eleven participants. A larger sample may have resulted in improved ordering of thresholds.

In this chapter each participant's pre-CoRe scores when engaging in each of the five TSPCK components are recorded according to the CoRe prompts as they appear on each participant's completed CoRes. In chapter five data from the post-CoRes will be recorded in a similar fashion as in Chapter 4. Later in the analysis and interpretation chapter a comparison will be made between the pre-and post-CoRes using the qualitative and quantitative analysis techniques to determine which TSPCK components were affected by the PTD workshop and what the extent of the effect was. These analysis techniques involve content analysis which is a qualitative data analysis technique and Rasch analysis which is a quantitative data analysis technique, which converts raw score data into intervals of measurements and provides for validity of measuring instruments (; Davidowits & Potgieter, 2016). Tennant & Conaghan, 2007)

During the scoring process some challenges emanated, mainly from the participants' CoRes that had no responses for some of the prompts and also from the participants who identified wrong key ideas. In the case of 'empty blocks' indicating no responses a 'limited' score was awarded based on the rationale that the participant either did not have acceptable responses or did not have sufficient time to write a response. It is also reasonable to assume that "no response" does not mean "no knowledge" about the component. However, if time was not sufficient to write a response an assumption was made that, requiring more time to complete a task could be a sign of lack of confidence as a result of limited knowledge about the task and a 'limited' score was in order and fair. In the case of wrong key ideas, all the prompts were scored as long as the key idea belonged to the energy concept. The expert CoRe gives an indication of what is considered as exemplary responses. Responses that fall short of the expert CoRe were scored as *limited, basic* or *developing* according to the rubric.

4.3.2 Summary of pre-CoRe levels assigned for each participant

Table 7 below is a summary of the levels assigned for the responses by each subject advisor to each component of the CoRe-tool. These scores were checked for inter-rater reliability as rater agreement was achieved between the researcher and the supervisor. It should be noted that there are only eleven participants in the table for the following reason: Participant SA-M01 and SA-M04 had responses to all the prompts identical to participants SA-T08 and SA-M09. Only the results of SA-M01 and SA-T08 were included, as including the other two had no significance to the results of the study. These participants engaged in some form of pair-discussion and that would pose a problem on analysis and interpretation. Participant SA-M11 was also not included as the participant only responded to the pre-CoRe and not the post-Core. This effectively reduced the sample size to eleven participants. Table 7 shows the summary of the scores that the subject advisors obtained for the pre-CoRes. These scores were checked for inter-rater reliability as rater agreement was achieved between the researcher and the supervisor.

Table 7: Summary scores for the pre-CoRes

Participant codes	**CoRe prompts**										
	A0	**A1**	**A2**	**A3**	**A4**	**B1**	**C1**	**D1**	**D2**	**E1**	**E2**
SA-M01	2	1	1	3	2	2	2	2	2	1	2
SA-Z02	2	1	1	2	2	2	1	1	1	3	4
SA-V03	2	2	1	1	1	2	1	2	2	2	2
SA-M05	1	2	1	1	1	2	2	1	1	2	2
SA-M06	1	2	1	3	2	2	1	2	1	2	1
SA-C07	1	1	1	2	2	1	2	1	1	1	1
SA-T08	2	1	1	2	1	1	1	2	2	2	3
SA-N10	2	1	1	3	1	2	2	1	2	2	2
SA-M12	3	1	1	3	1	1	2	1	1	1	2

SA-L13	3	2	1	2	2	1	2	1	1	3	3
SA-M14	3	2	3	1	2	1	1	1	1	2	2

4.3.3 Presentation and discussion of pre-CoRe data

In the section below the responses of each subject advisor are given verbatim in a typed version of the written CoRe. The scores for each response and for the component are indicated in the CoRe-table. A discussion of the responses and the reasoning behind the scores assigned to the components for each participant, follow after the CoRe-table. Each prompt is assigned a level based on the scoring done using the rubric and the expert CoRe. Since some TSPCK components such as *curricular saliency*, *conceptual teaching strategies* and *representations and analogies* have more than one prompt, eliciting a particular score for the component would involve adding the numerical values of all the levels assigned for the prompts and dividing by the number of prompts to get an average score which then becomes the score for the TSPCK component. A score of 'limited' has a numerical value of one and 'exemplary' has a value of four, while 'basic' and 'developing' have numerical values of two and three respectively.

Table 8: Subject advisor SA-M01 before workshop responses to the CoRe Prompts A0 to E2

SA-M01	**Pre CoRe**		Level
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	* Definitions of work and energy and calculations * Use the work energy theorem * Different kinds of energy		**2**
Key ideas	**Selected key idea 1** Definition of work and energy and calculations	**Selected key idea 2** Work-energy	
A1 *What do you intend learners to learn about this idea?*	To know what is energy and work and application	Understand the work-energy theorem	**1**
A2 *Why is it important for learners to know this?*	This will help learners to relate work and energy	To be able to use it in calculations	**1**
A3 *What concepts need to be taught before teaching this idea?*	Different types of forces, how to calculate the net force. Force diagrams	Kinetic energy, potential energy and work done	**3**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	The work-energy theorem	Application of the theorem in different situations e.g. calculating the Fnet	**2**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Differentiating between the scientific and everyday meaning of work	Identifying the angle to be used when calculating the work done, or the parallel component of weight from inclined plane	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	When a force is applied to an object and the object does not move learners still believe that work is done Confuse conservation of energy and conservation of mechanical energy	They use the angle of the inclined plane in the equation when calculating work done $W = F.\Delta x.\cos\theta$	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Enquiry and demonstration method, problem solving	Use the problem solving method	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	Give situations where work is done Define mechanical energy State the principle of conservation of energy	Define the work-energy theorem Break calculations in stages Calculate Fnet, Wnet and velocity using the work-energy theorem	**2**
Representations and analogies			**1**
E1 *What ways would you use to support learners' understanding?*	Demonstrations	Analogies	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Question and answer method Classwork based on the lesson	Problem solving	

Participant SA-M01 had challenges in identifying key ideas. The participant identified the definition of energy as a key idea while this could actually be a sub-ordinate idea for the teaching of work or energy (see Table 9). Energy as a concept is introduced in Grade 10 in the South African physical sciences curriculum and therefore should be included in the pre-concepts as well. Reasons provided why learners need to know the selected key idea are generic and limited to general application and benefits of education and do not show a clear link with other related topics. There is no evidence of scaffolding of concepts and no evidence of future anticipated learning. Participant SA-M01 identified at least one correct pre-concept for the first key idea and two for the second key idea in response to prompt A3. Knowledge about forces is a prerequisite for the teaching of the work concept and types of energy and work are suitable pre-concepts for the work-energy theorem. A score of 'developing' was therefore awarded for the knowledge about pre-concepts. In response to prompt B1, participant SA-M01 identified the selection of the angle to use when calculating power as difficult for learners and a score of 'basic' was awarded. This is a genuine area of difficulty especially when dealing with the inclined plane that involves trigonometric identities, however, the participant could have explained the difficulty associated with the angle 'θ' in terms of calculations linked to the component of gravitational force parallel to the plane and the effect of 'θ' on the frictional force acting on the object. Learners tend to forget to use the gravitational component when performing calculations linked to Newton's second law and as such fail to determine the correct net-force (DoBE diagnostic report 2012). A score of 'basic' was awarded for this TSPCK component

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Table 9: Subject advisor SA-Z02 before workshop responses to the CoRe Prompts A0 to E2

SA-S02	**Pre CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Energy is the ability to do work *Work is done only when a net force is applied *The net force causes a displacement in the direction of force *Work done is the product of displacement and resultant force		**2**
Key ideas	Net force causes a displacement in the direction of force	*The participant only selected one key idea and therefore has no responses for all the prompts*	
A1 *What do you intend learners to learn about this idea?*	Learners need to understand the meaning of displacement and resultant force $Wnet = Fnet. \Delta x. cos\theta$	*No response*	**1**
A2 *Why is it important for learners to know this?*	'Fnet' needs to identify by the learners if number of forces are acting on an object learners need to identify the vector nature of the forces	*No response*	**1**
A3 *What concepts need to be taught before teaching this idea?*	Vectors and scalars. Vector is a physical quantity with magnitude and direction. Force is a vector, displacement is a vector	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	When a force is applied at an angle on an object we need to consider the component of force which causes the displacement	*No response*	**2**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	When object is on an inclined plane learners have problems in identifying the Fnet	*No response*	
Learners' prior knowledge and misconceptions.			**1**
C1 *What are typical learners' misconceptions about this idea?*	Learners will forget to take components of Fg when they draw force diagrams	*No response*	

Conceptual teaching strategies			**1**
D1 *What effective teaching strategies would you use to teach this key idea?*	More examples must be given to draw force diagram and free body diagrams Revision of equations of motion is important	*No response*	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	Revision of grade ten concepts (vectors, scalars and resultant vectors). Components of vectors Conservation of energy Problems involving equations of motion	*No response*	**1**
Representations and analogies			**3**
E1 *What ways would you use to support learners' understanding?*	Demonstration with simple pendulum will make learners to understand conservation of mechanical energy Group learners and allow them to slide an object on an inclined surface	*No response*	
Knowledge about assessment			**3**
E2 *What ways would you use to assess understanding?*	Asking questions to check the knowledge Giving assignments Tests and do demonstrations	*No response*	

In demonstrating knowledge about curricular saliency, participant SA-Z02 identified a number of key ideas. However, instead of selecting two key ideas for the pre-CoRe, the participant chose only one contrary to the instruction. SA-Z02 chose definition of terms used in the teaching of work, energy and power, such as net-force and energy, as key ideas (see Table 10). However, energy as a concept could be classified under pre-concepts since it was already introduced and taught in Grade 10 and net-force as a concept is also dealt with in Grade 11 under Newton's laws in the South African physical sciences curriculum and hence it is a pre-concept.

The participant's response to prompt A1 is limited to being aware of equations and standardised definitions and in response to prompt A2 the participant provided vague reasons why learners should know the selected key ideas and there is no evidence of conceptual sequencing. The participant correctly chose vectors as pre-concepts for the teaching of the key idea "net-force" in response to prompt A3. Force is a vector, so in determining the resultant force it is important that learners understand vector addition and vector resolution, particularly when dealing with the inclined plane. I rated participant SA-Z02's knowledge about *curricular saliency* to be 'basic'. Even though the participant showed knowledge of pre-concepts, the lack of evidence of sequencing of concepts lowered the score to basic. The participant demonstrated basic knowledge about '*what is difficulty to teach*' when responding to prompt B1. The participant identified the determination of a net-force on an inclined plane as difficult to teach owing to the mathematical manipulations involved in trigonometry. However, determination of a net-force involves identifying and combining all the forces acting on the object into one force. The participant ought to have indicated which force is exactly problematic and link it to a common misconception such as the duplication of the gravitational force when learners use both the gravitational force and its components as separate forces.

In response to prompt C3 which seeks knowledge about *Learners' misconceptions*, the participant did not identify learners' misconceptions in teaching net-force as a concept, but identified a misconception around the confusion learners have about the definition of power. Learners understand power as energy instead of being the rate at which energy is transferred. In response to CoRe prompt E1, participant SA-Z02 demonstrated acceptable knowledge about representations and analogies relevant for teaching work, energy and power and as such was rated ‘developing’.

Table 10: Subject advisor SA-V03 before workshop responses to the CoRe Prompts A0 to E2

SA-V03	**Pre CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Work-done is equal to force x displacement in the direction of force *Work-done = change in energy = ΔEp or ΔEk *Unit of work and energy is a joul *Conservation of mechanical energy		**2**
Key ideas	Work-done	Energy transferred	
A1 *What do you intend learners to learn about this idea?*	Formula for work-done=F. Δx. cosθ The unit of work is joules, work is a scalar	Ep = mgh, Ek = $1/2mv^2$ Forms of energy Unit of energy is a joule and energy is a scalar	**2**
A2 *Why is it important for learners to know this?*	The direction of force e.g cosθ=0 and cos180=-1	Mechanical energy conserved $(Ep+Ek)_A = (Ep+Ek)_B$	**1**
A3 *What concepts need to be taught before teaching this idea?*	Work = Force x displacement W = F x d	Ep = potential energy Ek = kinetic energy	**1**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	The direction of force (applied) Friction act in the opposite direction to motion	Ep at the top ≠ Ek at the bottom The unit of energy is same as unit of work	**1**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Learners may not consider the direction of force Also direction of friction Trigonometric ratios	Misconception on conservation of mechanical energy	
Learners' prior knowledge and misconceptions.			**1**
C1 *What are typical learners' misconceptions about this idea?*	Work done = F x distance	Energy and work are two different unrelated quantities	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Informal experiment $W = F\ x\ \Delta x\ cos\theta$ Friction is at cos180	Pendulum experiment	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	Questions based on applied force Questions based on applied force and friction	Types of energies Potential energy Kinetic energy Heat, radiation and chemical energy	**2**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Informal experiment and calculations	Pendulum experiment and calculations	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Classwork Calculations based on experiment	Calculations based on pendulum experiment	

Responses to prompts A1 to A4 indicated that participant SA-V03 had ‘limited’ knowledge about *curriculum saliency.* The participant identified formulae and the unit of work as sub-ordinate ideas for teaching the chosen key idea *’work-done’* without focusing on the underlying concepts such as force and displacement. He provided unclear reasons to why it is important for learners to know the key idea. SA-V03 indicated the product of force and displacement as a pre-concept to the teaching of work, yet it is the actual concept to be taught indicating ‘limited’ knowledge about prompt A3. The participant could not provide adequate responses to prompt A4 and provided no evidence of anticipated future learning, which is an indication that the participant has ‘limited’ knowledge about sequencing and scaffolding of concepts. Responding to prompt B1 participant SA-V03 indicated the use of trigonometric ratios as difficult to teach, even though it is a genuine concern owing to the mathematics involved a ‘basic’ score was awarded because there was no explanation given as to why those aspects are considered difficult to teach.

The participant showed ‘limited’ knowledge about ‘*learners’ prior knowledge’* and ‘basic’ knowledge about *‘conceptual teaching strategies and representations and analogies*’ respectively. In response to prompt E1 the participant at least gave an actual representation by referring to a pendulum experiment, but did not elaborate on its application.

Table 11: Subject advisor SA-M05 before workshop responses to the CoRe Prompts A0 to E2

SA-M05	**Pre CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*power -ability to do work -Expressed as P = W/Δt -Units of power are Watts (W) or J/s -Power is a scalar quantity		**1**
Key ideas	Power		
A1 *What do you intend learners to learn about this idea?*	Work / power Learners should know definitions as key concepts Work is not done when force is perpendicular to displacement	Work- Force must be applied to an object for work to be done Applied force, frictional force, normal	**2**
A2 *Why is it important for learners to know this?*	For application in calculations	Gravitational forces	**1**
A3 *What concepts need to be taught before teaching this idea?*	Force $F = ma$ $W = F\Delta x$ $W = ma\Delta x$ $P = W/\Delta t$	*No response*	**1**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	It is not necessary to know derivation of formulae	*No response*	**1**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Learners find it difficult to choose the correct angles i.e. when is θ = 0, 180 or 90 Learners find it difficult to identify forces acting on an object and also assigning direction is a challenge	*No response*	

Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	Any activity that makes a person to be tired means that work is done even though force is not applied	*No response*	
Conceptual teaching strategies			**1**
D1 *What effective teaching strategies would you use to teach this key idea?*	Start identifying all forces acting on an object Emphasise on all the formulae that are used in the calculations Let learners highlight them in the data sheet	*No response*	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	Give learners scenarios and let them identify all the necessary forces Calculations on $P = W/\Delta t$ integrated with $W = mgh$	*No response*	**1**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Practical Learners can push wall, no work done since there is no movement Standing holding a heavy briefcase	*No response*	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Start with questions that require learners to identify what is given in the question and then substitute in the correct formula	*No response*	

Participant SA-M05 identified power as a key idea and included the definition and units of power as sub-ordinate ideas. A score of 'basic' was awarded for prompt A1 because, even though real sub-ordinate ideas were identified, the participant only selected two sub-ordinate ideas from a long list of possible sub-ordinate ideas, revealing a poor understanding of scaffolding of ideas. In response to prompt A2 the participant gave a generic reason based on calculations and general benefits of the power concept in terms of its relationship with work and energy. However, the participant did not show evidence of knowledge about concept linking, that is joining concepts towards a broader concept.

The participant showed some knowledge about '*learners' prior knowledge and misconceptions'*, however a score of 'basic' was awarded owing to the fact that the list of misconceptions learners can have regarding work as a concept is vast, as can be seen in the expert CoRe (Appendix 3). Participants with developing or exemplary knowledge about possible misconceptions would have been able to mention more than only one. Responding to prompt E1 the participant identified practical examples such as pushing a wall and standing holding a heavy briefcase indicating no work-done as ways of supporting learners' understanding. However, the participant could have mentioned as well the use of applicable simulations accompanied by detailed explanations and diagrams why work was not done in those scenarios.

Table 12: Subject advisor SA-M06 before workshop responses to the CoRe Prompts A0 to E2

SA-M06	**Pre CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Work energy theorem Definition-Net work done on an object is equal to the change in kinetic energy of the object *Wnet = ΔK *What is work net?		**1**
Key ideas	Work energy theorem		
A1 *What do you intend learners to learn about this idea?*	That the net work done in an object is equal to the change in kinetic energy of the object Units of energy are joules	Kinetic energy final – initial will give the net work done by a force over a change in position of the object in the direction of the force	**2**
A2 *Why is it important for learners to know this?*	They learn concepts of forces impact in doing work over a change in kinetic energy	If work is done in an object by frictional force, then it will be in an opposite direction denoted by a negative number. $W_{ff} = F_f . \Delta x. \cos 180^0$ hence this will provide Wnet, then find either vf or vi.	**1**
A3 *What concepts need to be taught before teaching this idea?*	Net work done, kinetic energy, frictional force, gravitational force and applied force	Learners should be taught expressions of forces e.g F_g, F_f and F_a and the Wnet done by those. Be able to find either initial or final velocity of the object and include units at the end of the calculations.	**3**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Proofing how did kinetic energy units become the same as those of work done Deriving the Wnet = ΔK	*No response*	**2**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Identifying work done by different forces (F_f, F_a, F_g) Applying Wnet = ΔK if the learner has to first calculate the F_f or any force not provided	*No response*	
Learners' prior knowledge and			**1**

misconceptions.			
C1 *What are typical learners' misconceptions about this idea?*	Learners' alternative conceptions are that the force and the displacement product can still determine the work done	*No response*	
Conceptual teaching strategies			**1**
D1 *Effective teaching strategies would you use to teach this key idea?*	Practical method. Apply all the steps from weighing the mass of an object, use a pulley and force meter to measure the applied force, measure the angle and obtain net work done.	The distance the object moved can be measured hence can calculate the velocity.	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	Collect data first Define work energy theorem Calculate the final velocity	*No response*	**1**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Analogies: Whenever force is applied and object changes position work is done	*No response*	
Knowledge about assessment			**1**
E2 *What ways would you use to assess understanding?*	Respond to questions on definitions and calculate Wnet.	*No response*	

The participant chose *'work-energy theorem*' as the key idea but did not provide appropriate sub-ordinate ideas other than, conservation of energy and types of energy. Reasons provided why learners should know the concept exclude conceptual thoughts such as progressive development of understanding for other topics linked to work, energy and power. In response to prompt B1 the participant identified the use of the work-energy theorem when a learner has to first calculate frictional force, as being difficult to teach, however did not link the problematic concept to common misconceptions in teaching the theorem and was therefore rated 'basic'.

When responding to prompt C1 the participant indicated as an alternative conception that learners tend to think the product of force and the displacement vector alone can determine the work done. Failing to realise the effect of the angle between the two vectors on the work done can be a sign of content knowledge gaps and not necessarily a misconception and as such the participant's knowledge about prompt C1 was rated 'limited'. In terms of teaching strategy for the chosen 'key idea' (D1) the participant indicated the use of a practical method, that involves measuring the mass, measuring the weight by use of a force meter to determine the net-force and hence determining net work. This approach clearly shows a conceptual method, however the method was not explained further and a 'basic' score was granted.

Table 13: Subject advisor SA-C07 before workshop responses to the CoRe Prompts A0 to E2

SA-C07	**Pre CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Power *Definition of power *Equation of power *Units of power		**1**
Selected Key ideas	Definition of power	Definition of a watt	
A1 *What do you intend learners to learn about this idea?*	The correct definition of power	Watt is the unit of power Be able to define exactly what 1 watt is or the amount of power that is referred to as 1 watt.	**1**
A2 *Why is it important for learners to know this?*	Power is sometimes carelessly used to mean a number of different things in street language e.g what people say when they buy electrical energy is sometimes referred to as power	Be able to define what exactly is a watt	**1**
A3 *What concepts need to be taught before teaching this idea?*	Work and energy definitions Rate (the inverse of time)	Work and its units	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	If no work is done then there is no power dissipated	Watt value i.e. its meaning 20W = 20J/sec i.e. 20J of work are done in 1 sec.	**2**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Street language used to refer to power making it difficult to understand the correct scientific meaning	Language competency of some learners	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	When people buy electricity (electrical energy) they refer to that as power	KWh taken the same as watt, as they buy electrical energy in KWh.	

Conceptual teaching strategies			**1**
D1 *What effective teaching strategies would you use to teach this key idea?*	When buying electrical energy, we are actually buying the capacity to do work, i.e. move charges from one point to the other in a circuit. How fast or how slow those charges are moving in a circuit is actually referred to as power.	Showing that a KWh is a unit of energy not power	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	*No response*	*No response*	**1**
Representations and analogies			**1**
E1 *What ways would you use to support learners' understanding?*	*No response*	*No response*	
Knowledge about assessment			**1**
E2 *What ways would you use to assess understanding?*	*No response*	*No response*	

Participant SA-C07 identified power and the unit of power as key ideas and included the definition of power as a sub-ordinate idea. The participant was rated with a 'limited' score for both prompts A0 and A1 as there are other sub-ordinate ideas also germane to the power-concept that one can identify (*refer to expert CoRe*). In response to prompt A2 the participant indicated that 'power' is sometimes carelessly used in street language to mean a number of different things, especially when people buy electrical energy which is sometimes referred to as power. This statement as a response to prompt A2 is inappropriate, as it does not show why it is important for learners to know this key idea. It can actually be taken as a misconception that learners and the general public have when it comes to energy and power and the participant correctly identified it as such in response to prompt C1. However, prompt C1 was rated as 'basic' owing to the long list of misconceptions available as can be seen in the expert CoRe (see Appendix 3). According to the expert CoRe the participant could have identified misconceptions about power in terms of work and time taken to do the work. Work and energy were correctly identified as pre-concepts to the teaching of power.

Table 14: Subject advisor SA-T08 before workshop responses to the CoRe Prompts A0 to E2

SA-T08	**Pre CoRe**		Level
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Work-energy theorem *Using the theorem to solve problems *Must be able to differentiate the angles i.e. when to use cosθ or sinθ *Be able to identify forces acting on the object		**2**
Selected key ideas	Identification of forces	Differentiate the angles in a plane	
A1 *What do you intend learners to learn about this idea?*	Be able to identify the forces acting on the object	Be able to differentiate the angles in the plane i.e. cosθ and sinθ	**1**
A2 *Why is it important for learners to know this?*	Be able to understand the concept and in turn solve the problem	Be able to understand the concept and in turn solve the problem	**1**
A3 *What concepts need to be taught before teaching this idea?*	Geometric concepts from maths e.g quadrants, forces and angles.	Geometric concepts from maths e.g quadrants, forces and angles.	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Coefficients of forces	Coefficients of forces	**1**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Angles in different planes Coefficient of the forces	Angles in different planes Coefficient of the forces	
Learners' prior knowledge and misconceptions.			1
C1 *What are typical learners' misconceptions about this idea?*	Identification of forces using a free-body diagram and angles involving the calculations	*No response*	
Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Demonstration using PHET simulations as well as performing the experiments if apparatus are available	*No response*	**2**
D2 *What questions would you consider important to ask in your teaching*	-Draw the forces in the planes and label them	*No response*	**2**

strategy?	-Identification of the angles -Do calculations		
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	-PHET simulations -Practical demonstrations; learners bring toy cars from home and creating a bridge	*No response*	
Knowledge about assessment			**3**
E2 *What ways would you use to assess understanding?*	Diagnostic assessment first and then summative (where learners can write tests on what was taught e.g. short tests and control tests	*No response*	

Responses to the prompts indicated that participant SA-T08 had ‘limited’ knowledge about the first four TSPCK components and only showed ‘basic’ knowledge about *representations and analogies* as appropriate ways of supporting learners understanding. The participant identified ‘forces acting on an object’ as a key idea, however, this cannot be a key idea as force vectors are introduced in Grade 11. Responses to prompts A1 to C1 were quite elementary, the participant did not show evidence of concept linking and knowledge about expected future learning of other concepts that have a direct link with the work-energy theorem. SA-T08 did not identify any relevant misconception learners can have around the selected key idea as shown by the response *‘Identification of forces using a free-body diagram and angles involving the calculations’.* This refers to a typical learner difficulty rather than a misconception and could probably have been mentioned in prompt B1. In response to prompt D1 the participant correctly listed some teaching methods such as demonstrations using PHET simulations and experiments where resources are available, however, no example was given of exactly which simulation and experiments would be effective to use to teach the key idea and as such this does not constitute a conceptual teaching strategy.

Table 15: Subject advisor SA-N10 before workshop responses to the CoRe prompts A0 to E2

SA-N10	**Pre CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Work-energy theorem *Formula Wnet=ΔK *For work to done object must move in the direction of the net force *Work is measured in Joules and it is a scalar		**2**
Selected key ideas	Work	*The participant only selected one instead of two key ideas*	
A1 *What do you intend learners to learn about this idea?*	That work can only be done if a net force is applied to an object and the object moves in the direction of the net-force	*No response*	**1**
A2 *Why is it important for learners to know this?*	Because it is not always that work is done in physics, only when the object is displaced.	*No response*	**1**
A3 *What concepts need to be taught before teaching this idea?*	-Definition of work and energy -Different types of forces -Difference between vectors and scalars -Free-body and force diagrams	*No response*	**3**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Work done on a body	*No response*	**1**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Work done on an inclined plane is difficult to learners because they are unable to identify components of Fg.	*No response*	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	The angle between horizontal and incline is taken as direction for all forces acting on the object	*No response*	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Teach learners to be able to identify all forces acting on an object so that they can ultimately come up with Wnet. Displacement is in the direction of the net force	*No response*	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	-Define work -Define energy -Identify all the forces acting on an object -Draw a free-body diagram	*No response*	**2**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	-Moving a book by pushing or pulling it a certain distance on the table. -Pulling a crate on the floor with a string attached and pulling at an angle to the horizontal.	*No response*	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	-Informal class activities involving calculations and definitions from text books, exemplar papers, previous exam papers.	*No response*	

When responding to prompt A1 and A2 the participant showed poor conceptual understanding in terms of the chosen key idea. The participant indicated that work is ‘only’ done if a net-force is applied, however this is not true as any other force or component of a force can do work on an object if the force or component and displacement vectors are parallel to each other. The problem could be that the participant had a language problem in formulating clear thoughts rather than poor conceptual understanding and probably meant that when a net-force is exerted it causes net-work to be done on an object. In response to A2 the participant mentioned that; “…*it is not always that work is done in physics only when the object is displaced”.* This also could be a language problem rather than poor conceptual understanding. However, it is very important that Grade 12 learners are taught to conceptualise work done on an object in terms of displacement in the direction of the force (NCS; physical science, examination guidelines). SA-N10 adequately indicated types of forces and free-body diagrams as pre-concepts that need to be taught before teaching the key idea and so knowledge about prompt A3 was rated ‘developing’. In response to prompt A4 the participant indicated that learners do not need to know the work done on a body yet; a sign that the participant does not understand what the key idea entails. Work is the selected key idea and it is what learners actually have to know and as such knowledge about this prompt was rated ‘limited’.

In response to prompt B1 the participant highlighted that teaching learners to perform calculations of work done on an inclined plane is difficult to teach as learners have problems in identifying the components of the gravitational force. A score of ‘basic’ was awarded as it is not just the identification of the components but rather the resolution of the gravitational force into these components which is generally problematic (DoBE, diagnostic report 2012). In response to prompt C1 the participant identified the fact that learners always use the angle of the incline in all calculations as a misconception. Yet, not knowing which angle to use in calculations is an indication of lack of conceptual understanding and is not necessarily a misconception.

Table 16: Subject advisor SA-M12 before workshop responses to the CoRe Prompts A0 to E2

SA-M12	**Pre CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Work-energy theorem *Work done on the object at different angles *Vectors (forces) *Concept of energy- Net transfer of energy *Force and displacement as vector quantities		**3**
Selected key ideas	Work-energy theorem	*Participant only selected one key idea instead of two as required*	
A1 *What do you intend learners to learn about this idea?*	State the theorem and apply it	*No response*	**1**
A2 *Why is it important for learners to know this?*	For them to be able to solve the problems that might be asked i.e. related to the idea	*No response*	**1**
A3 *What concepts need to be taught before teaching this idea?*	-Forces, applied, frictional and gravitational -Vectors and scalar quantities -Work done -Energy as a capacity to do work	*No response*	**3**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	*No response*	*No response*	**1**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Calculations when force is applied to objects at different angles Calculating the net force acted on objects in different direction.	*No response*	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	When an object is sliding on an incline plane there is an applied force. Objects of different masses fall at different times when released from the same point	*No response*	

Conceptual teaching strategies			**1**
D1 *What effective teaching strategies would you use to teach this key idea?*	Demonstration	*No response*	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	*No response*	*No response*	**1**
Representations and analogies			**1**
E1 *What ways would you use to support learners' understanding?*	Demonstration Allow them to draw sketches	*No response*	
Knowledge about assessment			**1**
E2 *What ways would you use to assess understanding?*	More tasks including different scenarios Include questions on the topic in monthly tests as this is poorly performed by most of the learners.	*No response*	

Participant SA-M12 identified quite a few key ideas in response to prompt A0, however he only selected one key idea to elaborate in the CoRe and did not provide responses to many prompts; prompt A4 and D2 were left blank. There are no sub-ordinate ideas given and the response to A2 was too general. The participant, however correctly identified energy as a pre-concept in teaching the selected key idea (*work-energy theorem*). The reason provided why learners should know the key idea was too vague, it did not show any sign that this key idea would need to be linked with other topics or sub-topics related to work, energy and power. The participant correctly identified work done and energy as pre-concepts for teaching the work-energy theorem in response to prompt A3. The participant's knowledge about *curricular saliency* was rated 'basic'. In response to prompt B1 the participant identified calculations that involve forces applied at different angles as being difficult to teach particularly when teaching learners doing mathematical literacy. It is a genuine area of concern as it involves trigonometry in resolving the forces, however a score of 'basic' was awarded as the participant failed to provide an explanation to why this is problematic. The participant correctly identified a misconception '*When an object is sliding on an inclined plane there is an applied force'*. This is a common misconception which is usually observed when learners have to draw a free-body diagram, however the participant could have identified other misconceptions as can be seen in the expert CoRe to warrant a score higher than 'basic'.

Table 17: Subject advisor SA-L13 before workshop responses to the CoRe Prompts A0 to E2

SA-L13	**Pre CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Work is done when a force is applied to an object and causes a displacement *Work is a vector and it is measured in joules J Work done = $Fapp. \Delta x. \cos\theta$ *Work-energy theorem *Work done by conservative and non-conservative forces *Power is the rate at which work is done		**3**
Key ideas	Work done	Work-energy theorem	
A1 *What do you intend learners to learn about this idea?*	Work is done when a net force is applied to an object $W = F. \Delta x. \cos\theta$ Perpendicular forces do no work (cos 90^0 = 0) Friction acts in opposite direction to the movement.	State the theorem and apply the theorem in calculations	**2**
A2 *Why is it important for learners to know this?*	There is movement of objects. How to move objects effectively and efficiently? What to take into consideration when applying a force to the object.	*No further responses for this key idea*	**2**
A3 *What concepts need to be taught before teaching this idea?*	Forces and vectors	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Motion on inclined planes. Work related calculations	*No response*	**2**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Easy: Definitions, units and theorem Difficult: Motion on inclined plane-work related calculations	*No response*	
Learners' prior knowledge and			**2**

misconceptions.			
C1 *What are typical learners' misconceptions about this idea?*	When an object is sliding down the inclined planes there is an applied force on the object	*No response*	
Conceptual teaching strategies			**1**
D1*What effective teaching strategies would you use to teach this key idea?*	Moving from the known to the unknown Question and answer method	*No response*	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	Build up on learners foundation and you are able to identify the gaps	*No response*	**1**
Representations and analogies			**3**
E1 *What ways would you use to support learners' understanding?*	Models Daily examples/practical examples, why do we pull a hand brake on the car on an inclined plane. Why does the car roll when not pushed on the incline	*No response*	
Knowledge about assessment			**3**
E2 *What ways would you use to assess understanding?*	Question and answer method in class giving them exercises to work in groups, individually at home and class tests.	*No response*	

Participant SA-L13 showed some lack of conceptual understanding when responding to prompt A1. *'Work is done when a net force is applied to an object'*, yet work is done by any individual force and not necessarily a net force as long as the object on which the force or component of the force is acting undergoes some displacement in the direction of or opposite to the force. Reasons provided why it is important for learners to know the selected key ideas indicated the participant's awareness of real-life application of the concept of work-done in moving objects 'effectively and efficiently' thereby minimising loss of energy. However, as no mention of the need to conceptually link notions towards broader concepts was made a score of 'basic' was appropriate. The participant's knowledge about *'what is difficult to teach'* and '*learners' misconceptions'* were both rated 'basic'. The participant indicated '*motion on inclined plane*' as being problematic to teach. This is consistent with my experience as a science teacher, however the participant did not indicate exactly which aspect of the inclined plane is difficult to teach or why it is difficult to teach. In response to prompt C1 the participant indicated a common misconception amongst Grade 12 learners. Learners tend to think that when objects are sliding down an inclined plane there is a force applied, not realising the effect of the gravitational component parallel to the plane (DoBE; Physical Science; Chief examiner's report, 2013).

Responses to D1 and D2 were quite elementary and did not show evidence of conceptual thought. The participant indicated appropriate knowledge about '*representations and analogies'* in response to prompts E1 and demonstrated sound knowledge about assessment in response to prompt E2 and was rated 'developing'. The participant mentioned the use of models and practical examples such as why a car rolls downwards on an inclined plane when the handbrake is not on, yet there is no force applied, this can assist in learner understanding and can help in clearing the identified misconception.

Table 18: Subject advisor SA-M14 before workshop responses to the CoRe Prompts A0 to E2

SA-M14	**Pre CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Power Power is the rate at which work is done Mathematical equation is p=W/Δt Units of components are: - work is joule (J) Change in time is seconds (s) Units of power are $J.s^{-1}$ = watts (W)		**3**
Key ideas	Power is the rate at which work is done	Mathematical equation	
A1 *What do you intend learners to learn about this idea?*	Definition of power and its application	Expression of a definition into mathematical equation Calculation of power using the above equation	**2**
A2 *Why is it important for learners to know this?*	To be able to understand further concepts associated with the sub topic	The concept is used to explain work energy theorem	**2**
A3 *What concepts need to be taught before teaching this idea?*	Vectors i.e. whether scalar or vector quantities. Explain what is meant by rate	Explain work concept and relationship with power, current and voltage	**1**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Concept of billing system i.e. municipal electricity accounts Load shedding effect on economy	Various scenarios whereby work is done at different angles Conservation of energy versus work done.	**2**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	It requires memory and no application necessary	Most learners enjoy calculations than explanations.	
Learners' prior knowledge and misconceptions.			**1**
C1 *What are typical learners' misconceptions about this idea?*	Interchanging work in equation with units of power in symbol i.e. W	Misconstrue units against symbols in equations	

Conceptual teaching strategies			**1**
D1 *What effective teaching strategies would you use to teach this key idea?*	Break done definitions into key words such as rate and work. Ask learners to remember those key words in constructing definitions	Use definition to build mathematical equations	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	Definition of current and voltage	What are conservative and non-conservative forces?	**1**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Simulations moving up the stairs Pushing against objects along horizontal and inclined planes	Diagrams extracted from geometry i.e. right angled triangles	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Class test Assignments	Test/classwork on geometric ratio calculations	

The participant's response to prompt A2 indicated sound knowledge about concept linking as highlighted by the statement: '*To be able to understand further concepts associated with the sub topic*'. However, the participant did not identify exactly which concepts and as such was rated 'basic'. The participant realised the role played by the chosen key idea in the understanding of further concepts in work, energy and power. Responses to prompts B1 to D2 showed low levels of knowledge about *'what is difficult to teach, learners' misconceptions* and *conceptual teaching methods'* and were all scored 'limited'. A score of 'basic' was awarded for the responses to prompts E1 and E2 respectively. The participant identified the use of analogies such as pushing objects on horizontal and inclined planes as a way to support learners' understanding and included class tests and assignments as a way of assessing that understanding. However, for a higher score the participant could have identified other relevant analogies and representations that could help learners understand the concept better.

4.4 Chapter summary

Results from the participants' responses to the pre-CoRe prompts before the PTD workshop have indicated a picture which is consistent with literature from the TIMSS (2011) report on South African science teachers. The TIMSS (2011) report indicated that South African teachers are among the least qualified in science education and generally lack content knowledge and have poorly developed PCK. This assertion is also supported by Mavhunga (2014). Only two participants managed to score 'exemplary' in any of the prompts before the PTD workshop. A few had a score of 'developing' for some prompts. A score of 'limited' and 'basic' featured most and is an indication that prior to the PTD workshop the subject advisors generally had a below average level of TSPCK about teaching the energy concept.

In responding to prompt A0 the participants generally did not have problems in identifying the key ideas, as they had to select any concept they considered to be key in the teaching of work, energy and power. However, many participants had problems in linking the selected key idea/s to the subordinate ideas. Responses to prompts A1 to A4 which solicited their knowledge about *curriculum saliency* were generally between 'limited' and 'basic' with a few responses indicating 'developing' and none were scored 'exemplary'. The scores for prompt B1, a prompt that was capturing participants' knowledge about '*what is difficult to teach'* were also low, the scores were ranging between only 'limited' and 'basic'. There was no participant that scored a 'developing' or 'exemplary' score before the PTD workshop.

Participants struggled in identifying appropriate misconceptions and as such no participant scored above 'basic' for this component. Many participants confused misconceptions with general lack of conceptual understanding or even gaps in content knowledge. Selection of conceptual teaching strategies that can assist learners in understanding the selected key ideas posed a challenge to many participants. Participants were merely listing teaching methods without providing exactly how they planned to teach, what questions they tended to pose and possible responses to the questions. As a result, no participant scored above 'basic' for prompts D1 and D2. Participants generally responded better to prompts E1 and E2 than to any of the other prompts. Participant SA-Z02 was awarded an 'exemplary' score for prompt E2 and some were rated 'developing' for the same prompt and quite a few scored a 'limited' for the prompt.

In the next chapter, data obtained from the interview, document analysis of the workshop study guide and post-CoRes is presented, this data when analysed will indicate the quality of subject advisors' knowledge about the five TSPCK components as captured by the prompts after the PTD workshop. The analysis and subsequent interpretation will provide answers to the second research sub-question which sought to determine the quality of subject advisors' TSPCK in teaching the energy concept after the PTD workshop.

CHAPTER 5
Post-CoRe Results

5.1 INTRODUCTION

In Chapter 4, the pre-CoRe results and the scores awarded to the participants for each CoRe prompt in response to research sub-question one were presented. In this chapter, the interview responses, data from the document analysis and post-CoRe results are presented. Each participant has been provided with a score for each prompt responded to in terms of the expert CoRe and the rubric. The data from the post-CoRes provides answers to the second research sub-question which sought to determine the quality of subject advisors' TSPCK in teaching work, energy and power after the PTD workshop:

- *What is the quality of the subject advisors' PCK after the PTD workshop in the teaching of work, energy and power?*

The post-CoRe results are presented similarly to the presentation of the pre-CoRe results in Chapter 4, where each participant's responses are typed verbatim from their hand written copies onto a table. Using the expert CoRe and rubric, responses to the CoRe prompts were rated and scored. The post-CoRe assessment was done immediately after the workshop and participants had no exposure to the content of the workshop other than the presentation and discussions with one presenter. One can therefore assume that an improvement if any in CoRes can be ascribed to the activities of the workshop.

5.2 INTERVIEW RESPONSES

The interview schedule consisted of seventeen questions that the workshop presenter had to respond to (*see Appendix 4*). This participant was the presenter of the PTD workshop. The interview questions included questions on the rationale for the PTD workshop, content covered and the duration of the workshop and the majority of the questions were based on the five components of PCK. The components included '*curricular saliency, what is difficult to teach, learners' prior knowledge, conceptual teaching strategies and representations and analogies'*. The participant's key responses are categorised in themes as shown in Table 19 below. Rationale and duration of the

PTD workshop constitute theme 1 and each TSPCK component constitute a theme. The entire interview transcript is presented as Appendix 5.

The table below indicates the six response themes, where a theme consists of linked questions that pertain to a specific TSPCK component.

Table 19: Interview **response themes**

Theme 1	Rationale for the PTD workshop
Theme 2	Curricular saliency
Theme 3	Prior knowledge and misconceptions
Theme 4	What is difficult to teach?
Theme 5	Representations and analogies
Theme 6	Conceptual teaching strategies

The Table 20 shows the participant's responses to questions stemming from theme one. Theme one focuses on the rationale and duration of the PTD workshop.

Table 20: Workshop presenter's interview responses (Theme 1)

Theme 1	**Rationale and duration of workshop**
Question 1	What was the main purpose of the workshop?
Response	*…so the purpose of the workshop was to enhance selected physical science teachers and subject advisors' conceptual understanding of identified topics.*
Question 2	What informed the decision to include work, energy and power as one of the topics to be covered at the workshop?
Response	*This topic was one of the topics identified by the provincial department of education based on the previous year's poor matric results they felt that teachers lacked sufficient content knowledge.*
Question 3	Would you classify the workshop in the category of in-service teacher training?
Response	*Yes*
Question 4	What was the duration of the entire workshop? How much time was spent on work, energy and power?
Response	*Three days from 8am to 4pm approximately 90 minutes of teaching on WEP*
Question 5	*Do you think the time spent on the workshop was sufficient?*
Response	*No!*

Responses to the questions stemming from theme 2 are recorded in Table 21 below. These questions are based on curricular saliency.

Theme 3	Prior knowledge and misconceptions

Table 21: Workshop presenter's interview responses (Theme 2)

Theme 2	**Curricular saliency**
Question 1	In your presentation, what did you consider to be the 'key ideas' or key concepts in teaching work, energy and power?
Response	*…work, work done by a net force, work-energy relationship (work-energy theorem) and power.*
Question 2	Which 'key ideas' did you teach first?
Response	*Definition of work, energy and force. Then…positive work, negative work and no work…seemed to be the most logical point to start from.*
Question 3	Do you consider it important to structure concepts in a particular order in terms of which one is taught first? If you do please explain.
Response	*Yes. Personal teaching strategy that helps me to teach as best as I can.*

Table 22 shows the participant's responses to questions stemming from theme three. These questions are based on knowledge about learner's prior knowledge and misconceptions.

Question 1	Did you find it necessary to focus on typical misconceptions about work, energy and power? Why?
Response	*Yes, it was necessary…it was the approach of the workshop, to determine teachers' misconceptions and improve content knowledge. Make teachers aware of learner misconceptions…help improve teaching, being aware of learner difficulties.*
Question 2	Did you pick particular misconceptions in teaching work, energy and power? If you did may you please give at least one example?
Response	*Yes I did, misconception around the use of work-energy theorem, not knowing when/how to apply the theorem.*

Table 22: Participant's interview responses (Theme 3)

Table 23 shows the presenter's responses to Theme 4 questions. These questions are based on the TSPCK component '*what is difficult to teach'*?

Table 23: Participant's interview responses (Theme 4)

Theme 4	**What is difficult to teach?**
Question 1	What did you consider to be difficult to teach on this topic?
Response	$W = Fdcos\theta$, θ *angle between applied force vector and the displacement vector.*
Question 2	Did the participants also consider the same aspects as being difficult to teach?
Response	*Don't really remember.*

Table 24 indicates the question stemming from the TSPCK component '*representations and analogies*' and the presenter's response.

Table 24: Presenter's interview responses (Theme 5)

Theme 5	**Representations and analogies**
Question 1	Did you make use of analogies, representations and animations in your presentation? If yes, please explain the impact of such use.
Response	*Yes I did make use of illustrations…free-body diagrams and real life examples and situations to elucidate the concept.*

Theme 6	**Conceptual teaching strategy**
Question 1	In your presentation which teaching strategy did you use?
Response	*Conceptual teaching approach. …assessing and addressing misconceptions unlike the traditional teaching strategies preferred by some teachers...we are aiming at improving conceptual understanding and not spoon feeding learners.*
Question 2	Which teaching strategy did you use to teach difficult concepts?
Response	*Use example situations to elucidate difficult concepts.*

Table 25: Presenter's interview responses (Theme 6)

5.3 RESULTS FROM THE DOCUMENT ANALYSIS

An analysis of the PTD workshop training manual section on work, energy and power has indicated some aspects that are very critical to the study. Even though the workshop was not explicitly presented in terms of TSPCK components, evidence existed that the approach followed a structure that supports the development of the components. There was evidence of *curriculum saliency* as key ideas pertaining to work, energy and power were clearly identified with their accompanying sub-ordinate ideas. Definition of key terms formed the introductory part of the presentation with energy being defined in terms of its ability to do work, that is, exert a force over a displacement. Types of energy formed part of the sub-ordinate ideas followed by energy transformation and conservation indicating a clear consciousness to conceptual sequencing which is a key aspect of curriculum saliency.

The training manual did not explicitly focus on misconceptions and aspects that are difficult to teach work, energy and power, but presented some conceptual questions before each key concept, these questions acted as a diagnostic tool to identify misconceptions and areas of difficulty (*see Figure 6*). This shows how the presentation was implicitly aligned with the TSPCK components. Even though the presenter was not consciously presenting in terms of the five TSPCK components one can see aspects of the components in the presentation. The presentation approach indicated a conceptual teaching strategy, where a diagnostic exercise is done through conceptual questions; then instruction followed on the concept providing the correct scientific views.

Question 1

A heavy box is pushed across the floor by a horizontal applied force. The other forces acting of the box are the force of gravity, the normal force and a frictional force which is less than the applied force.
1.1 Which of these forces does no work?
1.2 Which of these forces does positive work?
1.3 Which of these forces does negative work?

Question 2

As the speed of a free falling object increases, what happens to the power supplied by the gravitational force?

Question 3

The diagram below shows the position of a cart on a roller coaster track. What form of energy does it have at A, B and C?

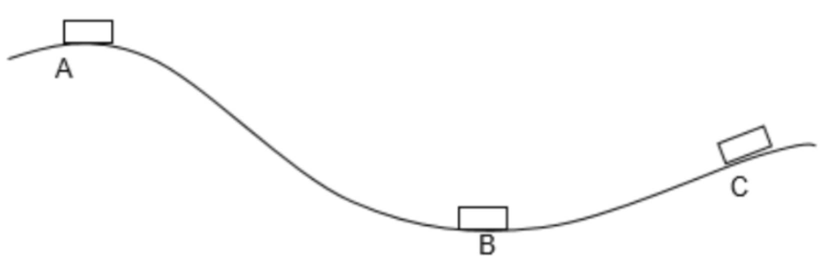
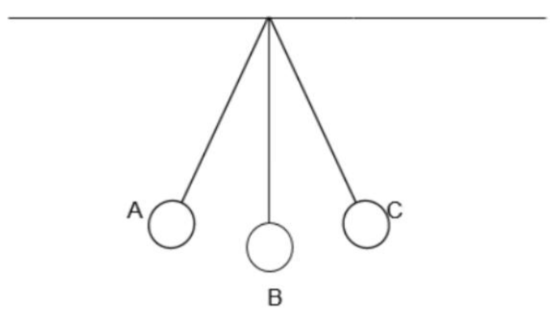


Figure 6: Extract from the workshop study manual indicating introductory questions

The questions in Figure 6 above are conceptual questions that are necessary in assessing learners' knowledge and understanding about forces doing work on an object and the type of work the forces are doing. Grade 12 learners lose marks on rather simple questions in their final physical science examinations on this section of work, because of their inability to identify forces doing work (DoBE; Physical Science; diagnostic report, 2012).

Question 3 assesses a learner's knowledge about energy transformations and conservation of mechanical energy. Learners need to understand that in a closed system a decrease in the gravitational potential energy of a falling body provides for an increase in the kinetic energy of the body (*see Figure 7*).

A pendulum with a mass of 300g is attached to the ceiling. The pendulum is pulled up to point A which is 30cm above its equilibrium position. Calculate the speed of the pendulum at point B.



Answer

Total energy at A = Total energy at B

EpB + EkB = EpA + EkA

$mgh + 0.5\ mv^2 = mg(0.3) + 0$

$0.5\ v^2 = g(0.3)$

$V^2 = 2(9.8)(0.3)$ therefore $v = 2.4$ m/s

Figure 7: Extract from the workshop study manual**.**

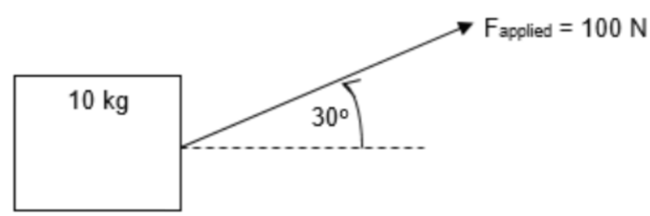
The system illustrated in Figure 7 above is a closed system and the mechanical energy at point A is equal to the mechanical energy at B. However, at point A all the mechanical energy has been converted to gravitational potential energy and as the pendulum bob swings to point B all the gravitational potential energy is converted to kinetic energy. While the pendulum bob swings past point A there is a gradual decrease in the kinetic energy of the pendulum bob and a gradual increase in the gravitational potential energy until at point C where it has maximum potential energy. At any other point between A and B or B and C the pendulum bob has both gravitational potential energy and kinetic energy.

The presenter used a number of representations in terms of force diagrams and free-body diagrams; these aided conceptual understanding as participants had an opportunity to use formulae to calculate the work done on a body and determine which forces are doing the work as illustrated by problem 3 from the manual (*see Figure 8).*

Problem 3

A 100 N force is applied to a 10 kg box at an angle of 30° to the horizontal. The box moves a distance of 5 m. Calculate the work done on the box.

Answer



Work done = Fapplied d cosΘ

= 100N (5m) cos(30°)

= 433 J

Figure 8: Extract from the workshop study manual

It is important that learners realise that, the horizontal component of the 100 N force is the one actually doing positive work on the 10 Kg block. The vertical component however, is not doing any work on the block as it is acting perpendicular to the direction of motion of the block. As a science teacher I find it useful in simplifying calculations that learners have to calculate the magnitude of the component of the force that is doing work first and then substituting the value into the work formulae, in this way they only have to deal with two values for θ which are 0^0 for positive work or 180^0 for negative work.

5.4 SUBJECT ADVISORS' POST-CoRe RESPONSES WHEN ENGAGING IN THE FIVE TSPCK COMPONENTS

Evidence of the participants' knowledge about each of the five TSPCK components after the PTD workshop is found from the participants' responses to the post-CoRe prompts A0 to E2. Each subject advisor's post-CoRe responses to the prompts were typed verbatim into a table. Each prompt solicits and captures a participant's knowledge about each specific TSPCK component. Table 26 below shows a summary of scores obtained by the subject advisors for each prompt during the post-CoRe assessment after the PTD workshop. These scores were checked for inter-rater reliability as rater agreement was achieved between the researcher and the supervisor.

Table 26: Summary of subject advisors' post-CoRe scores

Participant codes	**CoRe prompts**										
	A0	**A1**	**A2**	**A3**	**A4**	**B1**	**C1**	**D1**	**D2**	**E1**	**E2**
SA-M01	3	1	1	2	3	3	3	2	3	2	3
SA-Z02	3	1	2	2	1	1	2	3	2	3	4
SA-V03	2	2	2	2	2	2	1	2	1	1	2
SA-M05	1	2	1	2	1	2	2	2	3	3	2
SA-M06	2	3	2	2	1	1	2	2	2	1	1
SA-C07	2	1	2	2	2	1	2	1	2	2	1
SA-T08	3	1	1	2	1	1	3	2	1	2	3
SA-N10	3	1	1	2	1	1	3	1	2	3	3
SA-M12	3	2	1	2	1	2	2	2	1	1	1
SA-L13	3	2	3	2	2	1	2	3	2	2	4
SA-M14	3	2	2	3	2	2	3	2	2	2	2

5.4.1 Presentation and discussion of post-CoRe data

It is worth noting that in the post CoRe responses some subject advisors chose to answer the prompts in the CoRe for only one key idea, despite the instruction to respond to prompts for the two chosen key ideas. There is no obvious reason for that but an assumption is that the subject advisors had no pushing factor as there were no incentives for good work and also marks were not allocated. Therefore, information obtained from the CoRes, though vital, is generally not enough to fully reveal a person's tacit knowledge about the TSPCK components (Mavhunga and Rollnick, 2013).

Table 27: Subject advisor SA-M01 post-CoRe responses to the CoRe prompts A0 to E2

SA-M01	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Representing vectors *Force diagrams *Calculations of work done by different forces *Relationship between work done and energy, work done and energy transfer		**3**
Key ideas	**Selected key idea 1** Vectors	**Selected key idea 2** Work-energy theorem	
A1 *What do you intend learners to learn about this idea?*	Learners should be able to identify and draw different forces as vectors	Work is done when a force is applied to an object and there is displacement in the direction of the applied force	**1**
A2 *Why is it important for learners to know this?*	To use for calculating work done	To be able to identify its application in everyday life	**1**
A3 *What concepts need to be taught before teaching this idea?*	Scalars and vectors Angles of forces acting on an object	Forces Vectors	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Application of trigonometry	Motion on an inclined plane when multiple forces act on an object	**3**
What is difficult to teach?			**3**
B1 *What are the difficulties connected with teaching this idea?*	Learners who have challenge with geometry and trigonometry Learners do not comprehend that the product of a scalar and a vector results in a vector Graphical representation	When multiple forces act on an object they tend to get confused Confuse angle of inclination and angle between the force and displacement	
Learners' prior knowledge and misconceptions.			**3**
C1 *What are typical learners' misconceptions about this idea?*	*No response*	Learners believe that whenever force is applied work is done even when an object is not moving Object sliding down an inclined plane, there is an applied force.	

Conceptual teaching strategies			**3**
D1 *What effective teaching strategies would you use to teach this key idea?*	Problem solving Enquiry Demonstration	Problem solving Enquiry Demonstration	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	What is the difference between a scalar and a vector quantity? How is a vector represented? What is the resultant of the vectors in the given diagram? Resolve vectors into X and Y components	Draw force diagrams Calculate the work done in different scenarios	**3**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Demonstration and simulations	Demonstrations, analogies and simulations	
Knowledge about assessment			**3**
E2 *What ways would you use to assess understanding?*	Ask probing questions Pausing and passing questions Giving learners worksheets	Problem solving Question and answer Worksheets	

Participant SA-M01 identified vectors as a key idea yet this concept of vectors is introduced to learners in Grade 10 and further developed in Grade 11 in the South African physical science curriculum, it is therefore not a key idea in this context but rather a pre-concept. Similarly, for the second key idea the participant indicated as a sub-ordinate idea that '*work is done when a force is applied on an object and there is a displacement in the direction of the applied force*. This could be taken as a pre-concept to the teaching of the work-energy theorem and as such a score of 'limited' was awarded for prompt A1. The reasons provided why learners need to know the key idea and the selected sub-ordinate ideas are quite broad and do not show the participant's knowledge about anticipated future learning of concepts linked to the selected key ideas.

The participant erroneously identified pre-concepts in response to prompt A3, the identified pre-concepts involve vectors and scalars yet the identified key idea was 'vectors', this shows the participant's inability to correctly sequence concepts. In response to prompt A4 the participant indicated inappropriately that learners do not have to deal with multiple forces acting on an object placed on an inclined plane. According to the CAPS document (2011), learners in Grade 12 are expected to deal with a maximum of five forces acting on an object and five forces can be classified as multiple forces. SA-M01 indicated that teaching learners who possess poor mathematical prowess in terms of trigonometry and also teaching about motion on inclined planes involving multiple forces is very difficult, this is consistent with my experience as a science teacher and a genuine concern as can be seen in the expert CoRe (Appendix 2). The participant identified two genuine misconceptions, 'whenever force is applied work is done' and that 'when an object slides down the inclined plane there is an applied force'. These are very common misconceptions, for example; if a car is free-wheeling down a slope learners tend to think that a force other than gravitational component parallel to the plane is applied and is responsible for the motion.

Table 28: Subject advisor SA-Z02 post-CoRe responses to the CoRe prompts A0 to E2

SA-S02	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Definition of work and energy *Positive and negative work done *Force diagram to understand the direction of force *Conservation of energy and work-energy theorem *The meaning of power and method of calculating power		**3**
Key ideas	Work	*The participant only selected one key idea*	
A1 *What do you intend learners to learn about this idea?*	The net-work-done on an object is the product of net force and displacement in the direction of force.	*No response*	**1**
A2 *Why is it important for learners to know this?*	Learners will understand the concept of conservation of energy Learners are able to solve problems in daily life	*No response*	**2**
A3 *What concepts need to be taught before teaching this idea?*	Learners must be guided in drawing force diagrams Learners must know Newton's laws of motion	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	I don't have anything	*No response*	**1**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	If learners are not co-operative If their mathematical back ground is poor.	*No response*	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	Learners will consider work as product of force and displacement instead of using $W = F.d.\cos\theta$ They consider power as energy not as rate of work done	*No response*	

Conceptual teaching strategies			**3**
D1 *What effective teaching strategies would you use to teach this key idea?*	Perform simple experiments and demonstration like pushing an object on a table or dropping an object from a height Ask learners to analyse the concept of conservation of energy Ask learners to draw force diagrams	*No response*	**3**
D2 *What questions would you consider important to ask in your teaching strategy?*	Give learners some example problems to solve Explain the answers in detail Expose learners to hard and easy questions	*No response*	**2**
Representations and analogies			**3**
E1 *What ways would you use to support learners' understanding?*	Use some simulations Explain example problems During teaching allow learners to participate actively Bring examples from daily life	*No response*	
Knowledge about assessment			**4**
E2 *What ways would you use to assess understanding?*	Homework, classwork, tests and practical tasks. Allow them to explain answers to the class Divide class into 2 groups and organise debate or quiz competition	*No response*	

In selecting the two key ideas, participant SA-Z02 only identified one contrary to the instruction. Work was identified as a key idea but when responding to prompt A1 the participant mentioned a net-force doing net-work on an object leaving out important sub-ordinate ideas; a clear sign of inappropriate sequencing of concepts. It is necessary to deal with work done on an object by different types of forces before calculating the net effect of the forces. My personal experience as a Grade 12 physical science teacher has shown me that, it is much easier for learners to comprehend the net effect of a number of forces acting on an object once they understand the effect of one force. In response to prompt A2 the participant showed basic understanding of conceptual linking by making reference to the conservation of energy when dealing with the concept of work. SA-Z02 identified lack of co-operation by learners in response to prompt B1, however, this applies to general teaching and is not specific to teaching work, energy and power. A score of 'basic' was awarded for prompt B1 since the participant also appropriately mentioned another difficulty associated with teaching trigonometry.

The participant correctly identified a misconception learners have in terms of power, learners take power as energy and not as the rate at which energy is transferred or rate at which work is done. However, a score of 'basic' was awarded for prompt C1 as there are a number of other misconceptions the participant could have identified (*refer to expert CoRe*). In response to prompts D1 and D2, I rated the participant's knowledge about *conceptual teaching methods* 'developing'. The participant demonstrated awareness that conceptual teaching strategies are not a mere list of teaching methods but exactly how one intends to act in order to increase conceptual understanding. In response to prompts E1 the participant revealed sound knowledge about representations and analogies relevant for teaching work, energy and power and as such was rated 'developing'. The participant also demonstrated sound knowledge about ways of assessing learners understanding by highlighting various assessment methods.

Table 29: Subject advisor SA-V03 post-CoRe responses to the CoRe prompts A0 to E2

SA-V03	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Force of gravity *The direction of the force applied *The scalar nature of work-done *The relation between work-done and energy transferred $W = \Delta Ek \ or \ \Delta Ep$		**2**
Key ideas	Work-energy	*The participant did not select the second key idea*	
A1 *What do you intend learners to learn about this idea?*	The learners should know the relationship between work and energy and calculations involved in the topic	*No response*	**2**
A2 *Why is it important for learners to know this?*	It helps to solve problems involved in work, energy, conservation of mechanical energy	*No response*	**2**
A3 *What concepts need to be taught before teaching this idea?*	Force, displacement and direction of displacement Friction is opposite direction to displacement	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	The calculations of power	*No response*	**2**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	$Wnet = F.\Delta x$ Net-work done when there is friction or object on the inclined plane	*No response*	
Learners' prior knowledge and misconceptions.			**1**
C1 *What are typical learners' misconceptions about this idea?*	Energy at the top = energy at the bottom $W = F.\Delta x$ only	*No response*	

Conceptual teaching strategies			**1**
D1 *What effective teaching strategies would you use to teach this key idea?*	Simple informal experiment with an object moving on a horizontal plane and an inclined plane	*No response*	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	The direction of forces acting on the object and its numerical values	*No response*	**1**
Representations and analogies			**1**
E1 *What ways would you use to support learners' understanding?*	Explain force diagrams and free-body diagrams Definition of total mechanical energy	*No response*	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Explanations in different context of motion of an object Calculations involving work and energy Draw free-body diagrams	*No response*	

The participant identified force, displacement and direction as the pre-concepts to the teaching of the selected key idea. A score of 'basic' was awarded for this prompt because the subject advisor omitted an important pre-concept for teaching work, which precedes the teaching of the work-energy theorem (*refer to expert CoRe*). The participant provided an acceptable response to prompt A4 indicating some understanding of the need to link concepts but did not provide explanations to link the concept of power with the current topic. Responding to prompt B1 the participant identified calculations that involve the inclined plane as difficult to teach, this is consistent with my experience as a science teacher. The participant's knowledge about *'what is difficult to teach'* was rated as a 'basic' score as there was no explanation given to why teaching about the inclined plane is considered problematic. In response to prompt C1 the participant demonstrated a meagre understanding of learners' typical misconceptions about the selected key idea as can be seen by the response below.

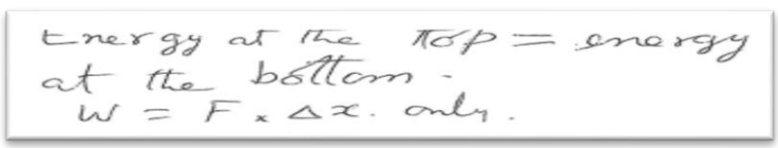


Figure 9*:* Participant SA-V03 response to prompt C1

The participant did not provide definite misconceptions. It is unclear whether the participant understood the prompt or not and as such a 'limited' score was awarded. Responses to prompts D1 and E1 were both rated 'limited' as there is no evidence of sound understanding of the prompts, rather the participant used introductory remarks such as definitions as a way to support learner understanding.

Table 30: Subject advisor SA-M05 post-CoRe responses to the CoRe prompts A0 to E2

SA-M05	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Power -Power is defined as the rate at which work is done -Power = $W/\Delta t$ -Power is a scalar quantity		**1**
Key ideas	Power	*Participant did not provide the second key idea*	
A1 *What do you intend learners to learn about this idea?*	Definition of power and the SI units Calculations when using Ep and Ek in relation to power	*No response*	**2**
A2 *Why is it important for learners to know this?*	It is very important that they know the relationship between work, energy and power and not confuse them	*No response*	**1**
A3 *What concepts need to be taught before teaching this idea?*	Vector and scalars Work ($W = F.\Delta x$) Power is rate of work and also can be expressed as energy transferred over time Electrical power ($P=VI$), $P = I^2R$	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Many formulae related to power should not be derived as data sheet will be given to learners	*No response*	**1**
What is difficult to teach?			**3**
B1 *What are the difficulties connected with teaching this idea?*	Integrating other concepts in calculations of power can be difficult. Learners find it difficult to identify forces acting on the object	*No response*	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	Work is done when object is carried When pushing an object and it does not move work is done and power can be calculated	*No response*	

Conceptual teaching strategies			**3**
D1 *What effective teaching strategies would you use to teach this key idea?*	Learners should be asked questions first to check what they know and also to check misconceptions that should be cleared. Questions that check for scientific reasoning	*No response*	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	Practical questions like - Is the power the same for walking and running? - Experimenting when power is greater	*No response*	**3**
Representations and analogies			**3**
E1 *What ways would you use to support learners' understanding?*	Practical examples and more experiments should be conducted PHET simulations can also be used to simplify concepts	*No response*	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Learners should answer questions before taught Engage in experiments after then correct their previous answers It is easy to learn by seeing	*No response*	

Subject advisor SA-M05 identified power as a key idea and included definition and units of power as sub-ordinate ideas. A score of ‘basic’ was awarded for prompt A1 because, even though appropriate sub-ordinate ideas were identified the participant only selected two sub-ordinate ideas when there are quite a number of other possible sub-ordinate ideas more fundamental to the conceptual development of the concept (*refer to expert CoRe*). Providing a minimum number of sub-ordinate ideas can be an indication that the participant either did not have sufficient time to respond to the prompt or that the participant did not know what to write, I therefore assumed the latter as ample time was provided during the workshop. In response to prompt A3 the participant correctly identified work-done as a concept to be taught before teaching power and also included the idea of energy transfers and power, where power is the rate at which energy is transferred ($P=\Delta E/\Delta t$). However, the participant also inappropriately included vectors and scalars as pre-concepts for the teaching of power, where these could be pre-concepts for teaching work.

The participant identified the integration of other concepts in calculations of power as difficult to teach and also indicated that learners find it difficult to identify forces acting on an object. I gave the participant a score of ‘developing’. However, the participant did not indicate which other concepts are difficult to integrate with power. The participant identified two appropriate misconceptions learners have regarding work. Even though the selected key idea was power. having such misconceptions about work will impact on the understanding of power. Responding to prompt E1 the participant appropriately identified experiments, PHET simulations and practical examples such as pushing a wall demonstrating that work is not done. This is an indication that the participant has sound understanding of the significant role played by analogies in helping learners to conceptualise a particular concept.

Table 31 Subject advisor SA-M06 post-CoRe responses to the CoRe prompts A0 to E2

SA-M06	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Work energy theorem *Work and energy used to analyse motion of objects *Energy is the property of a system that enables it to do work		**2**
Key ideas	Work-energy theorem Conservation of energy	*Participant did not provide a second key idea.*	
A1 *What do you intend learners to learn about this idea?*	Energy cannot be created nor destroyed Forms of energy: Kinetic, potential, thermal, nuclear and light energy	*No response*	**3**
A2 *Why is it important for learners to know this?*	For a better understanding of concepts of work and energy. That energy cannot be lost but rather transferred from one form to another	*No response*	**2**
A3 *What concepts need to be taught before teaching this idea?*	The force applied on an object and the impact it causes in an object.	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Explain who is doing work on which object, rather understand how work is done.	*No response*	**1**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Conceptualising the idea of work done in an object	*No response*	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	No relationship between energy and matter Energy is truly lost in many energy transformations Gravitational energy depends on the height of object only	*No response*	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Using analogies that will not confuse learners Teaching using PHET simulations	*No response*	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	When is work done on an object? Who will do more work a body of mass m and a body of mass 2m?	*No response*	**2**
Representations and analogies			**1**
E1 *What ways would you use to support learners' understanding?*	A mass M is moving horizontally and a vertical force is applied does the force do work?	*No response*	
Knowledge of assessment			**1**
E2 *What ways would you use to assess understanding?*	Assess learners on the basic understanding of the concepts of work and energy. Kinetic energy and net force and work net done.	*No response*	

In response to prompt A1 the participant provided essential sub-ordinate ideas for the selected key idea which included the conservation of energy and types of energy. The participant demonstrated partial understanding why learners need to understand the selected key idea as demonstrated by the response to prompt A2, which focused mainly on the law of conservation of energy. Force and the effect of a force on an object were selected as pre-concepts, however in view of the selected sub-ordinate ideas force and types of forces are actually the concepts to be taught. The participant responded inadequately to prompt A4, as no indication is made to those aspects under the energy theorem, which learners do not need to know yet. The participant provided an inappropriate response to B1 as "*conceptualising the idea of work*" is generally too broad, the participant was supposed to provide a more specific area of difficulty and justification why the concept is problematic.

Three misconceptions were provided, however two of them could rather be taken as a sign of lack of conceptual understanding by learners and not as misconceptions. He mentioned '*Energy is lost during transformations*' as this is a common misconception by learners as they tend to believe energy is 'lost'. Learners usually fail to account for an observed decline on the amount of a particular type of energy during transformations particularly where mechanical energy is not conserved (DoBE diagnostic report, 2012). In response to prompts E1 the participant demonstrated inadequate understanding of ways that can be used to improve learner understanding through the use of appropriate representations and analogies.

Table 32 Subject advisor SA-C07 post-CoRe responses to the CoRe prompts A0 to E2

SA-C07	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Power *Definition of power *Equation of power *Units of power *Relationship between power and current		**2**
Selected Key ideas	Definition of power	Units of power (Watt)	
A1 *What do you intend learners to learn about this idea?*	How to accurately define power	Clearly understand what a watt means i.e. the amount of energy given to a coulomb of charge	**1**
A2 *Why is it important for learners to know this?*	It is only when students know how to define power accurately that they will have a clear understanding of this concept	So that they clearly understand the concept and know how to apply it in real life situations e.g a 100 W bulb uses more energy than a 60 W bulb.	**2**
A3 *What concepts need to be taught before teaching this idea?*	Work and rate	Joule (unit of work done)	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Current and power relationship i.e. power depends on current.	Relationship between a Watt and KWh	**2**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Learners confuse time and rate Poor understanding of the concept of work	Stating what a watt is	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	Learners tend to think that time and rate means the same thing	Confusing a watt and a joule	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Explaining key words in definitions i.e.; Rate is the inverse of time Work done = F x Δs	Explaining key words in definitions i.e. energy and coulomb	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	When is work done on an object? What is the difference between time and rate?	Differentiate between a watt and a joule	**2**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Analogy: A machine has more power than a man as it can do more work in the same time than man	*No response*	
Knowledge of assessment			**1**
E2 *What ways would you use to assess understanding?*	Learners to be able to accurately define power	Learners to be able to clearly explain what a watt is	

The responses to prompts A1 to A4 indicated that participant SA-C07 had basic knowledge about curriculum saliency. Work was correctly identified as a pre-concept to the teaching of power, however the participant did not include such concepts as energy transfer and rate of transfer of energy indicating inappropriate sequencing. The participant mentioned that the learners do not need to know the relationship between power and current yet, however in this context mentioning current is a bit misplaced as the main topic falls under mechanics in the curriculum and not under electricity. The response to prompt C1 indicated an appropriate misconception relating to time and rate, learners tend to confuse the two, however owing to a number of other possible misconceptions that were not mentioned, a score of 'basic' was awarded.

In responding to prompts D1and D2 the participant merely mentioned concepts to be explained and not really strategies and a 'basic' score was awarded for the component. In terms of questions to ask during the teaching of the selected key idea, the participant posed elementary questions not necessary for the chosen key idea. On prompt E1 participant stated '*a machine has more power than a man as it can do more work in the same time than man*'. The statement can be used in explaining the effect of time on work-done. Different amounts of power can be dissipated when the same amount of work is done provided the time taken in doing the work is different. This response is acceptable and a 'basic' score was awarded, a higher score could not be given as the prompt required analogies and representations.

Table 33: Subject advisor SA-T08 post-CoRe responses to the CoRe prompts A0 to E2

SA-T08	**Post CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Identify the forces and angles in the planes *Identify different types of energies that objects have *Draw free-body/ force diagrams of a given scenario *Calculate the components of forces *Calculate work done on the object		**3**
Selected key ideas	Identify the forces and angles in planes	Calculate the components of forces having effect on object	
A1 *What do you intend learners to learn about this idea?*	To understand different forces and angles acting on different objects	θ is the angle between applied force vector and displacement vector	**1**
A2 *Why is it important for learners to know this?*	To be able to use them in calculating the components of forces	Calculate force and ultimately the work done on an object	**1**
A3 *What concepts need to be taught before teaching this idea?*	What is a vector quantity and classify them e.g force and displacement? Know θ as angle between applied force vector and displacement vector	Different types of energies When is work done on an object? Conservation of energy and give everyday examples Relate power to work done	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Components of forces and calculations thereof	*No response*	**1**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Calculations using the work-energy theorem (difficulty) Drawing and labelling force diagrams (easy)	Relating power to work done When is work not done	
Learners' prior knowledge and misconceptions.			**3**
C1 *What are typical learners' misconceptions about this idea?*	-Object is stationary because no force acts on it. -An object that is thrown upwards goes up because of the applied force not inertia	If force is applied to an object, even if object does not move work is done	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Teach free-body diagrams/ force diagrams and identify and label forces acting on it Identification of direction of motion of the object Emphasise different types of energies that objects have	*No response*	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	Use free-body diagrams to label forces acting on the object Calculate net work done on the object	*No response*	**1**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	PHET simulations usage Perform experiments if apparatus are available	*No response*	
Knowledge of assessment			**3**
E2 *What ways would you use to assess understanding?*	Give them conceptual questions without numbers Then followed by applications where real problems with numbers are now given	*No response*	

Responses to prompts A1 and A2 did not show evidence that the participant understood what the prompts entailed, prompt A1 required the participant to indicate sub-ordinate ideas that link with the selected key idea and the participant responded by saying "*to understand different forces and angles acting on different objects*". This does not reveal knowledge about the sequencing of appropriate sub-ordinate ideas and as such a 'limited' score was awarded. The response to prompt A2 was also awarded a 'limited' score as no reason was given why it is important for learners to know the selected key idea apart from the general application of forces in calculations. When discussing forces, knowledge about vector quantities are appropriate pre-concepts. The participant indicated vectors and included definition of a vector as a pre-concept and a score of 'basic' was awarded. The participant indicated inappropriately that learners do not need to know about the components of a force yet. It is inappropriate since an understanding of forces acting on objects at different angles was identified earlier as a sub-ordinate idea in response to prompt A1, therefore a score of 'limited' was awarded for prompt A4.

SA-T08 indicated 'calculations using the work-energy theorem' as difficult to teach. I found this not to be clear enough as no indication was given of which aspects were problematic and as such a score of 'limited' was awarded. The participant demonstrated sound knowledge about learners' misconceptions by identifying two common misconceptions around the interaction of a force and an object. One of the misconceptions is; '*An object is stationery because there is no force acting on it*'. I have noticed as a science teacher that learners tend to associate forces with definite movement and displacement not realising the effect of inertia of a body and relationship between the applied force and static friction. Similarly, learners tend to conceptualise the vertical movement of objects in air only in terms of a constant applied force on the object and not inertia. A score of 'developing' was awarded for prompt C1. In response to prompt D1 the participant listed concepts to be taught and not necessarily a conceptual teaching approach. A 'basic' score was awarded as the identified concepts indicated appropriate sequencing.

Table 34: Subject advisor SA-N10 post-CoRe responses to the CoRe prompts A0 to E2

SA-N10	**Post CoRe**		**Level**
Curricular saliency			**1**
A0 Suggested key ideas (as on first page of test)	*Work-energy theorem *Force diagrams and free-body diagrams *Definition of work *SI units for both work and energy *Difference between vector and scalar and examples		**3**
Selected key ideas	Work-energy theorem	*Participant did not provide the second key idea.*	
A1 *What do you intend learners to learn about this idea?*	Relationship between the two Both are scalars How to calculate the two	*No response*	**1**
A2 *Why is it important for learners to know this?*	Because these are being used in their everyday real life situation	*No response*	**1**
A3 *What concepts need to be taught before teaching this idea?*	Trigonometric ratios Geometry because they will be dealing with angles	*No response*	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Negative answer for work and energy	*No response*	**1**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Calculations using work-energy theorem will be difficult for learners to do	*No response*	
Learners' prior knowledge and misconceptions.			**3**
C1 *What are typical learners' misconceptions about this idea?*	-Object is stationary because there is no force acting on it -An object that is thrown vertically upwards is going up because of the applied force not inertia and Newton's first law	*No response*	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	-Free-body diagrams -Able to identify the direction of motion of the object	*No response*	**1**
D2 *What questions would you consider important to ask in your teaching strategy?*	-Use free-body diagrams so that learners can identify and label all forces acting on an object. -Calculate the work done on an object.	*No response*	**2**
Representations and analogies			**3**
E1 *What ways would you use to support learners' understanding?*	-Using PHET simulations -Perform experiments with learners -Using diagrams to explain concepts	*No response*	
Knowledge about assessment			**3**
E2 *What ways would you use to assess understanding?*	-Using conceptual questions without figures just to test for the concept -Using diagnostic reports and moderators reports to address problems and misconceptions	*No response*	

The participant identified the work-energy theorem as a key idea, from a list of key ideas identified in response to prompt A0, however inappropriate sub-ordinate ideas were identified. This could be a sign that the participant has limited knowledge about the theorem and also about concept linking. The reason provided why learners need to know about the work-energy theorem is confined to general application in everyday real life situations and does not show evidence of scaffolding and linking with other physics topics the learners are likely to encounter in future. As such a score of ‘limited’ was awarded for both prompts A1 and A2. The pre-concepts identified in response to prompt A3 are appropriate for work-done on an object by a force applied at an angle, where learners have to resolve the force using trigonometry-ratios to get the component of the force doing work, and pre-concepts directly associated with the work-energy theorem were omitted. Yet, because there is a conceptual link between force, work and energy a score of ‘basic’ was awarded.

The participant provided appropriate misconceptions that learners usually have around the effect of a force on the movement of an object, “*an object that is thrown vertically upwards is going up because of the force applied not inertia*…”. This is a common misconception the researcher has observed amongst learners when teaching about Newton’s laws (*refer to expert CoRe*). The participant was awarded a score of ‘developing’ for prompt C3. The participant demonstrated sound knowledge about representations and analogies that are relevant in supporting learner understanding and a score of ‘developing’ was awarded for prompt E1.

Table 35: Subject advisor SA-M12 post-CoRe responses to the CoRe prompts A0 to E2

SA-M12	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Calculating work done using $W = F\Delta x cos\theta$ *Calculating work done by all the forces acting on the object (Wnet) *How the Wnet will be affected if the angle between the applied force and the displacement is changed *Stating the work-energy theorem *Relationship between energy and work		**3**
Selected key ideas	Calculating work-done by each force	How will Wnet be affected by the change in θ	
A1 *What do you intend learners to learn about this idea?*	-Always draw a force diagram showing all the forces acting on an object -Consider the angles of each force	-That there is always an angle between the displacement and the relevant force -The angle is measured from the displacement vector anticlockwise -Work is maximum when the force is parallel to the displacement	**2**
A2 *Why is it important for learners to know this?*	It is important to know that it is possible that work done by a force is zero even when the displacement is non-zero	*No response*	**1**
A3 *What concepts need to be taught before teaching this idea?*	Vectors Work	Trigonometric functions Work Vectors	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	*No response*	*No response*	**1**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Learners who do physical sciences with mathematical literacy since they do not do trigonometric functions	Having a vertical and horizontal displacement	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	As long as force is applied to an object there will be work done	*No response*	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	-Demonstrations -Give more exercises with different scenarios -Illustrations and drawings	*No response*	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	No response	*No response*	**1**
Representations and analogies			**1**
E1 *What ways would you use to support learners' understanding?*	Demonstrations	*No response*	
Knowledge about assessment			**1**
E2 *What ways would you use to assess understanding?*	Through assessment and do remedial work if there is a need	*No response*	

The participant selected '*work-done by a force'* as a key idea and selected two sub-ordinate ideas, however, drawing of force diagrams is not an appropriate sub-ordinate idea as it is not the focus in the discussion of work and energy, but can be considered as a pre-concept. The reason provided why learners should know the key idea was vague, it did not show any sign that this key idea is interrelated to other topics or sub-topics associated with work, energy and power. In response to prompt A3 the participant identified vectors and work as pre-concepts and added trigonometric functions as a pre-concept for the second key idea. However, 'vectors' as a concept is very broad and the participant did not identify which vectors are linked to work and energy. Furthermore, work cannot be a pre-concept when the selected key idea is 'work done by a force'. The participant was awarded a score of 'basic' for identifying trigonometric functions as appropriate pre-concepts for teaching net-work done on an object by different forces applied at various angles.

In response to prompt B1 the participant selected trigonometric functions as difficult to teach particularly to learners doing mathematical literacy. This is a common area of difficulty (*refer to the expert CoRe*). However, since no suggestion was provided on how to help learners understand the concept a score of 'basic' was awarded. Similar to the previous two participants, SA-M12 identified the same common misconception around the effect of a force on an object in terms of the work done by the force. This is an appropriate misconception that learners have however, for a higher score than 'basic' the participant should have identified two or three other misconceptions as can be seen on the expert CoRe. Responses to prompts D2 and E1 were quite elementary and were both scored 'limited'.

Table 36: Subject advisor SA-L13 post-CoRe responses to the CoRe prompts A0 to E2

SA-L13	**Post CoRe**		**Level**
Curricular saliency			**3**
A0 Suggested key ideas (as on first page of test)	*Define work (done) *Link work done to energy transferred *Work is done when the applied force causes displacement in the direction of the applied force. *Define conservative and non-conservative forces *Work-energy theorem and power *Motion on the inclined plane		**3**
Key ideas	Definition of work done	Work-energy theorem	
A1 *What do you intend learners to learn about this idea?*	Work is done when there is a displacement in the direction of the applied force Frictional force or force acting in the opposite direction to the motion of object does negative work	Determine at least one of the following: Net work done Final or initial velocity of an object, mass of an object.	**2**
A2 *Why is it important for learners to know this?*	It is the basic or fundamental concept of the chapter (without which it will be difficult to do other parts of the chapter)	Learners must be able to apply this knowledge to day to day life experiences.	**3**
A3 *What concepts need to be taught before teaching this idea?*	Forces, resolution of vectors Force and free-body diagrams	Kinematic equations	**2**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Calculating work done on objects on inclined planes	Calculating work done on vertical motions and objects on inclined planes	**2**
What is difficult to teach?			**1**
B1 *What are the difficulties connected with teaching this idea?*	Learners with poor mathematical competence (in geometry and trigonometry)	Learners not understanding forces	
Learners' prior knowledge and misconceptions.			**2**
C1 *What are typical learners' misconceptions about this idea?*	When force is applied there is work done.	When the object slide down the inclined plane there is an applied force (not necessary due to the component of the weight parallel to the inclined plane)	

Conceptual teaching strategies			**3**
D1 *What effective teaching strategies would you use to teach this key idea?*	Moving from the known to the unknown Question and answer method Use of worksheets and problem solving method	*No response*	**3**
D2 *What questions would you consider important to ask in your teaching strategy?*	Define work done (scientifically) Calculate the work done on various scenarios	State work-energy theorem. Calculate Wnet, V initial, V final or kinetic energy	**2**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Discovery learning Detail explanation of fundamental concepts/principles Work-sheets Pausing during the lesson for questions and answers	*No response*	
Knowledge about assessment			**4**
E2 *What ways would you use to assess understanding?*	Pausing during the lesson for questions and answers Work-sheets and classwork, homework/ group work and integration of these methods Term tests and examinations	*No response*	

The participant identified '*work-done*' as the first key idea and selected work-energy theorem as the second key idea and provided definition of work and work done by frictional force as appropriate sub-ordinate ideas. The response to prompt A2 showed that the participant is cognisant of the need to link concepts "*it is the basic / fundamental concept of the chapter…"* The participant pointed out that teaching other concepts under work, energy and power depends on a sound understanding of this fundamental concept. Vectors, force resolutions and free-body diagrams were correctly selected as pre-concepts necessary for teaching the first key idea. However, owing to the fact that there are other pre-concepts more appropriate to the key idea than what the participant selected a score of 'basic' was awarded. (See expert CoRe, (Appendix 2). A common misconception was also identified that involves the concept of force and movement of an object. Learners tend to associate movement on an inclined plane to an applied force and not to the component of gravity parallel to the plane. The participant was rated 'basic' because for any higher score two or more misconceptions should have been identified.

The participant demonstrated sound knowledge about teaching strategies, as reference was made of a teaching approach that moves from the known into the unknown. This strategy acknowledges the need to approach concepts from the familiar and easy to the new and complex indicating a conscious awareness of the need to conceptually link aspects and building towards bigger concepts. I rated the participant 'developing' for prompt D1.

Table 37: Subject advisor SA-M14 post-CoRe responses to the CoRe prompts A0 to E2

SA-M14	**Post CoRe**		**Level**
Curricular saliency			**2**
A0 Suggested key ideas (as on first page of test)	*Power -Explain scalar and vector quantities using examples -Explain work done on an object when a force is applied -Energy is the capacity to do work -Use work and energy concepts to explain power as the rate at which work is done		**3**
Key ideas	Scalars and vectors	Work done on an object	
A1 *What do you intend learners to learn about this idea?*	Scalar quantity has magnitude only Vector quantity has both magnitude and direction	Work is done when a force acts on an object and causes it to move in a direction parallel to the force.	**2**
A2 *Why is it important for learners to know this?*	Knowledge of vectors will assist learners to identify forces acting on an object and representing them using free-body diagrams	It will help learners understand that a force causes energy to be transferred when work is done	**2**
A3 *What concepts need to be taught before teaching this idea?*	Ask learners to distinguish vectors from scalars from a list of quantities given. Resolving vectors and determining their resultants	Force and types of forces acting on an object placed on a particular place	**3**
A4 *What else do you know about this idea that you do not intend learners to know yet?*	Work is a scalar quantity and energy like work is also a scalar quantity	Power is the rate at which work is done	**2**
What is difficult to teach?			**2**
B1 *What are the difficulties connected with teaching this idea?*	Representation of a magnitude using a line and direction using an arrow Resultant of vectors can be obtained using tail-to-head method or parallelogram method	Identification of forces acting on an object placed on top of a table Forces acting on a moving object in a particular direction	
Learners' prior knowledge and misconceptions.			**3**
C1 *What are typical learners' misconceptions about this idea?*	Parallelogram method is different from tail-to-head. Components are rigid and cannot be moved around	Work is done on an object even if it does not move although force is applied on it When object moves upwards force of gravity is upwards	

Conceptual teaching strategies			**2**
D1 *What effective teaching strategies would you use to teach this key idea?*	Discovery methods Demonstration	Always make learners aware that force of gravity always acts downwards	**2**
D2 *What questions would you consider important to ask in your teaching strategy?*	Identify vectors from scalars in a given list of quantities Find resultant of two vectors of given magnitudes	Differentiate between work and energy Differentiate between positive and negative work Is work done on an object if carried up a flight of stairs?	**2**
Representations and analogies			**2**
E1 *What ways would you use to support learners' understanding?*	Trigonometric ratios, right-angled triangles	Demonstration of work done on an object pulled along a horizontal plane also force applied along an inclined plane	
Knowledge about assessment			**2**
E2 *What ways would you use to assess understanding?*	Tutorials Assignments Construction/diagrams	Ask learners to find work done on different scenarios	

In response to prompt A0 the participant properly selected power, work-done and energy as key ideas, however when selecting two key ideas as required for responses to prompt A1 to E2, SA-M14 identified vectors and scalars as the first key idea and work-done as the second key idea. Vectors and scalars are not appropriate key ideas for work, energy and power, but should rather be seen as pre-concepts for teaching about forces and work. The reasons provided why learners need to know both key ideas were vague, they only focused on the understanding of the current topic and no reference was given for anticipated future learning of concepts linked to the key ideas. The participant suitably identified pre-concepts for the second key idea, since teaching about types of forces and their effect on an object precedes the teaching about work done on an object. A score of 'developing' was awarded.

The participant identified two appropriate misconceptions, "…*when object moves upwards force of gravity is upwards*". This misconception is based on the tendency by learners to attribute motion of objects to a particular force disregarding Newton's first law. It is a common misconception and consistent with my experience as a physical science teacher. The response to prompt D1 was rated 'basic' as the participant merely identified teaching methods and provided elementary questions to ascertain learner understanding.

5.5 CHAPTER SUMMARY

The post-CoRe data, though essential, was marred by a lot of '*no responses*' for a number of prompts as some participants only provided responses for one key idea, which resulted in those prompts being rated 'limited'. An assumption was made earlier at the beginning of Chapter 5 that a '*no response*' could be a result of lack of motivation due to the absence of incentives for the participants, as marks were not allocated or it could mean a lack of conceptual understanding. Considering also that the post-CoRes were completed after the PTD workshop, tiredness and the eagerness to finish the workshop could have contributed to a hurried completion of the CoRes resulting in participants omitting some prompts or responding without genuine conceptual thought. However, the prompts that were responded to, provided important data which, when analysed, revealed the quality of subject advisors' PCK about work, energy and power after the PTD workshop. It is worth noting however, that due to a lot of data missing as a result of participants not responding to all prompts, the data collected by the post-CoRes is not sufficient to effectively measure the participants' tacit knowledge about the TSPCK components. The data, however, shed some light on the quality of the subject advisors' knowledge about the components after the PTD workshop. In the following chapter an analysis and interpretation of the pre-CoRe data, interview data, data from the workshop manual and post-CoRe data will be made. A comparison will be made between the pre- and post-CoRes to determine the effect of the PTD workshop on each of the TSPCK components.

CHAPTER 6
DATA ANALYSIS AND INTERPRETATION

6.1 INTRODUCTION

In this chapter an analysis and interpretation of the results presented in Chapter 4 and Chapter 5 are presented. The pre- and post-CoRe scores for each TSPCK component were compared with the expert CoRe in response to research sub-questions one and two respectively. In this chapter, a comparison between the pre- and post-assessment CoRes is made in response to research sub-question three. Interview data is analysed on the basis of the TSPCK components as revealed through responses to the interview questions and an interpretation is then done to assess the effect of the workshop on each TSPCK component. The workshop manual is also analysed with reference to the five TSPCK components. The structure and the way concepts were presented in terms of sequencing and arrangement in the manual is compared with the expert CoRe.

6.2 ANALYSIS OF PRE- AND POST- CORE RESPONSES

The analysis of the data collected from the completed CoRes is presented with reference to each TSPCK component. Figure 11 shows the number of subject advisors whose knowledge about the TSPCK components was rated a particular score. From Figure 11 it can be seen that only two subject advisors obtained a score of ‘developing’ before the PTD workshop and none obtained an ‘exemplary’ score. However, after the workshop the number of subject advisors who obtained a ‘basic’ score increased and each TSPCK component now has at least one subject advisor whose knowledge was rated ‘developing’. Four subject advisors where at least scored ‘developing’ for their knowledge about ‘learners’ prior knowledge’ and ‘conceptual teaching strategies” respectively. A detailed comparison between the pre- and post-CoRe responses is then done. Examples of responses that are on the extreme ends of the continuum are presented as ‘extracts’ to either illustrate very poor or exceptional responses.

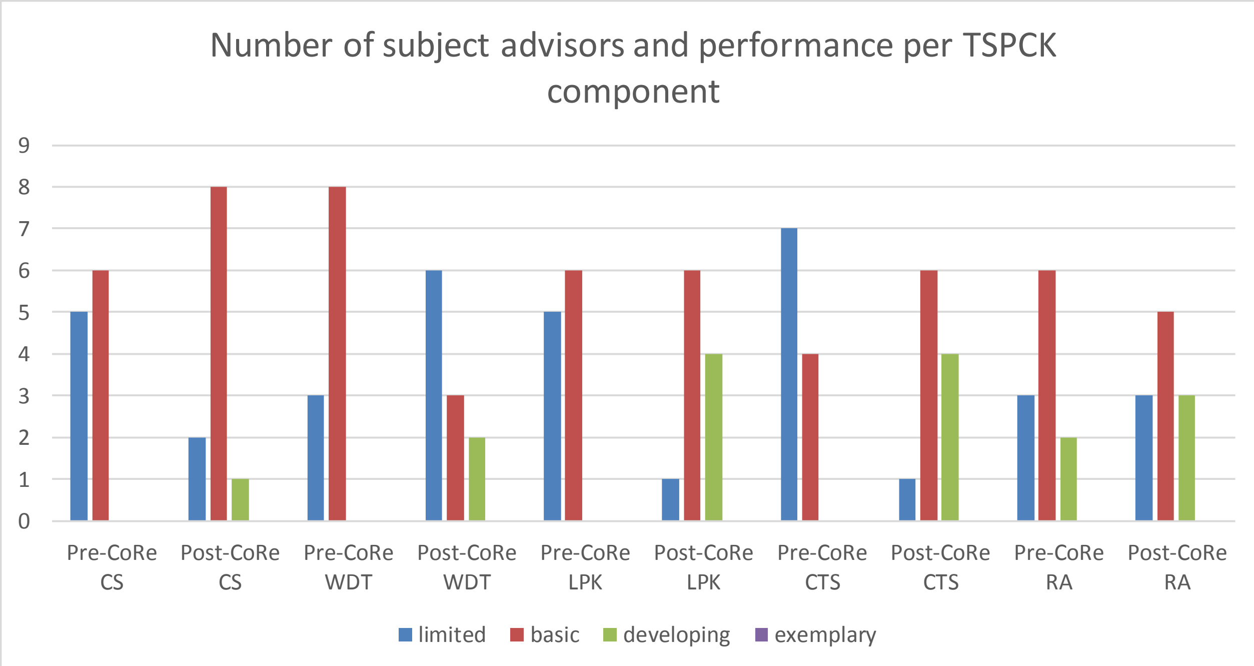
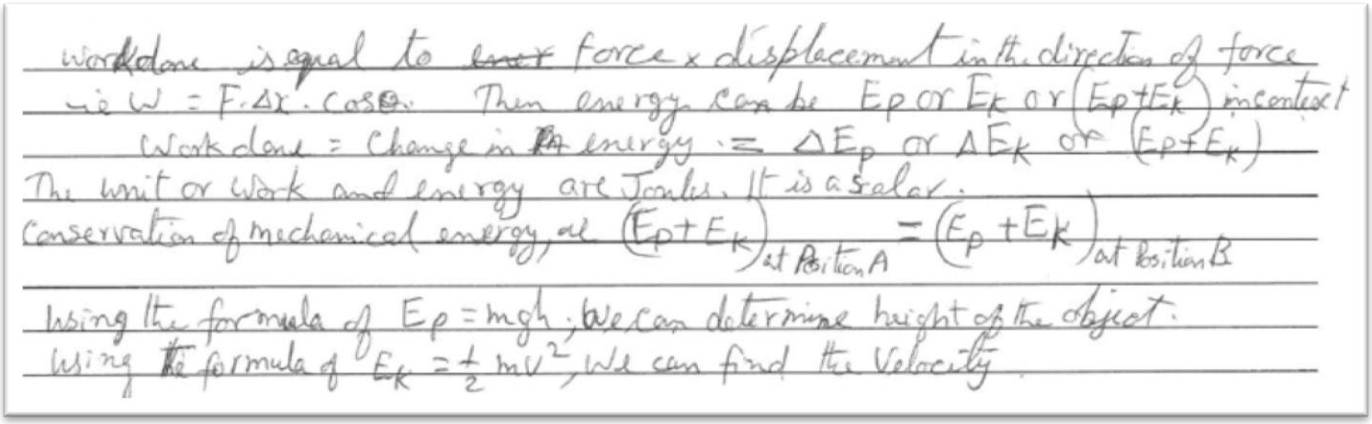


Figure 10 Number of subject advisors and performance per TSPCK component.

Curricular saliency (CS), what is difficult to teach (WDT), learner prior Knowledge (LPK), conceptual teaching strategy (CTS), representations and analogies (RA).

6.2.1 Curricular saliency

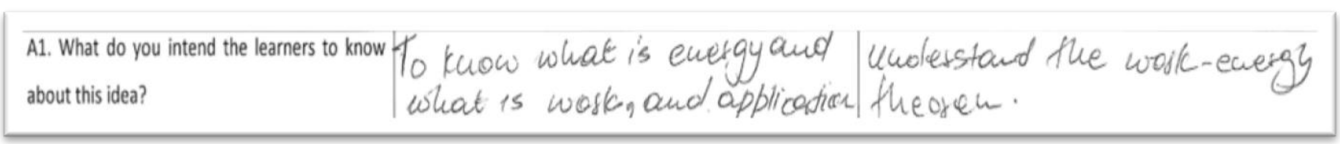
During the scoring process, evidence of a participant's knowledge about curricular saliency from the participant's responses to the CoRe prompts A1 to A4 and also their selection of key ideas were obtained (*see Appendix 1*). Curricular saliency as a TSPCK component was challenging to score. It involved participants identifying two key ideas and for each selected key idea the participant had to provide responses to the pre and post-CoRe prompts A1 to A4. Many participants did not follow the instruction on the CoRe template and instead only provided responses for one key idea in the post-CoRe making it difficult to assess the effect of the PTD workshop. Participants struggled in identifying key ideas since most of them could not differentiate key ideas from sub-ordinate ideas and also key concepts from pre-concepts (*see Figure 11*).



workdone is equal to force x displacement in the direction of force
ie $W = F.\Delta x.\cos\theta$. Then energy can be E_p or E_k or (E_p+E_k) in context
Work done = Change in energy := ΔE_p or ΔE_k or (E_p+E_k)
The unit or Work and energy are Joules. It is a scalar.
Conservation of mechanical energy, ie $(E_p+E_k)_{at\ Position\ A} = (E_p+E_k)_{at\ Position\ B}$
Using the formula of $E_p = mgh$, we can determine height of the object.
Using the formula of $E_k = \frac{1}{2}mv^2$, we can find the Velocity.

Figure 11: SA-M03's selection of key ideas in the pre-CoRe

Participant SA-M03, like many other participants, identified pre-concepts as key ideas. In teaching about work, energy and power conservation of mechanical energy is not a key idea but rather a sub-ordinate idea or it can be an appropriate pre-concept to the energy concept, since the law of conservation of mechanical energy is introduced in earlier grades in the South African physical sciences curriculum. In both the pre- and post CoRes, vectors and scalars were inappropriately identified by many participants as key concepts, yet they form part of introductory concepts in the Grade 10 physical sciences section on mechanics and should rather be listed as pre-concepts to the teaching of forces with reference to work. Prompt A1 posed challenges to participants, as they appeared not to know what the prompt required.



A1. What do you intend the learners to know about this idea?	To know what is energy and what is work, and application	Understand the work-energy theorem.

Figure 12: SA-M01 pre-CoRe response to prompt A1

The pre-CoRe responses to prompt A1 by participant SA-M01 above are too simplistic as they do not clearly state what exactly learners need to know and as such do not show the participant's knowledge about sub-topics and sub-concepts that are within the selected key idea. The participant's post-CoRe response to A1 slightly improved as he identified the definition of work as a sub-ordinate idea instead of just stating that learners need to '*understand the work-energy theorem*' as in Figure 12 above.

Prompt A2 was poorly responded to in both the pre- and post-assessment CoRes, many participants could not provide sound reasons why it was important for learners to know the identified sub-ordinate ideas. Most of the reasons provided were vague as they only related to the general benefits of education without evidence of anticipated future learning and scaffolding of ideas towards broader understanding of the topic and other related topics in physics (*see Figure 13*). The participants should have provided reasons that indicate awareness for the need for current concepts to be linked to other concepts and provide a developmental pathway towards major concepts through a process of scaffolding of ideas.

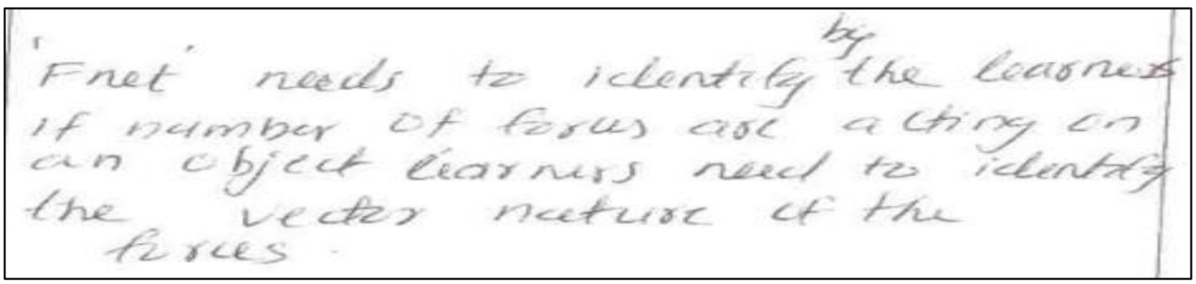

'Fnet' needs to identify by the learners if number of forces are acting on an object learners need to identify the vector nature of the forces.

Figure 13: Participant SA-Z02 pre-assessment response to prompt A2

Participant SA-Z02 identified net-force as a concept to be taught, however the participant's response to why it is important for learners to know this concept is quite vague. The reason provided does not show conceptual linking in terms of anticipated future learning. Prompt A3 which required participants to identify concepts that should be taught before teaching the chosen key ideas or sub-ordinate ideas was also not properly responded to. Participants identified concepts that they thought constituted pre-concepts, however most of these pre-concepts involved key and sub-ordinate ideas or concepts from other topics not linked to work, energy and power. Prompt A4 was also poorly responded to particularly in the pre-CoRes, many participants included what they had selected in response to prompt A2 as that which they do not want their learners to know yet. Participant SA-V03 selected 'work-done' as a key idea and included calculations of work as sub-ordinate ideas but proceeded in stating as a response to A4 in the pre-CoRe that learners do not need to know the direction of the force applied (see Figure 14).

A4 *What else do you know about this idea that you do not want learners to know yet?*	The Direction of force (applied) friction act in the opposite direction of motion.	The Calculation of Power.
	SA-V03's Pre-CoRe response	**SA-V03's post-CoRe response**

Figure 14: SA-V03 pre- and post-CoRe responses to prompt A4

The pre-CoRe response by SA-V03 is inappropriate; the direction of an applied force has an effect on the direction and nature of the work done on a body. If, in a closed system, the applied force is the only force acting on an object the object will move in the direction of the applied force (net-force) and positive work will be done by the force on the object. In the post-CoRe the participant's response to prompt A4 slightly improved as teaching about work precedes the teaching about power. It is therefore appropriate that learners do need not to know about power yet. Participant SA-L13's knowledge about curricular saliency showed a significant improvement from pre- to post-CoRe. Knowledge about this TSPCK component improved from a score of 'basic' to 'developing'. This improvement is largely because of the improved response to prompt A2 in the post-CoRe. In the pre-CoRe the participant's response did not show why it was important for learners to know the selected key-idea as opposed to the post-CoRe where the participant appropriately indicated that the selected key idea was a fundamental concept for the understanding of other concepts of the topic (see Figure 15). The participant's score improved from limited in the pre-CoRe to developing in the post-CoRe.

• There is movement of objects. How to move objects effectively and efficiently. • What to take into consideration when applying force to the object	It the basic/fundamental concept of the chapter (without which it will be difficult to do other parts of these chapter).
SA-L13's pre-CoRe response to A2	SA-L13's post-CoRe response to A2

Figure 15: SA-L13's pre-CoRe response to A2

The post-CoRe responses indicated the participant's awareness that the current topic provides the foundation upon which other linked topics and concepts can be developed. Five of the eleven participants, 45%, are rated as 'limited' and 55% are rated as 'basic' before the PTD workshop on curricular saliency. This shows that the participants' knowledge about curricular saliency before the PTD workshop was low. The number of participants rated 'limited' dropped from five to two after the workshop and the number of those rated 'basic' rose to eight with one being rated 'developing' after the PTD workshop. Three participants' knowledge about curricular saliency improved slightly from limited to basic. This improvement was not across all the prompts and also not by all the participants.

6.2.2 What is difficult to teach?

In analysing and making interpretations from the data collected for this TSPCK component, it is important to highlight that this component is also dependant on context and not only on content. Some of the challenges the participants indicated might not be universal areas of difficulty in teaching about work, energy and power but unique to schools in that province. Many participants identified the use and integration of trigonometry in resolution of forces as difficult to teach. It could probably be that the teaching of maths and science is not at an acceptable level at many of the schools, hence it is a genuine area of difficulty. A lack of knowledge about science and maths from earlier grades could be a problem in the districts these subject advisors come from. Many participants identified aspects that are generally difficult to teach in physics education and not necessarily in teaching the selected key idea under work, energy and power. Some of the concepts identified as difficult to teach are so basic and form the foundations of other aspects that could be difficult to teach. As an example participant SA-M14 selected the '*identification of forces acting on an object placed on top of a table'* as difficult to teach. This aspect of identification and naming of forces acting on objects is introduced in grade eleven mechanics and should not be difficult at Grade 12. However, considering that each subject advisor represents a number of teachers and that many considered this aspect as difficult when teaching about work, energy and power, one can speculate that the teaching of forces in many of the schools in the province is not at a desired standard. Other participants like SA-M12 and SA-N10 who identified the use of trigonometry identities as a difficult aspect to teach indicated that it is so particularly to those learners who are studying mathematical literacy and physical sciences and those with poor mathematical skills. This observation is consistent with the findings from the DoBE diagnostic report of 2012 (see Figure 16).

NATIONAL DIAGNOSTIC REPORT ON LEARNER PERFORMANCE 2012

(i) Poor mathematical skills and handling of calculators contributed to the poor performance of some centres.

Figure 16*:* Extract from the DoBE diagnostic report 2012.

Poor mathematical abilities limit learners' performance in mechanics and related topics, as these require use of formulae and calculations based on mathematical principles such as trigonometry identities.

Participant SA-M05 identified the identification of angles as a difficult aspect to teach, however, the participant did not realise that it is not about the identification of the angles per-se but the understanding of the relationship between the force vector and the displacement vector. Forces that are parallel and in the same direction as the displacement vector do positive work, while those in the opposite direction do negative work, (see Figure 17).

B1 *What do you consider easy or difficult about teaching this idea?*	Learners find it difficult to choose the correct angles i.e. when is $\theta = 0^\circ$, 180, 90°.	Intergrating other concepts in calculation of power can be difficult. Learners find it it difficult to identify forces acting on the object.
	Pre-CoRe response	Post-CoRe response

Figure 17: SA-M05's response to prompt B1

This aspect of choosing the correct angles to use when performing calculations that involve work done by multiple forces acting on an object was also addressed during the PTD workshop (*see Figure 18*) from the workshop study manual indicating which force is doing positive and negative work and those not doing any work.

Solutions

Q1: The vertical forces do no work on the object as it does not experience any vertical displacement. The applied force does positive work on the object and the force of friction does negative work on the object.

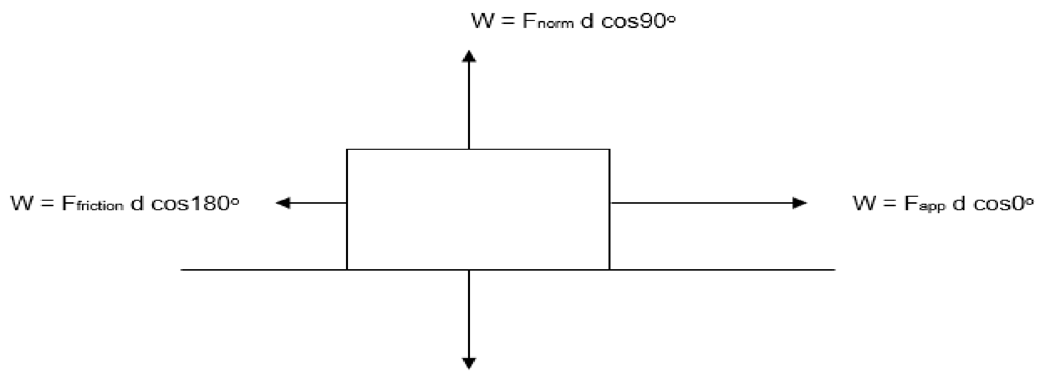


Figure 18: Extract from the workshop study manual

The area of geometry and trigonometry as it relates to resolution of forces was identified by many participants as a source of difficulty in teaching key ideas under the topic '*work, energy and power*'. However most of the participants did not show evidence of sufficient knowledge about what to consider as difficult to teach, they only identified aspects without explicitly stating why and which facet is difficult to teach. In the pre-CoRe participant SA-N10 made an attempt to explain why it is difficult to teach about work done on an inclined plane, as can be seen in Figure 19.

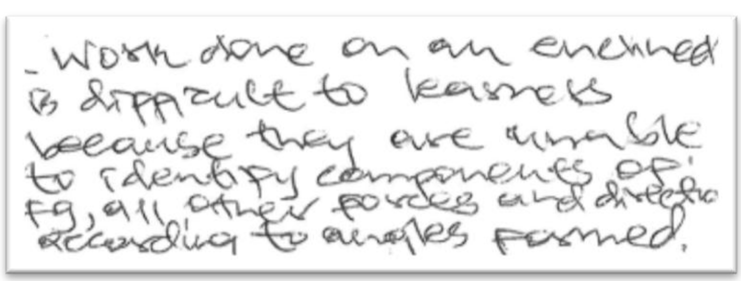

- Work done on an enclined is difficult to learners because they are unable to identify components of Fg, all other forces and directio according to angles formed.

Figure 19: Extract from SA-N10's pre-CoRe

The participant could have explained the need for learners to have knowledge about trigonometrical identities so that they can formulate components of the forces such as gravitational force acting on an object placed on an inclined plane. As a result, the participant was scored 'basic' in the pre-CoRe. However, the same participant was later scored ‘limited’ after the workshop. As the participant merely stated that calculations using the work-energy theorem are difficult to teach. This could be attributed to lack of seriousness in completing the CoRes after the workshop due to lack of motivation as no incentives such as mark allocation and certificates were given. The overall impact of the PTD workshop on the participants’ knowledge about this component was minimal. Possibly because the teacher knowledge about this TSPCK component stems from experience and it is contextual, which is something the PTD workshop did not focus on.

Selection of an effective teaching strategy is argued to stem from an understanding of which aspects of a concept requires conscious attention in terms of the level of difficulty (Trumper, 1998). When a teacher understands the level of competency required in teaching a specific concept the process of selecting the teaching strategy and pacing of content becomes much easier. Many participants who could not identify aspects which were difficult to teach when teaching the selected ‘key ideas’ probably failed to do so because they also could not identify areas that required special attention when dealing with the concept.

6.2.3 Learners’ prior knowledge

Responses to CoRe prompt C1, provided evidence of the SAs’ knowledge about learners’ prior knowledge and misconceptions. According to Hake, (1998) most misconceptions possessed by learners are a result of a poor understanding about a concept either as a result of wrong intuitive reasoning or incorrect prior information given to them. Having knowledge about this TSPCK component “learners’ prior knowledge”, is critical to achieving conceptual change as the teacher knows about learners’ thinking and how their thinking impacts on the teaching of the topic. Five participants were scored ‘limited’ and six were scored ‘basic’ respectively before the workshop. No one was rated any score higher than ‘basic’. However, after the workshop four participants were rated ‘developing’. This improvement indicates the impact of the PTD workshop on this TSPCK component. For instance, participant SA-T08 showed remarkable improvement in responses from pre- to post- CoRe (see Figure 20).

Identification of forces using a free body diagram Angles involving the calculation regarding those	An object is stationery because there is no force acting on it. - An object that is thrown upwards is going up because of the applied force not inertia
Pre-CoRe response	Post-CoRe response

Figure 20: Extract from SA-T08's pre- and post-CoRe responses to C1

The pre-CoRe response does not indicate any misconceptions about the selected key idea, either the participant did not know what was meant by 'prior knowledge' or did not understand what the prompt required. However, in the post-CoRe the participant indicated one of the common misconceptions around the concept of inertia and Newton's first law. Learners having this kind of misconception, as identified by SA-T08 in the post-CoRe, do not realise that objects have a tendency to resist change in their state of motion or rest, as best explained by Newton's first law. If the object is given an initial vertical impetus, the object would want to continue in the original direction of the push. This kind of reasoning would probably cause learners to include an extra upward force when calculating the work done on an object moving upwards. My experience as a science teacher and examiner has also shown me that this misconception leads to learners unsuccessfully calculating the net-work done and hence failing to use the work-energy theorem. Another example of improved responses is by participant SA-M14. In the pre-Core the participant's knowledge about learners' prior knowledge was rated 'limited' and in the post- CoRe he was rated 'developing' (see Figure 21).

Interchanging work in equation with units of power in symbol i.e W	Work is done on an object even if it does not move although force is applied on it. i.e it moves upwards.
Pre-CoRe response	Post-CoRe response

Figure 21: SA-M14 pre- and post-CoRe responses to C1

Interchanging the symbol for work with the unit of power cannot be taken as a misconception but rather poor conceptual understanding and as such the participant was scored 'limited' before the PTD workshop. After the workshop the participant identified an appropriate misconception around the concept of work, force and displacement. This remarkable improvement by participant SA-M14 and SA-T08 and also marginal improvements from 'limited' to 'basic' by other participants are because the presenter of the PTD workshop focused on this TSPCK component as can be seen in Figure 22 from the workshop manual.

5. If an applied force is at right angles to the displacement of an object, no work is done. If a force is applied to an object and the displacement is 0 m, no work is done. If the

Figure 22: Extract from workshop manual

Participant SA-M06 improved marginally from 'limited' in the pre-CoRe to 'basic' in the post-CoRe. In the post-CoRe the participant appropriately identified a misconception learners have around energy transfer and transformations. "*Energy is truly lost in many energy transformations*", this misconception is a common one. However, the participant was scored 'basic' as he also inappropriately mentioned other aspects on the same response such as '*no relationship between energy and matter*'. This cannot be a misconception but rather a lack of conceptual understanding. Learners tend to think that energy is 'lost' when in actual fact the decrease of a particular type of energy results in an escalation of another type of energy within a system. A way of addressing this misconception could be the explanation of the conservation of mechanical energy of a falling object, where a decrease in gravitational potential energy results in an increase in the kinetic energy of the object as it falls towards the ground.

Some participants identified a misconception around the use of the 'angle θ'. In performing calculations using the general work formula, ($W = F \times d \cos\theta$) the angle θ indicates the direction between the force vector and the displacement vector. Yet, when dealing with the inclined plane there is the angle of inclination denoted by angle 'θ' as well. Learners tend to have some confusion in choosing which angle 'θ' to use. This could be a misconception or general lack of understanding which can be addressed through proper explanation and practice.

There was an improvement after the workshop as more acceptable misconceptions were identified and this improvement can be attributed to the PTD workshop. The workshop was not initially intended to address teachers' misconceptions but rather to make teachers aware of the learners' misconceptions, however it became apparent during the workshop that some subject advisors also had misconceptions regarding some aspects of work, energy and power. Hence the need to focus on teacher's misconceptions as well and to improve content knowledge (*see Table 38*).

Table 38: Extract from Interview responses.

Theme 3	**Prior knowledge and misconceptions**
Question 1	Did you find it necessary to focus on typical misconceptions about work, energy and power? Why?
Response	*Yes, it was necessary…it was the approach of the workshop, to make teachers aware of learner misconceptions…help improve teaching being aware of learner difficulties.*

As the participants interacted with the presenter some misconceptions were identified as can be seen from the differences in pre- and post-CoRe responses. This TSPCK component was one of the components that showed significant improvement after the workshop. It is worth noting that some of the misconceptions learners and even teachers have are also consistent with the misconceptions other learners and teachers have across the whole country (*see Figure 23).*

QUESTION 5: WORK AND ENERGY

Common errors and misconceptions

(a) The drawing of the free body diagram improved from previous years (Q5.1). Common errors were:

- Inclusion of a frictional force despite the statement in the question that friction should be ignored;
- Drawing a free body diagram for an object on an incline;
- Incorrect labeling of forces;
- Drawing arrows without arrow heads.

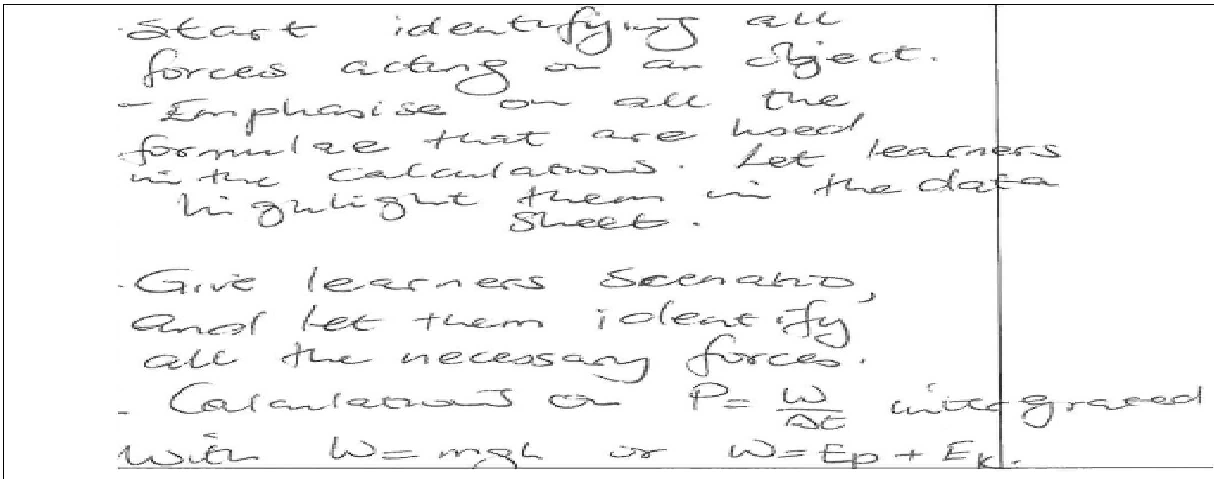
Figure 23: Extract from DoBE physical science Diagnostic report, 2012.

6.2.4 Conceptual teaching strategies

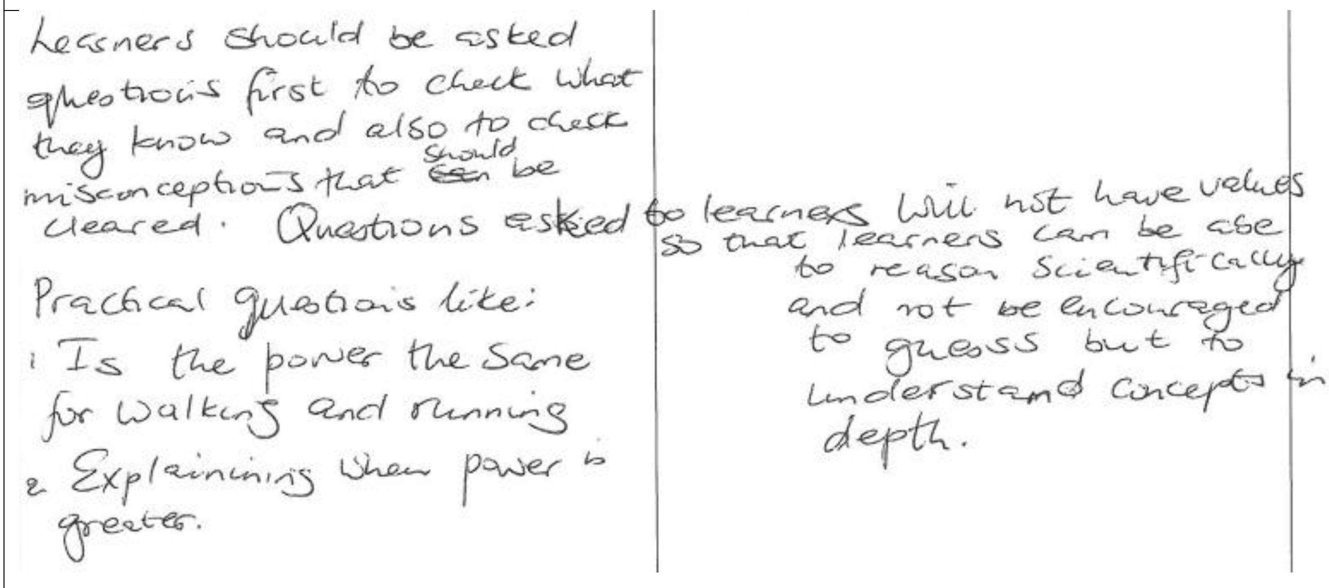
Articulating a step by step account of what exactly a teacher is going to do in ensuring conceptual understanding is an indication of the teacher's sound knowledge about conceptual teaching strategies. This is another TSPCK component that participants had to show knowledge about by responding to the CoRe prompts D1 and D2. Scoring this TSPCK component was challenging as it involved identifying the effective teaching strategy in response to D1 and then providing appropriate questions in response to D2. Some participants posed questions that were appropriate for science in general but did not link well with the current topic and the teaching strategy to be followed. Many participants gave a list of teaching methods, however providing a list of teaching methods without specifically mentioning what one has to do in teaching a concept reveals no knowledge of an effective conceptual approach. The teaching strategy should take into account the sequencing of concepts and should incorporate pre-concepts and also enable the teacher to address misconceptions (Resnick, 1983).

In the pre-CoRe, seven participants were scored 'limited' and four were rated 'basic'. There was an improvement after the PTD workshop as four participants were rated 'developing', while the number of 'limited' dropped from seven to one. At the same time number of 'basic' increased from four to six. Participant SA-Z02 and SA-M05 are good examples of those whose knowledge about conceptual teaching strategies improved after the PTD workshop.

The participants were rated 'limited' before the workshop and were scored 'developing' after the workshop. Figure 24 shows participant SA-M05's pre- and post-Core responses indicating an improvement after the PTD workshop.



SA-M05's pre-Core response to D1 and D2



SA-M05's post-CoRe response D1 and D2

Figure 24: Extract from SA-M05's pre- and post-CoRe responses to D1 and D2

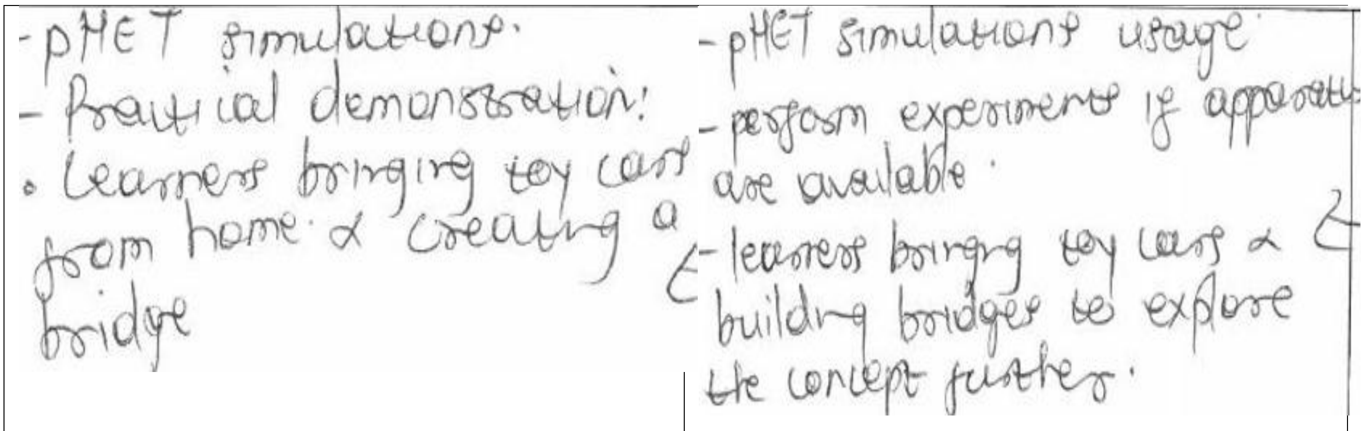
In the post-CoRe, participant SA-M05 stated that "*Learners should be asked questions first to check what they know and also to check misconceptions that should be cleared*". This approach was also used by the presenter of the PTD workshop as some conceptual questions were asked as a diagnostic measure before teaching. This approach enables the teacher to ascertain the level and depth of teaching required and also provides a platform for identification of misconceptions. The participant also provided questions that could test the conceptual understanding such as "*is the power the same for walking and running?"* This is a basic question but provides genuine measure for conceptual understanding as compared to merely asking learners to perform calculations based on formulae. On the other hand, indicating an improved response to D1 from pre- to post-CoRe participant SA-L13 identified '*moving from the known to the unknown*' as a teaching strategy. This shows that the participant is aware of the critical role played by prior knowledge in formulating a teaching sequence.

Some participants such as SA-N10 did not show any improvement from pre- to post-CoRe. The participant SA-N10 stated "*able to identify the direction of motion of the object*" in response to prompt D1 in the post-CoRe. This is not a teaching strategy and one wonders why the participant responded as such. Either the participant has a lack of knowledge of teaching strategies or misunderstood the prompt. Other participants merely listed the teaching method without appropriate questions in both the pre- and the post-CoRe. This resulted in scores ranging between 'limited' and 'basic'.

SA-M01 identified problem solving and enquiry as teaching methods, but did not show how these strategies could be effective in teaching key ideas under work, energy and power. The scores for the responses to prompt D1 and D2 ranged between 'limited' and 'basic' only before the PTD workshop. After the workshop four participants were scored 'developing' as indicated earlier. This improvement of the participants' responses to this TSPCK component can be attributed to the PTD workshop.

6.2.5 Representations and analogies

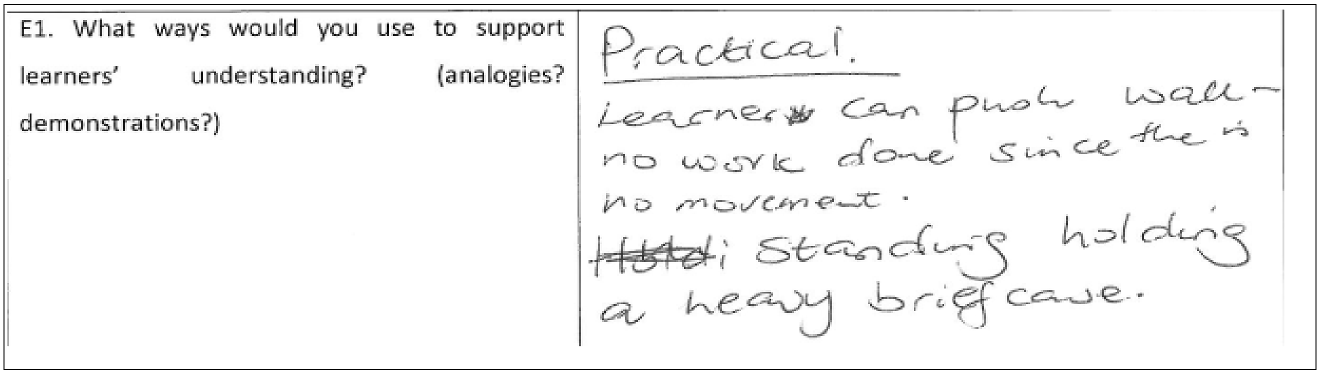
In response to CoRe prompt E1 the participants had to demonstrate knowledge about effective representations and analogies that they could use to support learner understanding and also provide an appropriate way of assessing that understanding in response to E2. However, it must be noted that responses to prompt E2 will not be analysed as this prompt is not within the framework of the study. There has to be evidence of the use of applicable demonstrations, experiments and appropriate use of visual representations such as graphical, pictorial and diagrammatic representations to enforce understanding. Many participants identified one or two representations but these lacked explanatory notes that linked the different representations to aspects being considered. In general, the post-CoRe responses had a slight change from the pre-CoRe responses as participants included appropriate demonstrations. The improvement was marginal as participants continued listing the use of demonstrations, experiments and of simulations, particularly the PHET simulations, without specifying which specific experiment or simulation. Certain participants showed no real change in responses from pre- to post-CoRe. For instance, participant SA-T08 provided the same responses for both the pre-and post-CoRes (*see Figure 25*).



- PHET simulations. - Practical demonstration: . Learners bringing toy cars from home & creating a bridge	- PHET simulations usage - perform experiments if apparatus are available. &- learners bringing toy cars & building bridges to explore the concept further.
SA-T08 pre-CoRe response to prompt E1	SA-T08 post-CoRe response to prompt E1

Figure 25: SA-T08 responses to E1

Participant SA-T08 gave a similar response to prompt E1 in both the pre- and the post-CoRes. The participant mentioned the use of PHET simulations, experiments and demonstrations using a toy car, but did not show exactly what demonstrations and experiments to perform as they are no explanatory notes to link these to the concepts under consideration. The fact that the pre- and post-CoRe responses for participant SA-T08 are similar could mean that this TSPCK component was not adequately and consciously addressed during the PTD workshop. It must be noted that the presenter was not focusing on the TSPCK components, even though the presentation and the workshop manual addressed some elements of the TSPCK components. A few other participants like SA-M05 made an effort to provide an analogy in teaching the selected key idea. In demonstrating situations when work is not done, participant SA-M05 produced an analogy of a learner pushing a wall (*see Figure 26*).



E1. What ways would you use to support learners' understanding? (analogies? demonstrations?)	Practical. Learners can push wall – no work done since there is no movement. ~~Hold~~ Standing holding a heavy briefcase.

Figure 26: SA-M05's pre-Core response to D1 and D2

This analogy can be used to address the misconception about the effect of a force and displacement on work-done. When standing holding a heavy briefcase there is no work-done since there is no displacement. This demonstration can be used to address a misconception that was identified earlier saying that any activity that gets one tired means work is done. The person holding the briefcase will eventually get tired but still no work is done as long as there is no displacement in the direction of the force. This TSPCK component was one of the components least affected by the intervention.

According to Cook (2006) the use of representations and analogies aids to understanding as it evokes in a learner the use of other senses that provides a platform for cognitive growth. Illustrations and animations are very effective in the attainment of conceptual change in a science class when properly done and well represented (Cook, 2006).

Before the PTD workshop three participants had a score of 'limited', six had a score of 'basic' and two had a score of 'developing' and none had an 'exemplary' score. After the workshop three had 'limited', five had 'basic' and three had 'developing'. Two participants' knowledge about representations and analogies improved from 'basic' to 'developing' and two also improved from 'limited' to 'basic'. This improvement in knowledge about representations and analogies, though marginal, can possibly be attributed to the workshop.

6.2.6 Comparison between pre- and post-CoRe performance using Rasch analysis

After the discussion in Chapter 4 and five an understanding was reached of the quality of SAs' TSPCK before and after the PTD workshop. The effect of the workshop on the improvement of the quality of participants' TSPCK can be seen in the person-distribution graph below. This graph can be used to indicate the improvement of participants from pre- to post-assessment after an intervention (Davidowitz & Potgieter, 2016) Pre-CoRe data and post-CoRe data were entered into the Rasch model (RUMM) and the output was a person-item distribution graph (Figure 27).

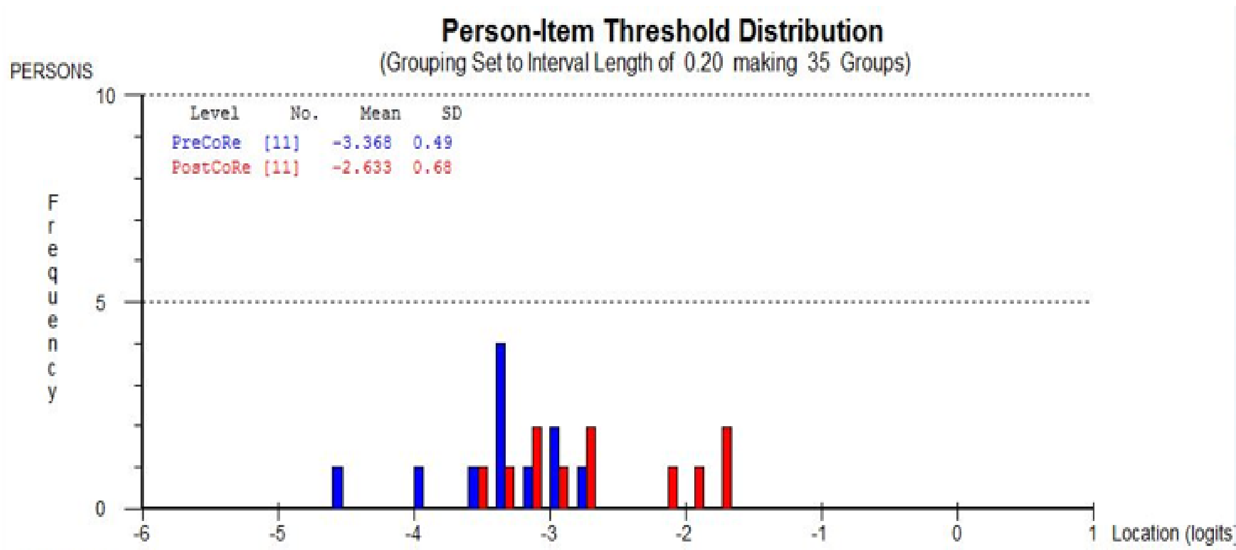


Figure 27: Person-item threshold distribution

A person at the zero-person location indicates a person with average ability measured against the particular instrument. The low person locations in this sample show that the participants scored below average in both the pre- and post-CoRe. In all the prompts for both pre- and post-CoRes no participant scored an 'exemplary' score, because the subject advisors did not reveal knowledge at that level about any of the components. The most prominent score was a 'basic'. However, an improvement is clear as the post-CoRe person locations are higher on average than the pre-CoRe locations. The mean person location improved from -3.37 to -2.63. The higher mean person locations in the post-CoRe indicate that the knowledge for many subject advisors was rated at higher scores than in the pre-CoRe. It shows that the subject advisors' knowledge about teaching the energy concept improved for some participants after the PTD workshop. The improvement was not across all the TSPCK components but in some individual components as discussed later under conclusion on 6.4.

6.3 Interview and workshop training manual data

The interview with the presenter of the PTD workshop revealed substantial information critical to the study. The information ranges from the rationale of the workshop to the general presentation focusing critically on the approach, content covered and teaching strategy used during the training. The team of presenters designed the training manual which was provided to the participants as a resource pack for the workshop. The interview schedule consisted of seventeen questions and these questions were categorised into six themes. Five of these themes are based on the five TSPCK components; therefore, an analysis would show the effects of the PTD workshop on the components from the perspective of the presenter even though the presenter was not consciously focusing on the TSPCK components.

Table 39: Various Themes

Theme 1	Rationale for the PTD workshop
Theme 2	Curricular saliency
Theme 3	Prior knowledge and misconceptions
Theme 4	What is difficult to teach?
Theme 5	Representations and analogies
Theme 6	Conceptual teaching strategies

Responding to questions on the rationale for the PTD workshop the presenter of the workshop stated that;

> *"…so the purpose of the workshop was to enhance selected physical science teachers and subject advisors' conceptual understanding of identified topics".*

This indicates that it was an in-service teacher training workshop because the teachers and subject advisors were selected from the districts where they work in the province. The purpose of the training was to improve the teachers' conceptual understanding of selected science topics. Work, energy and power was identified by the DoBE of the province as one of the topics to be covered during the training on the rationale that teachers lacked sufficient content knowledge based on the poor matric results of the previous year. This accession by the provincial leadership that teachers in the province lacked sufficient content knowledge was supported by an analysis of the participants' pre-CoRe responses which indicated low TSPCK, as the most prominent score across the five TSPCK components was 'limited'. However, this level of TSPCK improved slightly after the workshop as indicated by the analysis of the individual's pre- and post-CoRe responses. It can be argued that enhancing one's content knowledge enhances their TSPCK. However, according to the presenter of the workshop the time was not sufficient to create any significant change in the teachers and subject advisors' quality of their content knowledge.

Responding to the question; '*In your presentation, what did you consider to be the 'key ideas' or key concepts in teaching work, energy and power?*' This is a question from theme two based on 'curricular saliency' with a focus on 'key ideas' in teaching work, energy and power. The presenter responded by stating:

> "*…work, work done by a net force, work-energy relationship (work-energy theorem) and power".*

The presenter selected work, work-done by a net force and work-energy theorem as 'key ideas' and started with definitions in the presentation. The definitions formed part of the sub-ordinate ideas and when asked which 'key idea' was taught first, the presenter stated:

> "*Definitions of work, energy and force. Then…positive work, negative work and no work…seemed to be the most logical point to start from".*

The strategy used by the presenter shows an approach from simpler concepts to more complex ones and shows logical linking of concepts, evidence of sound knowledge about curricular saliency. It is this strategy that could possibly be attributed to the slight improvement of the subject advisors' knowledge about curricular saliency after the workshop.

The presenter also responded to questions that were exploring knowledge about learners' prior knowledge and misconceptions and it must be noted as stated earlier that the PTD workshop was not focusing on teachers' misconceptions but making teachers aware of learners' misconceptions. It however, came out during class discussions that many teachers had similar misconceptions. In responding to the question; '*Did you find it necessary to focus* *on typical misconceptions about work, energy and power? If yes, Why?* The presenter responded by saying;

> *"Yes, it was necessary…it was the approach of the workshop, to make teachers aware of learner misconceptions and to determine teachers' misconceptions and improve content knowledge.…help improve teaching being aware of learner difficulties".*

Participants' knowledge about learners' misconceptions as a TSPCK component indicated a significant improvement after the workshop which could possibly be attributed to the training. The approach was to make teachers aware of learners' misconceptions and provide a way of addressing such misconceptions. The presenter, like some participants, singled out a general difficulty as a misconception that learners have with regard to the work-energy theorem.

> "*…misconception around the use of work-energy theorem, not knowing when/how to apply the theorem".*

Personally, I would rather consider this as an area of difficulty and not a misconception, learners would want to equate the change in kinetic energy to work-done by any other force, not necessarily the net-force. A perfect teaching plan or strategy should identify and address learners' misconceptions and in the process create an opportunity for conceptual change (Thompson & Logue, 2006). The presenter's approach assisted participants in identifying some misconceptions and provided opportunities for conceptual change resulting in the post-assessment scores being better than the pre-assessment scores.

The presenter's response to questions from theme four was not convincing. Theme four questions were based on the TSPCK component that explored a teacher's knowledge about which aspects of the chosen 'key ideas' were difficult to teach. The presenter responded by stating;

> "*…angle θ the angle between applied force vector and the displacement vector. Don't really remember".*

The presenter did not really remember exactly which aspects were difficult to teach, there was no special focus on that aspect in the presentation and in the training manual as the training was not addressing TSPCK components explicitly. It must also be noted that this particular presenter was not quite familiar with the TSPCK components model. This also explains why there was almost no change between the participants' pre- and post-CoRe scores. This is one of the TSPCK components where the PTD workshop had the least effect.

In the training manual and also during presentation the presenter made use of a number of illustrations and diagrams to support understanding. In response to questions on whether representations and analogies were used during the training the presenter's response was:

> "*Yes I did make use of illustrations…free-body diagrams and real life examples and situations to elucidate concept".*

Even though the presenter made use of a number of illustrations many participants did not use them in both the pre- and post-CoRes. This could be that the participants did not really understand what was referred to by term 'representations and analogies', or they simply did not have any to include. Many indicated the use of PHET simulations only yet there are other representations and analogies to use (*see expert CoRe*).

The presenter's teaching approach was a conceptual one, diagnostic questions were presented preceding instruction on the key concepts. When asked which teaching strategy was used during the training the presenter stated;

"*Conceptual teaching approach …assessing and addressing misconceptions unlike the traditional teaching strategies preferred by some teachers...we are aiming at improving conceptual understanding and not spoon feeding learners".*

However, many participants merely listed a number of teaching strategies such as demonstrations and experiments without clearly explaining a step by step approach of how one intends to effectively teach a concept. The reason could be that prompt D1, a prompt on the CoRe template that was probing a participant's knowledge about teaching strategies, did not precisely state that the teaching strategy should be conceptual.

6.4 Conclusion

Analysis of the pre-CoRe scores has indicated that the participants' knowledge about all the five TSPCK components was generally low before the PTD workshop as the most prominent rating was a 'limited' score. There was a development, however, after the workshop in terms of the participants' knowledge about the five TSPCK components as the most prominent rating was 'basic'. This is a substantial improvement and it indicates the effect of the workshop. However, according to the presenter of the workshop the time allocated for the workshop was not enough to create a significant change in the participants' PCK. The presenter further argued that a similar follow up workshop was necessary, since developing content knowledge does affect PCK.

A comparative analysis of the pre- and the post-CoRe scores of all five the TSPCK components indicated that '*curricular saliency*' and '*learners*' *prior knowledge'* were the components that were affected the most by the workshop. Many participants showed improved knowledge about these components after the workshop. The rationale of the workshop was to improve conceptual understanding and bridging the content gap, and since the two components mentioned depend on sound content knowledge, an improvement in knowledge about these TSPCK components could be expected. The improvement shows that the workshop was effective; however, more would be required to bring subject advisors to a 'developing' or 'exemplary' level.

The least affected TSPCK component was '*what is difficult to teach'*? It is not surprising that this component was the least affected by the workshop. The presenter and the training manual did not focus on aspects that were difficult to teach but on key concepts that participants needed to know. It can therefore be argued that since this TSPCK component was not addressed directly or indirectly during the workshop, the participants' knowledge also more or less remained unchanged.

CHAPTER 7
CONCLUDING REMARKS

7.1 CONCLUDING REMARKS

The study set out to explore the effect of a PTD workshop on the development of subject advisors' TSPCK in the teaching of work, energy and power. Focus of the study was on the energy concept as according to CAPS work, energy and power are treated as a topic. Work is done when energy is transferred and power dissipation indicates the rate of transfer of the energy. The main research question was addressed by answering the three research sub-questions. The three research sub-questions were:

- What was the quality of the subject advisors' TSPCK before the PTD workshop on the teaching of work, energy and power?
- What was the quality of the subject advisors' TSPCK after the PTD workshop in the teaching of work, energy and power?
- In which ways were the components of TSPCK influenced by the workshop?

Based on the analysis of the pre-CoRe responses and the ratings given to each participant it showed that the quality of subject advisors' TSPCK was low. The reason why the quality was so low could possibly be attributed to a number of factors. Firstly, it is reasonable to argue that some participants had challenges in responding to the CoRe-tool since articulation of one's TSPCK is not easy owing to the complexity of teacher professional knowledge (Mavhunga & Rollnick, 2013). Secondly, the time allocated for the participants to complete their CoRes might have been short. Some of the CoRe prompts required a high level of cognitive preparedness and reasoning. Many participants struggled in explaining why it was necessary for learners to know the 'key ideas' and also had challenges in identifying pre-concepts as well as identifying learners' misconceptions. Thirdly and most critical is that the participants lacked knowledge about the TSPCK components probably because during their teacher training this aspect of conceptualisation of TSPCK and PCK frameworks was not taught. It must also be noted that the PCK frameworks are new and courses probably still have to catch up. Universities and colleges predominantly put emphasis on theories of

education and not precisely on PCK (Mavhunga, 2014). This assertion is consistent with my experience as a pre-service science teacher.
The quality of the subject advisors' TSPCK improved slightly after the workshop. This improvement in quality can be attributed to the PTD workshop, since the participants wrote the post-CoRes directly after the workshop and had no opportunity to enhance their knowledge from any other source. The TSPCK components that were directly or indirectly addressed during the workshop indicated significant improvements particularly from 'limited' to 'basic'. A few moved from 'limited' to even 'developing' after the workshop.

The TSPCK components were not affected the same by the workshop. Analysis of the results has shown that '*curricular saliency*' and '*learners' prior knowled*ge' were affected the most and resulted in the knowledge of many participants improving. The reason, as stated earlier, was probably that the requirements of the prompts for these TSPCK components were in line with the rationale of the workshop. These prompts focused on a teacher's content knowledge and the workshop was initiated to improve conceptual understanding. The participants' knowledge about '*what is difficult to teach'* was the least affected and, as pointed out earlier, the presenter did not focus on those aspects that are difficult to teach since the workshop was not addressing TSPCK components per se.

7.2 RECOMMENDATIONS

There are critical recommendations that can come out of this study. It is the mandate of any education system to develop critical thinkers and individuals who can solve problems. The DoBE is mandated by the South African government to produce high school graduates who are able to take up university programmes in sciences in a bid to solve the problem of a massive shortage of practitioners in STEM. Attainment of this objective is based on the quality of in-service science teachers and the training of pre-service teachers.

7.2.1 Recommendations for possible action

Development of in-service science teachers is generally through workshops co-ordinated by subject advisors. It therefore follows that the quality of subject advisors is key to the effective development of teachers.

- The first recommendation is therefore on the initial appointment of physical science subject advisors. A subject advisor should be an expert in content knowledge and possess high quality TSPCK since one of their key responsibilities is to develop in-service teachers.

- Secondly, there should be on-going training workshops to develop the quality of subject advisors' TSPCK, and these workshops should be awarded sufficient time to cover key concepts for the training to yield meaningful results. These workshops should not only focus on content but specifically focus on the TSPCK components and also the conceptualisation of PCK.
- The third recommendation which also concurs with a recommendation by Mavhunga (2014) is that Universities should incorporate the teaching aimed at improving pre-service teachers' TSPCK in their education and methodology modules. This recommendation is based on the assumption that conceptualisation of TSPCK is currently not being done at some institutions. Pre-service science teachers should be introduced to the five TSPCK components earlier in their training.
- The fourth recommendation for action is that Universities, in collaboration with senior and experienced science teachers who possess well developed PCK, should develop teaching packages per topic based on the five TSPCK components and should also develop a type of lesson plan that includes prompts similar to the CoRe prompts used in this study.
- Lastly, teaching practice sessions should be organised in such a way that pre-service teachers are assigned to experienced teachers who generally have better developed TSPCK

7.2.2 Recommendations for further study

- The first recommendation for further study is that researchers should embark on studies to explore the extent to which Universities train pre-service science teachers towards developing TSPCK in their specialist subjects.
- Secondly, as revealed by this study, no subject advisor demonstrated exemplary TSPCK, it is therefore recommended that further studies be conducted to find out what must be done to develop TSPCK to exemplary level.
- Thirdly, there is a need to continuously conduct research in science education aimed at improving teacher effectiveness and inevitably learner performance.

- Lastly, there is a need for further research into the effects of PTD workshops as in-service teacher training programmes. This study merely scratched the surface in terms of valuable information available out there.

7.3 LIMITATIONS OF THE STUDY

There are limitations to this study, even though the findings are credible and consistent with other studies such as the TIMSS report of 2011 and Mavhunga (2014) on the assertion that some South African science teachers lack requisite content knowledge enough to effectively teach their learners. The use of a few participants means that the findings cannot be generalised to a broader population but remain credible in the province where the study was conducted. Small samples are easy to work with and detailed qualitative data can easily be obtained, however findings from such small samples cannot be generalised to larger population sizes (Creswell, 2009). Another limitation to the study is the actual use of the CoRes tool. The prevalence of empty boxes and out of context responses could possibly be because the CoRe-tool was a new experience for the participants. Although the CoRe was explained to the participants before completing it was such a new experience that the discussion did not always made sense to the participants hence the empty boxes. Participants possibly did not understand some of the prompts and as such gave wrong responses not because they did not know but failed to understand what was required of them. As a result, a lot of data was left out which could have aided to better findings. The third limitation to the study is researcher bias. Being a science teacher and having my own unique teaching philosophy and unique TSPCK, my scoring of the CoRes, analysis and interpretation of the data thereof could have been biased towards my epistemological and ontological stance. However, the effect of such an inevitable bias was minimised by the use of credible measuring instruments such as the expert CoRe and the rubric together with multiple raters. My supervisor and co-supervisor were also involved in the design of the rubric and the scoring process.

7.4 VALUE OF THE STUDY

There is some significance of this study to the science education community that can be derived from the findings. Firstly, as was the case with Mavhunga and Rollnick's 2013 study, this study has validated the credibility of the CoRe as a tool capable of capturing a teacher's TSPCK. Other researchers and academics can possibly use a similar tool to capture teachers' TSPCK in their various specialist disciplines. Secondly, the rubric which was developed and used in the study to measure the subject advisors' TSPCK can also be further used in measuring science teachers' TSPCK for other topics. Thirdly the difference in responses between the pre- and the post-CoRes indicated the effect of the intervention, which is the PTD workshop, on the development of science teachers' TSPCK in teaching about work, energy and power. Similar workshops can be conducted to develop science teachers' TSPCK in other topics and using appropriate instruments such as the CoRe-tool and an appropriate rubric essential data can be collected to ascertain an individual's level of TSPCK. Once a teacher's level of TSPCK is known, mapping a developmental protocol for the individual becomes simple. Last but not least, the findings have revealed that even after the PTD workshop a larger number of physical science subject advisors from the province where the research took place still have not reached the level of 'exemplary'. This indicates the need to further develop the subject advisors' TSPCK in teaching about work, energy and power in view of the five TSPCK components if their mandate as facilitators of teacher development programmes is to be realised and ultimately lead to the improvement of the Grade 12 physical science results of the province.

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APPENDICES

Appendix 1- CoRe template

Pre-Test: Knowledge about teaching work, energy and power

Surname: ____________________________

Name: _______________________________

Signature: ____________________________

ID number: ____________________________

District: _______________________________

Question 1

In the grade 12 curriculum the following are sub-topics that are indicated for the main topic **Work, Energy and Power:**

(i) Work-energy theorem

(ii) Conservation of energy with non-conservative forces and

(iii) Power

Choose any one of these sub-topics and write down 4 to 6 key ideas that you will teach to help learners understand the topic. The key ideas are "smaller" ideas that learners need to understand before they can understand the bigger topic.

You should select only one of the sub-topics of work, energy and power and write the key ideas in the sequence that you would teach it.

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____

Question 2

Choose two of the **key ideas** that you mentioned in question 1 for **Work, Energy and Power**, and complete the following table for these two ideas

Key idea:	**Key idea 1**	**Key idea 2**
A1. What do you intend the learners to know about this idea?		
A2. Why is it important for learners to know this?		
A3. What concepts need to be taught before teaching this idea?		
A4. What else do you know about this idea (that you do not intend learners to know yet)?		
B1. What do you consider easy or difficult about teaching this idea		
C1. What are typical learners' misconceptions about this idea?		
D1. What effective teaching strategy would you use to teach this key idea?		
D2. What questions would you consider		

important to ask in your strategy?		
E1. What ways would you use to support learners' understanding? (Analogies and demonstrations)		
E2. What ways would you use to assess learners' understanding?		

Post-Test: Knowledge about teaching work, energy and power

Surname: ___________________________

Name: ______________________________

Signature: ___________________________

ID number: ___________________________

District: ______________________________

Question 1

Please note: This post-test is a repetition of the pre-test. The purpose is to assess whether your understanding of teaching of the topic has broadened as a result of the training.

In the grade 12 curriculum the following are sub-topics that are indicated for the main topic **Work, Energy and Power:**

(i) Work-energy theorem

(ii) Conservation of energy with non-conservative forces and

(iii) Power

For the same topic you selected for the pre-test write down 4 to 6 key ideas that you will teach to help learners understand the topic. The key ideas are “smaller” ideas that learners need to understand before they can understand the bigger topic.

____

____

____

____

Question 2

Choose two of the **key ideas** that you mentioned in question 1 for **Work, Energy and Power**, and complete the following table for these two ideas

Key idea:	**Key idea 1**	**Key idea 2**
A1. What do you intend the learners to know about this idea?		
A2. Why is it important for learners to know this?		
A3. What concepts need to be taught before teaching this idea?		
A4. What else do you know about this idea (that you do not intend learners to know yet)?		
B1. What do you consider easy or difficult		

about teaching this idea		
C1. What are typical learners' misconceptions about this idea?		
D1. What effective teaching strategy would you use to teach this key idea?		
D2. What questions would you consider important to ask in your strategy?		
E1. What ways would you use to support learners' understanding? (Analogies and demonstrations)		
E2. What ways would you use to assess learners' understanding?		

Appendix 2- Rubric for scoring the CoRes instrument (Energy concept)

TSPCK component 1: Curriculum saliency				
(Evidence to score this component is found in participants' responses to prompts A0 to A4 in the CoRe-tool)				
	Limited	**Basic**	**Developing**	**Exemplary**
A0	-No key ideas or only one key idea selected	-Selected at least two relevant key ideas for work, energy and power.	-Identified at least three relevant key ideas for work, energy and power.	-Identified more than three key ideas appropriate for work, energy and power.
A1	- No subordinate ideas provided for the identified key ideas. - Subordinate ideas identified but mostly incorrect and not linked to work, energy and power.	-Identified at least one correct subordinate idea and included equations and standardised definitions of terms under work, energy and power.	-Identified at least two correct subordinate ideas for teaching the selected key ideas on work, energy and power including equations and definition of terms but did not provide additional explanations to link concepts. -The identified subordinate ideas revolve around manipulation of equations and reproducing definitions.	- Identified at least three or more correct subordinate ideas and explain links to key ideas focusing on understanding the concepts underlying the equations and definitions in work, energy and power.
A2	-Reasons provided have no link with the key idea and or subordinate ideas.	-Reasons why learners should know the concept have some link with key ideas but exclude conceptual considerations such as sequantial development of understanding for other topics linked to work, energy and power.	-Reasons provided for the importance of learners knowing the key ideas include reference to conceptual scaffolding / sequencial development of understanding of other topics in physical sciences without giving specific examples and pointing links with work, energy	-Reasons provided include conceptual scaffolding / sequential development of understanding of specified subsequent topics in physical sciences. Provided examples and pointed links with the energy concept.

			and power.	
A3	-Identified wrong pre-concepts, including those to be taught in work, energy and power and concepts from other topics not linked to work, energy and power. -No evidence of correct sequencing of concepts.	-Identified at least one correct pre-concept to the teaching of the selected key idea. -Sequencing can be followed, however has illogical placing of pre-concepts for the key ideas.	-Identified at least two correct pre-concepts linked with teaching the key idea.	-Identified at least three correct pre-concepts including those needed in discussing the introductory definitions and those sequentially needed in the next key ideas in teaching work, energy and power.
A4	Provided nothing about the idea or concept that learners should not know yet.	Provided one concept linked to the teaching of work, energy and power that learners do not have to know yet.	Provided at least two concepts linked to the selected key idea in the teaching of work, energy and power, but provided no reason why learners should not know the concept yet.	Provided more than three aspects/concepts linked to the selected key idea and also linked to the next topic to be taught Provided explanations to why learners do not have to know the concept yet.
TSPCK component 2: What is difficult to teach?				
(Evidence to score this component is found in participants' responses to prompt B1 in the CoRe- tool)				
	Limited	**Basic**	**Developing**	**Exemplary**
B1	- Identifies broad topics without specifying the actual sub-concepts that are problematic. - Reasons not given. - No knowledge about this component is evident	- Identifies specific concept/s as being problematic but provides no reasons why the concept is difficult to teach.	-Identifies specific concept/s or sub-ordinate ideas as being problematic to teach and provides reasons related to specified prior knowledge of learners or common misconceptions.	- Identifies specific concepts with reasons related to prior knowledge or common misconceptions. - Provides reasons linking to specific gate keeping concepts that when not fully understood add to the difficulty of a concept regarded as difficult.

TSPCK component 3: Learners' misconceptions				
(Evidence to score this component is found in participants' responses to prompt C1 in the CoRe-tool)				
	Limited	**Basic**	**Developing**	**Exemplary**
C1	Provides misconceptions / prior knowledge not linked to work, energy and power.	-Identifies at least one correct misconception or prior knowledge linked to work, energy and power. - Provides standardized knowledge as definition. - Repeats standard definition with no expansion or with incorrect explanation.	- Identifies at least two correct misconceptions or prior knowledge linked to work, energy and power. - Provides standardized knowledge as definition. - Expand and rephrase explanation correctly.	- Identifies more than two correct misconceptions or prior knowledge. - Provides standardized knowledge as definition. - Expand and rephrase explanation correctly. - confronts misconceptions / confirm accurate understanding.
TSPCK component 4: Conceptual teaching strategies				
(Evidence to score this component is found in participants' responses to prompts D1 and D2 in the CoRe-tool)				
	Limited	**Basic**	**Developing**	**Exemplary**
D1	-Provides only one teaching strategies -No evidence of acknowledgement of learners' prior knowledge and misconceptions evident in the strategy. - Lacks aspects of curriculum saliency.	-Provides at least two teaching strategies that: -Acknowledges learner prior knowledge and misconceptions but,- Lack aspects of curriculum saliency.	- Identifies at least three teaching strategies which are workable and, - Considers learner prior knowledge and / or misconceptions. - Considers at least one aspect related to curriculum saliency: sequencing or what not to discuss yet or emphasis of important concepts. -Evidence of intergration of concepts	- Identifies more than three teaching strategies which are excellent in teaching the required concept. - Considers at least two aspects related to curriculum saliency. - Evidence of intergration of prior concepts with work, energy and power. - Provides conceptual questions that solicit for learner prior knowledge and / or misconceptions.
	-No questions provided to	-Provides generic	-Provides specific	-Provides conceptual

D2	solicit learners' prior knowledge and to ascertain understanding.	questions pertaining to the current concepts without links with previous concepts. -No evidence of intergration of concepts. -No specific questions or activities to ascertain understanding. - Limited involvement of learners.	conceptual questions that link prior concepts with work, energy and power. -Provides questions and activities that test understanding. - But does not provide learners possible responses.	questions that link previous concepts to work, energy and power. -Provides questions and activities that test for undertsanding and provides learners' possible responses. - Highly learner centered lesson.
TSPCK component 5: Representations and analogies				
(Evidence to score this component is found in participants' responses to prompts E1 and E2 in the CoRe-tool)				
	Limited	**Basic**	**Developing**	**Exemplary**
E1	-Use of only material artifacts in demonstrations and experiments no visual and symbolic representations.	-Demonstrations and experiments relevant to work, energy and power. -Use of visual and symbolic representations, such as charts and posters but no explantory notes to link concepts.	-Demonstrations and experiments relevant to work, energy and power. -Use of visual and symbolic representations such as flow charts, diagrams and pictures with explantory notes to link aspects under consideration.	- Use of demonstrations and experiments relevant to work, energy and power. - Extensive use of visual representations (graphical / pictorial / diagrammatic) representations to enforce specific aspect(s) of concepts being considered. - Presence of explanatory notes linking the different kinds of representations to aspect(s) of concepts being explained. -Use of relevant animations such as PHET simulations.
	-Provides no way of assessing learner understanding	-Provides one way to assess learner	-Provides at least two ways of assessing learner	-Provides more than two ways to assess learner

E2		understanding, eg short class test.	understanding Eg short class test, quiz sessions.	understanding. Eg class test, quiz sessions and question and answer sessions.

Appendix 3- Expert CoRe

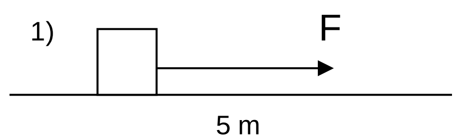
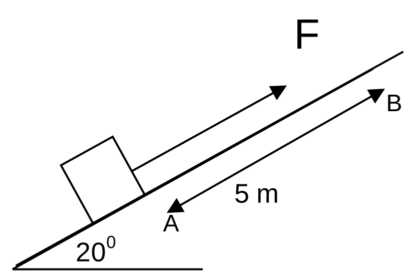
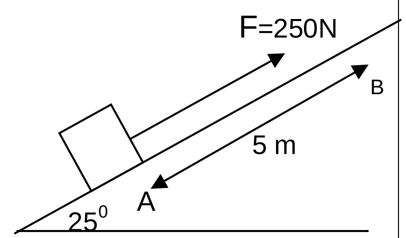
The CoRe includes the prompts and the TSPCK components that correspond with the key ideas.

Main ideas: Work-energy theorem, energy conservation and power.

Main topic: Work, energy and power (Grade 12)				
Sub-topic: Work, work-energy theorem and power.				
TSPCK components	**CoRe prompts**	**Key idea 1:**	**Key idea 2**	**Key idea 3**
	Key ideas	Work	Work-energy theorem	Power
• Curricular saliency.	A1. What do you intend the learners to learn about this idea?	• Work is done when a force is applied to an object and a component of that force causes the object to be displaced in the direction of the component. • Work is measured in Nm or J. • W = F.d cos ϑ. Where ϑ is the angle between the applied force vector and the displacement vector. • F-force vector (all types of forces can do work as long as cos ϑ is not equal to zero. d-displacement vector, work is done if d is not equal to 0 m. **Positive and negative work**. A force does negative work if the angle between the force and the displacement vector is 180^0 • Learners need to understand conditions under which work is done. They need to understand that **contact or non-contact forces** are all capable of causing objects to undergo some form of displacement if sufficient enough, hence they	• Work done by a net force is equal to the change in kinetic energy of the object. • $W_{net} = .\Delta E_k$ • Work done by a non-conservative force (Wnc) is equal to the sum of the change in kinetic energy and change in potential energy. • $W_{nc} = \Delta E_k + \Delta E_p = \Delta E_m$ • Learners need to understand that a net force causes an object to accelerate (Newton's 2nd law), and acceleration is the rate of change of velocity. When velocity of an object changes its kinetic energy changes	• Rate at which work is done or the rate at which energy is transferred. • Power is measured in Nm/s or J/s and the SI unit is a Watt (W) • $P = W/\Delta t$ (Nm/s) • $P = E/\Delta t$ (J/s) • $\mathbf{P_{AV} = FV_{AV}}$ where F is a constant force and V is the average velocity.

		do work.		
• Curricular saliency.	A2. Why is it important for learners to know this?	• Preparation for future learning about work-energy relations. • Scaffolding of ideas towards key concepts, understanding of work concept builds up to the concept of work-kinetic energy theorem and power.	• Preparation for future learning about power. • Understanding of work done in electric circuits.	This helps learners to understand and appreciate that time is the indicator of power and the amount of work done or energy transferred is the factor of power. Also helps learners with calculations that involve power. Future learning of electrical energy consumption billing and rates.
• Curricular saliency	A3. What concepts need to be taught before teaching this idea?	• Force and displacement vectors • Contact and non-contact forces • Resolution of force vectors • Trigonometric identities • Frictional force • Free-body diagrams • Force diagrams	• Vector addition **(Fnet)** • Energy transformations • Types of energy • Calculations of work by individual forces	• Types of energy • Energy transfer and transformation • Learners should understand that work is a way to transfer energy
• Curricular saliency.	A4. What else do you know about this idea (that you do not Intend learners to know yet)?	Work-kinetic energy relationship.	Mathematical expressions and calculations that involve changes in internal energy of a system ΔE $\Delta E = Q + W$ Q is the thermal energy W is the work done on the system.	Power dissipation in electrochemical reactions and electric circuits.
• What is difficult to teach?	B1. What are the difficulties/limitations connected with teaching this idea?	Calculations of work done by forces on the inclined plane in particular the cosine of the angle between the force and displacement vectors. Learners have challenges in distinguishing a force from its components and vice versa and also distinguishing which component is doing work. Determination of the net force	Mathematical manipulation of the work-energy formula and formula for calculating work done by a non-conservative force in dealing with vertically displaced objects. Calculation of net force $W_{net} = \Delta E_k$ $W_{nc} = \Delta E_k + \Delta E_p$ $W_{net} = W_{nc} - \Delta E_p$	Learners' prior conceptions about power, learners associate sheer size and strength to power not realising that time is the indicator of power. Learners find it difficult to understand that power is the rate of transfer of ANY type

				of energy Understanding the relationship between energy and power when dealing with E=VIΔt where E is the electrical energy VI is equal to power giving the units of E as KWh as used in electricity billing.
• Learners prior knowledge and misconceptions	C1. What are typical learners' misconceptions about this idea?	• Learners believe that once a force is applied on an object work is done even if the object remains stationary. • Some learners think that applied force does positive work all the time. • Learners think that when objects move there is always an applied force • Learners have problems with calculations that involve the gravitational force on the inclined plane. $Fg_{//}$ is the parallel component that does work on the object placed on an inclined plane. • Learners need to know and understand why the angle of inclination is not the angle between the force vector and the displacement vector. • Learners think when a person performs an activity and gets tired work is done	Learners tend to think that every force applied is capable of changing the kinetic energy of an object not realising that its only **Fnet** Learners tend to have challenges in identifying path dependent variables which makes it difficult to teach learners how to solve problems that involve non-conservative forces using: $W_{nc} = \Delta E_k + \Delta E_p$ Some learners think that energy is completely 'lost' during transformation	Learners tend to think that when the same amount of work is done it follows that the same amount of power was dissipated. Learners' understanding of the factor and indicator of power, P_1=200/4 = 50 W P_2= 200/2 = 100 W In both cases the same amount of work was done but different power dissipation due to time difference.
• Conceptual teaching	D1.What effective teaching strategies	• Integrated learning • Problem solving. • Conceptual teaching	• Problem solving • Conceptual teaching	• Integrated learning • Problem solving. • Conceptual teaching

strategies.	would you use to teach this key idea?	For example, asking learners to determine if work is done on a brief case if it is carried by a person through a displacement. Calculations that involve different types of forces exerted at various angles causing objects to undergo some displacement hence doing work.	Calculations that involve conceptual questions on W_{net} and W_{nc}.	
• Conceptual teaching strategies	D2. What questions would you consider important to ask in your teaching strategy?	Conceptual questions that involve the inclined plane. **For example:** Calculate the **total** work done on a 10kg block if the block moves a displacement 5 m, F =120 N, coefficient of kinetic friction (μ_K) = 0,25 1)  2)  Learners will not necessarily have problems with Q 1 but are likely to have challenges with Q 2 since it involves the gravitational component and also involves trig identities in calculating frictional force.	Conceptual questions. For example Using the work-kinetic energy theorem calculate the velocity of a 10 kg block at point B up the incline if it started from rest at point A. $\mu K = 0.4$  Once learners are able to perform calculations and get the correct answer to this question then it is acceptable to think they now have some level of understanding of the concept.	Conceptual questions that involve work done and power associated with the work. Making use of a number of formulas for power and their derivatives If learners are able to perform calculations of power using a variety of available formulas it can be assumed that they now possess the correct scientific understanding of power. Asking questions such as:- Is power dissipated by a walking man the same as when the man is running?

• Representations and analogies	E1. What ways would you use to support learners' understanding?	• Use of animations e.g. PHET simulations. • Demonstrations and experiments • Flow charts	• Use of animations • Experiments • Flow charts	• Use of animations • Experiments • Flow charts showing energy pathways during transformations
	E2. What ways would you use to assess understanding?	Short class tests Quiz sessions Question and answer sessions	Short class tests Quiz sessions Question and answer sessions	Short class tests Quiz sessions Question and answer sessions

Appendix 4: Interview schedule

I understand you conducted a developmental workshop in North West province that involved physical science subject advisors in the teaching of some physics topics in the South African curriculum including work, energy and power. I am currently involved in a study that seeks to determine the effect of that workshop on the development of the physical science subject advisors' PCK in the teaching of work, energy and power.

1. What was the main purpose of the workshop?
2. Would you classify the workshop in the category of in-service teacher training?
3. What informed the decision to include work, energy and power as one of the topics to be covered at the workshop?
4. What was the duration of the entire workshop? How much time was spent on work, energy and power?
5. What was your teaching approach to the workshop in terms of presentation was it interactive? If so, in which way?
6. Did you find it necessary to focus on typical misconceptions about work, energy and power? Why?
7. As you were presenting and interacting with the participants, did you pick particular misconceptions in teaching work, energy and power? If you did may you please give one example?
8. In your presentation on the teaching of this topic, which conceptual teaching strategy or strategies did you use? And did you give the participants a chance to suggest other teaching strategies? If yes please give examples.
9. In your presentation, what did you consider to be the 'key ideas' or key concepts in teaching work, energy and power?
10. Were the participants able to identify 'key ideas' to your satisfaction?
11. Which 'key ideas' or key concepts did you teach first and why?

12. Do you consider it important to structure concepts in a particular order in terms of which one is taught first? If you do, please explain

13. What did you consider to be difficult to teach on this topic? And did the participants also consider the same aspect as being difficult to teach.

14. What strategy did you use and also suggest to participants to use in teaching the difficult concepts?

15. Did you make use of analogies, representations and animations in your presentation? If your answer is yes can you, please explain the impact of using them?

16. Topic specific pedagogical content knowledge (TSPCK) of a teacher includes the following components: Students' prior knowledge**,** Curricular saliency**,** What is difficult to teach**,** Representations including analogies**,** Conceptual teaching strategies. In your own view how were these components of TSPCK addressed by the workshop?

17. Do you think the time spent on the workshop was enough to achieve the purpose mentioned above?

Appendix 5- Letter to Dean

Science, Mathematics and Technology Education

18 February 2016

Prof Irma Eloff
Dean Faculty of Education
University of Pretoria

Dear Prof Eloff

Request to involve a Faculty member in a MED research

I am currently involved in a MED study under the supervision of Mrs. Corene Coetzee and co-supervised by Dr Estelle Gaigher.

In my study titled; **The effect of a professional development programme on the subject advisors' PCK of the energy concept**. I am investigating the effect of a Professional Teacher Development (PTD) workshop on the development of Physical science subject advisors' TSPCK on work, energy and power. TSPCK is a construct which falls under the broad PCK of a teacher focusing on a specific curriculum topic and consists of critical knowledge components from which transformation of teacher knowledge emerges.

A strong and well developed TSPCK distinguishes novice from experienced teachers and also distinguishes good from bad teachers in terms of their content knowledge, pedagogical knowledge, knowledge about learners and knowledge about context. Subject advisors in their respective districts are mandated by the Department of Basic Education to conduct developmental workshops as an intervention to improving teachers' content knowledge and general pedagogy aimed at improving learner results. The subject advisors' role of teacher development justifies their selection in the study as it is envisaged that a subject advisor with a well-developed TSPCK can then share that knowledge with science teachers in their districts thereby raising the level of the teachers' TSPCK.

In my study I want to investigate how a professional teacher development (PTD) workshop on work, energy and power develop the quality of Physical science subject advisors' TSPCK?
To accomplish this goal, I will employ data collection strategies that include document analysis and content analysis and will also conduct an interview with the Faculty member who presented the workshop. The main purpose of the interview would be to determine the extent at which the components of TSPCK were addressed during the workshop and also to be closer to the participants through the eyes of the Faculty member.

I request your permission to allow me to involve the Faculty member as a participant in my study, The Faculty member will be asked to sign a letter of informed consent and the identity of the member will be kept anonymous.

Your favourable consideration of my request will be highly appreciated.
Sincerely

…………………………………………… ……………………………………….

Weston Munyurwa (Student) Corene Coetzee (Supervisor)

Appendix 6- Letter from Dean

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Office of the Dean: Faculty of Education

3 March 2016

Mr Weston Munyurwa
MEd student
Department of Science, Mathematics and Technology Education

Dear Mr Munyurwa

REQUEST TO INVOLVE A FACULTY MEMBER AS A PARTICIPANT IN A RESEARCH PROJECT

Your request, dated 18 February 2016, to involve Dr Trisha Salagaram as a participant in your MEd project: ***The development of subject advisors' topic specific PCK on work, energy and power***, refers.

Permission to involve the faculty member as a participant is granted.

Kind regards

Prof I Eloff
Dean: Faculty of Education

Appendix 7- Consent letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Faculty member XXX
XXX University
Department of SMTE
Pretoria
South Africa

Dear Sir/Madam

I am a Master of Education student at the University of Pretoria and I am currently involved in a research study titled ***The development of subject advisors' Topic Specific Pedagogical Content Knowledge (TSPCK) on work, energy and power***. I am requesting you to take part in the study as a primary participant.

The study is focusing on the effect of a professional teacher development (PTD) workshop on the development of subject advisors' TSPCK and will involve a semi-structured interview as data collection strategy among others. I am therefore kindly requesting for your willing participation in this research.

Should you accept this request, anonymity and confidentiality will be guaranteed at all times. Your name will not be disclosed to anyone. The information collected during the research will be used for research purposes only. All data collected may be made available in an open repository for public and scientific use, but the identity of every person and institution involved will be kept anonymous.

Thank you in anticipation for assisting me in this research. It is my hope that the findings obtained from this study will be of benefit in determining the impact and effectiveness of such PTD workshops in developing the content levels of in-service science teachers. Kindly complete the Declaration of Consent memo attached below.

Yours sincerely

W. Munyurwa
MED student
University of Pretoria
South Africa

Appendix 8- Permission letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Dear Sir/ Madam

Request for permission to use results of the pre- and post-tests of the North West Physical Science for FET Educators Workshop, as data for research purposes.

The staff in the Science, Mathematics and Technology Education department in the Faculty of Education at the University of Pretoria has as its core function the training and development of pre-service teachers and doing related research on Teacher Education. The development of in-service educators is also of interest to us as we are often involved in workshops such as the North West Physical Science for FET Educators workshop. It is of importance to us to evaluate and assess the impact of such workshops on different aspects of teacher knowledge and competences.

The data obtained during the said workshop can lead to two valuable studies:

- The impact of continued professional teacher development programs on the pedagogical content knowledge (PCK) of subject advisors.
- The impact of continued professional teacher development programs on the content knowledge and conceptual understanding of science teachers.

During the initial meeting between the delegates of the University of Pretoria and North West Department of Education we were told that we would be allowed to use the results of the pre-and post-test both of the teachers and the subject advisors as data for these studies. With this letter we request your permission in writing, for the purposes of ethical clearance at our own institution. We assure you that the names of any educator, school, district or subject advisor will not be mentioned in any report of the studies and when the studies are completed the reports will be made available to you if you so wish. All data collected may be made available in an open repository for public and scientific use, but the identity of all persons and institutions will be kept anonymous.

Your signature at the bottom of this letter will indicate your permission for us to use the data gathered in this project as described above.

Thank you

Dr S van Putten

Acting HoDSMTE Department

………

Name: Dr. I.S Molale **Date:** 02/10/2015

Capacity: Head of Department

Signature:

Appendix 9- Ethics approval letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Fakulteit Opvoedkunde
Lefapha la Thuto

Ethics Committee
15 September 2016

Dear Mr Munyurwa

REFERENCE: SM 16/08/02

Your application was carefully considered by the Faculty of Education Ethics Committee and the final decision of the Ethics Committee is:

Your application is approved.

This letter serves as notification that you may continue with your fieldwork. Should any changes to the study occur after approval was given, it is your responsibility to notify the Ethics Committee immediately.

Please note that you will have to fulfil the conditions specified in this letter from the Faculty of Education Research Ethics Committee. The conditions include:

1) The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment (Section E) for approval by the Committee.
   - Any amendments to this approved protocol need to be submitted to the Ethics Committee for review prior to data collection. Non-compliance implies that the Committee's approval is null and void.
   - Final data collection protocols and supporting evidence (e.g.: questionnaires, interview schedules, observation schedules) have to be submitted to the Ethics Committee before they are used for data collection.

2) The researcher should please note that this decision covers the entire research process, until completion of the study report, and not only the days that data will be collected.
3) Should your research be conducted in schools, please note that you have to submit proof of how you adhered to the Department of Basic Education (DBE) policy for research.

4) The Ethics Committee of the Faculty of Education does not accept any liability for research misconduct, of whatsoever nature, committed by the researcher(s) in the implementation of the approved protocol.

Please note that this is not a clearance certificate.
Upon completion of your research, you need to submit the following documentation to the Ethics Committee:

- **Integrated Declaration Form (Form D08),**
- **Initial Ethics Approval letter and,**
- **Approval of Title.**

On receipt of the above-mentioned documents you will be issued a clearance certificate. Please quote the reference number **SM 16/08/02** in any communication with the Ethics Committee.

Best wishes

Appendix 10- Workshop training manual

Work, energy and power

Introductory questions

Question 1

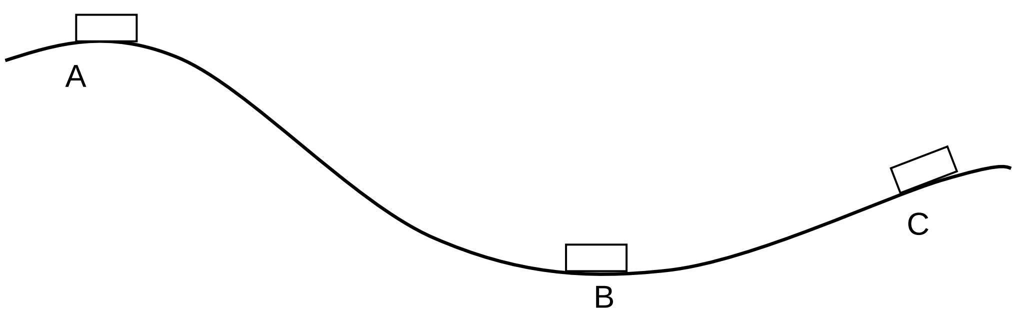
A heavy box is pushed across the floor by a horizontal applied force. The other forces acting of the box are the force of gravity, the normal force and a frictional force which is less than the applied force.
1.1 Which of these forces does no work?
1.2 Which of these forces does positive work?
1.3 Which of these forces does negative work?

Question 2

As the speed of a free falling object increases, what happens to the power supplied by the gravitational force?

Question 3

The diagram below shows the position of a cart on a roller coaster track. What form of energy does it have at A, B and C?



Important concepts

1. Work and energy are used to analyse the motion of objects.
2. Energy is the property of a system which enables it to do work, that is, exert a force over a distance.
3. Work is done when a force is applied to an object and a component of the applied force causes the object to be displaced.
4. The equation for calculating force is
   $W = F\ d\ \cos\Theta$,

where Θ is the angle between the applied force vector and the displacement vector. To calculate work done you need to know the force applied, the displacement caused and the angle between the applied force and the displacement.

5. If an applied force is at right angles to the displacement of an object, no work is done. If a force is applied to an object and the displacement is 0 m, no work is done. If the applied force hinders displacement, for example when a rolling object slows down, then the negative work is down on the object.
6. Conservation of energy means that energy cannot be created or destroyed. In the absence of external work input or output, the energy of a system remains unchanged.
7. There are many forms of energy: potential, kinetic, thermal, nuclear, light, etc.
8. Potential energy is the energy stored by an object when it is moved from its equilibrium position, for example, a stretched elastic band, a charge at some point in an electric field, a book on a table.
9. Gravitational potential energy is the energy stored in an object when it is placed at some vertical distance above the earth's surface. It is due to the attraction of the object by the earth.
10. Gravitational potential energy is proportional to the mass of the object and its height above the earth's surface: $E_p = mgh$
11. Kinetic energy is the energy which a moving object has, e.g., vibration, rotation and translation.
12. Kinetic energy is proportional to the mass of an object and to the velocity squared: $E_k = 0.5\ mv^2$.
13. Mechanical energy is the energy acquired by an object when work is done on the object. It can be either kinetic energy or potential energy.
14. Total mechanical energy is the sum of the kinetic and potential energy. An object that possesses mechanical energy has the ability to do work on another object.
15. Power is the rate at which work is done. It is measured in Watts.

Questions for conceptual understanding and critical thinking

Question 4

A mass M is moving horizontally at a constant speed. A vertical force is applied to M and causes no vertical displacement. Is work done on M?

Question 5

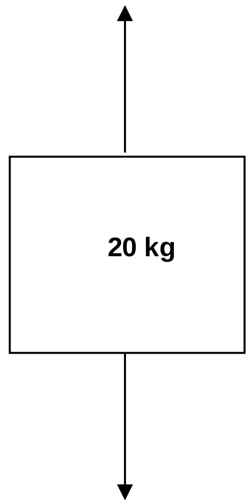
A boy and a girl climb up a flight of stairs. The boy is twice as heavy as the girl. The girl climbs the stairs in half the time that the boy climbs the stairs. Does the boy or the girl do the most work? Who has the most power?

Example problems

Problem 1

A vertical force applied to a 20 kg mass causes the mass to move a distance of 5 m at constant velocity in the same direction as the applied force. Calculate the work done on the mass.

Answer



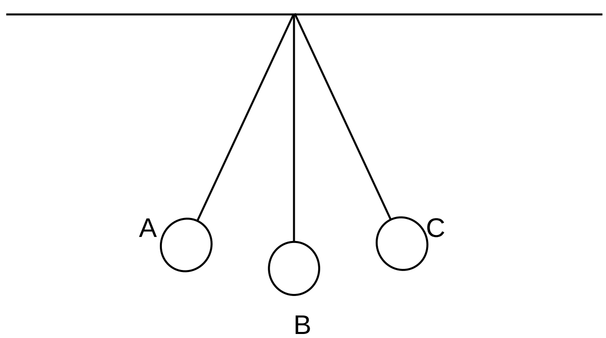
Constant velocity: $|\underline{F}_{applied}| = |\underline{F}_{grav}|$

$\mathbf{\Theta = 0^o}$

Work done = $F_{applied}$ d cosΘ = 20(9.8) x 5 x 1 = 980 J

Problem 2

A pendulum with a mass of 300g is attached to the ceiling. The pendulum is pulled up to point A which is 30cm above its equilibrium position. Calculate the speed of the pendulum at point B.



Answer

Total energy at A = Total energy at B

EpB + EkB = EpA + EkA

mgh + 0.5 mv^2 = mg(h+0.3) + 0

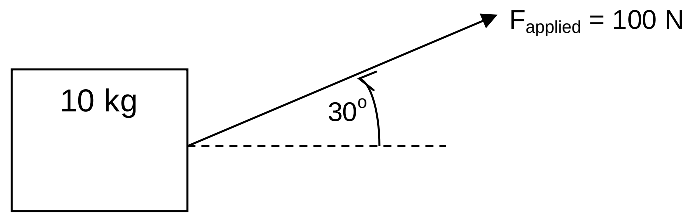
0.5 v^2 = g(0.3)

$V^2 = 2(9.8)(0.3)$ therefore $v = 2.4$ m/s

Problem 3

A 100 N force is applied to a 10 kg box at an angle of 30^o to the horizontal. The box moves a distance of 5 m. Calculate the work done on the box.

Answer



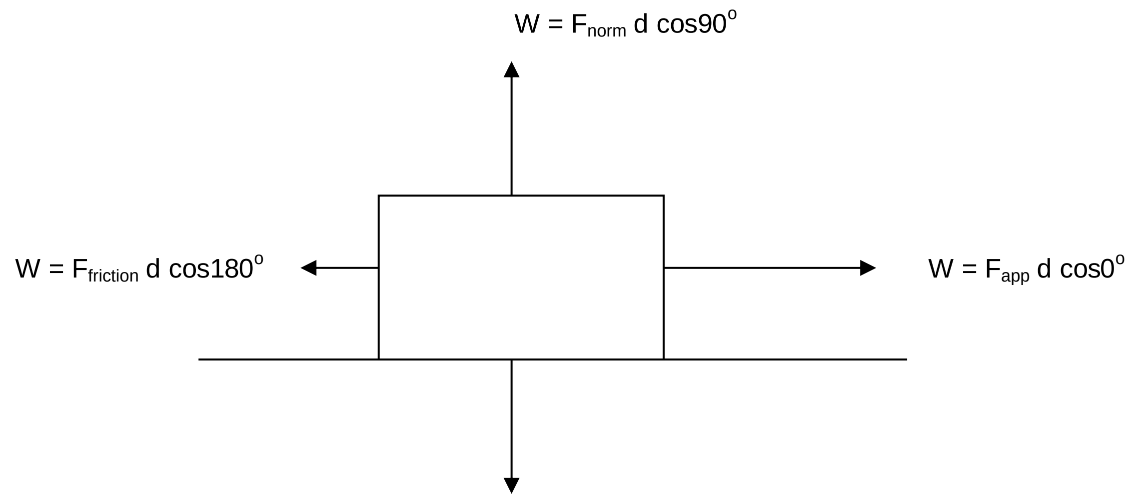
Work done = Fapplied d cosΘ

= 100N (5m) $\cos(30^o)$

= 433 J

Solutions

Q1: The vertical forces do no work on the object as it does not experience any vertical displacement. The applied force does positive work on the object and the force of friction does negative work on the object.



Q2: The power increases: $P = W/t = Fd/t = Fv$. Power is directly proportional to velocity, therefore if the velocity increases the power increases.

Q3: A: potential energy, B: kinetic energy, C: potential and kinetic energy

Q4: No work is done on the object: $W = F_{app}\, d \cos\Theta = F_{app} \times 0 \times \cos\Theta = 0$ J

Q5: Work done = energy transferred. Work done by girl = mgh, Work done by the boy = (2m)gh therefore the boy does the most work.
Power of the boy = (2m)gh/t, Power of the girl = mgh/(0.5t) = 2mgh/t. Both have the same amount of power when climbing the stairs.

Appendix 11- Interview transcript

Thank you so much for agreeing to take part in this interview. I am very grateful for your agreeing to take this interview. I understand you conducted a developmental workshop in North West province that involved Physical Science teachers and subject advisors in the teaching of some physical topics in the South African Curriculum that included work, energy and power. I am currently involved in a study that seeks to determine the effect of such workshops on the development of physical science subject advisors' topics specific pedagogy content knowledge. If I may start by asking:

Interviewer: *What was the actual main purpose of the workshop that you conducted?*

Participant: In 2014 the North West Department of Education identified around 20topics in Physical Science where in service teachers lacked sufficient content knowledge to teach these topics successfully, and they obtained this information by looking at the matrix examination results, so the purpose of the workshops were conceptual understanding of the identified topics which included work, energy and power and although the training was for specifically for Physical Science teachers, there was a special workshop arranged for this subject specialist as well.

Interviewer: *So you would classify this workshop as in service teacher training?*

Participant: Yes

Interviewer: *Okay, so it is in service teacher training. I think you have already touched part of the question that I am going to ask, but I am still going to ask never the less. What informed the decision to include work, energy and power as one of the topics to be covered at the workshop?*

Participant: Again it was a topic that was identified by the North West Department of Education, in which they based on the matric results of the previous years, they felt that teachers, the physical science teachers lacked sufficient content knowledge to teach these topics and work, energy and power was of the topics that was identified.

Interviewer: *I take it the results were not good is not it?*

Participant: Yes the results were negative, so when I say negative, students performed poorly in these areas in the exams. I do not know what the percentages were exactly, however the rational given by the North West Department of Education for identifying these topics was that leaners performed poorly in these topics identified, and they linked that to one of the possible reasons for students performing badly could have been related to lack of content knowledge, sufficient content knowledge on the teachers, physical science teachers part.

Interviewer: *Okay. Thank you so much for that, with work, energy and power also involved in that, meaning I can take it as well that teachers also lacked content knowledge in terms of work, energy and power as a topic.*

Participant: Yes, so what happened was the North West Department of Education noticed that leaners performed poorly in the work, energy and power topics, right along with other topics, and that is why the workshop included work, energy and power as a topic to be covered.

Interviewer: *Okay, thank you for that. What was the duration of the entire workshop?*

Participant: The workshop for this specialist was 3days, and we taught from 8am until 4pm, and we spent approximately 90minutes on work, energy and power. I am not sure if this information is necessary, however the original 4days were allocated for the workshop, but due to some administrative obstacles in the North West Department of Education, so we lost one day and we had to condense, we had to distribute the topics over 3days, so the topics that were originally supposed to be covered in 4days had to be fitted in 3day program, and the so time that we had to spent on each topic had to be reduced.

Interviewer: *I was still going to ask you about whether you think actually time that was allocated was sufficient, but I think you have already started touching on it, maybe you can elaborate again. Do you think the time that was allocated for specifically work, energy and power were it sufficient?*

Participant: I do not think that it was sufficient; I do not think the time allocated for any of the topics was sufficient; my opinion is that issues such as these teachers, the development of teachers of in-service teacher's pedagogy content knowledge cannot be satisfactorily addressed with one workshop.

Interviewer: *I would want to think that during your presentation at the workshop, you had a particular teaching approach, or teaching strategy, that you were using. What was your teaching approach at the workshop in terms of the presentation of work, the instructiveness of the whole workshop, was it interactive if it was please may you explain?*

Participant: We decided to use a conceptual teaching approach so we wanted to identify misconceptions that teachers had in the topic of work, energy and power and the other topics, and we did this by giving them a pre-test. In the workshop what we did was once we knew what areas they had difficult in, we tried to address, what we did was they had a pre-test, but what we did in any case was to take a conceptual teaching approach, and this meant that in the workshop were we did work, energy and power we would try to identify what areas of difficulty the teachers had, by first giving them a couple of questions to answer. That was one part of the aspect, we also tried to give them a summary of what has been identified through research, in order to help them have an awareness of what difficulties leaners face when they teach work, energy and power. It was a conceptual teaching approach, were we tried to get them to answer conceptual questions and focus on the fundamental physics concepts underline work, energy and power. The workshop, the presentation, we allowed an interactive approach, the teachers did, we gave them problems to work on, to solve and to ask questions on that specifically for work, energy and power. For other topics where practical investigations were possible the teachers did practical investigations, but for work, energy and power we used conceptual problems that teachers could work on, if they have difficulties then they could ask questions. It was interactive in the sense that we were engaged with the teachers in our conversation, about the areas of difficulties.

Interviewer: You have basically touched also on the fact that you identified misconceptions before you even started you gave some form of like a pre-assessment too, because I was still going to ask if you were focusing on typical misconceptions, but you have touched that, but if I may proceed and say, during presentation did you pick particular conceptions from the teachers themselves in terms of work, energy and power.

Participant: Yes, I think it was, there were some, it was possible to do that during presentation many of the teachers did not have a physics background, they probably did chemistry and they had to teach physical sciences, and then so they had misconceptions relating to vectors, and forces of vector and how the rule of net force comes to into work. The work energy relationship for example, so yes we did try to focus on the misconceptions that the teachers had. We also took the approach of trying to make them aware of learnable misconception and not actually say that they have misconceptions themselves, teachers can have the same misconceptions. This was to help them improve their teaching, if they are aware of at least one aspect of learner difficulties which are misconceptions then they can at least try to address that or become more aware of that when they are teaching.

Interviewer: As you were teaching particular on this topic on work, energy and power, in your presentation, what did you consider to be the big ideas or the key concepts in the teaching of work, energy and power?

Participant: We looked at the work, energy relationship you know work done by net force, conservation of energy and work energy theorem. I know that underneath those they are others but basically those are the key aspects.

Interviewer: During the presentation did you see the participants as being able to identify the big ideas to your satisfaction or there were some gaps.

Participant: I think they did, it appeared that they were able to do that, possibly that this was one of the topics they did not struggle too much. I think so but perhaps one of the areas that was an issue was when it came to this idea that the definition of work is work is equal to the force times the cosine of theta and it was difficult for them to realise that theta was the angle between the applied force and the displacement. That will probably be something, as well as the teachers when to use the work energy theorem, if you are solving a particular problem.

Interviewer: They were having challenges in identifying exactly when to start using the work, energy kinetic theorem.

Participant: Yes, that is correct.

Interviewer: In terms of the concept of energy itself, how was their conceptualization of energy itself.

Participant: Sorry, can you ask that again.

Interviewer: You, just highlighted that they were having problems in actually identifying when to use the work kinetic energy theorem, and probably research has shown that also learners usually have problems, learners not necessarily teachers. From my own experience as a teacher, leaners sometimes have the problem in actually understanding the whole concept of energy itself, why do we then associate net work done to kinetic energy? I thing you kind of touched it again already when you mentioned the fact that they were struggling in identifying when to use it.

Participant: They are used to one way of solving work or energy problems and I think it is difficult for them to remember. I don't know why they don't seem to remember that there is more than one way to solve a problem. What happened was that we gave them a problem and in the course test and with the information in that problem, if they looked at the information they would have realised the need to use the work energy theorem. But what these teachers, what many of them came back and said is that, there is information missing. But these are not the specialist we are talking about, because the specialist, I don't think they wrote the course test, they just did the pre-test, and so the teachers were the ones that were not able to realise with the information they have that they could apply the work energy theorem. They came to us and said there is information missing from this problem.

Interviewer: In teaching of, as you were presenting on work, energy and power, did you consider it important to structure the concepts in a particular order, in terms of which one comes first and if you did so did you have a particular reason why you think which one should come first before the other?

Participant: I started by looking at what is work, and what is energy, so I like to have a starting point, and then progress in what is a logical sequence for me, so that it helps me to teach the best as I can, you know that's just my approach. I'm not sure if that answers your question, but that's just my answer to that question.

Interviewer: Actually I would want to thing you have really answered my question then probably the best approach to teaching a concept is structuring the concept in small chunks that can be presented one after the other in terms of maybe probably approaching symbol to the concept.

Participant: Yes, I prepared best by doing things in a logical way, and my sequence of topics may not necessarily be same as someone else's. But that is how I chose to present it, so that when I was out there in the workshops, presenting the material there was a logical flow for me so that I presented the materials in the best way that I could, that I felt was logical and showed the connection between various big ideas.

Interviewer: Yes, as you were presenting on this topics specific energy, work and power did you consider aspects that were difficult to teach and probably if you did, did the participants also consider the same aspects as being difficult to teach?

Participant: In truth I think the difficulties arose, the difficulties that I experienced was if I explained something and the teachers did not get it, so to find alternative ways of presenting it in short, in that limited amount of time. So this was for the specialist of course, that was the difficult for me, not necessarily the concept but the time in which I had to sort of help them, with areas they had difficulties with you know, and sometimes they would not believe what I said, but that's fine and that's was it. In terms of work, energy and power I don't think there were too many things that were difficult, I think it was this idea that in the definition of work, the equation work is equals to force F- cos theta; the theta is the angle between the applied force vector and the displacement vector. I think it took a long time to convince them that are or to get them to apply it correctly that was the difficulty.

Interviewer: Okay. You basically touched my next question as well, am going to the next one, did you make use of analogue, presentation or animation, in your presentations

Participant: Not for work, energy and power, we didn't use animation, illustration, analogues and representations. I guess not to a large extent I think. I don't know what representations are?

Interviewer: Maybe the use of even diagrams representing a concept probably an object called a block and is being displaced something like that.

Participant: Yes we did that of course, so in the problems that we presented to them, there were pictures that they had to use.

Interviewer: So you basically used them.

Participant: Yes

Interviewer: Topics specific pedagogical content knowledge, as a pedagogical concept of a teacher, it is a type of knowledge that teachers have, and it is categorized by so many scholars into components of which the first component is student prior knowledge. What we would want to call alterative conceptions or prior knowledge per se curriculum saliency, referring to how the content is structured and what is difficult to teach, representations including analogues and then conceptual teaching strategy. In your own view how were these components of topics specific P.C.K addressed by the workshop?

Participant: How did I apply it or how did we make the teachers aware of this?

Interviewer: I think how you made the teachers aware of, because what we are looking for here is the development of the teachers.

Participant: But you must remember that the workshops were content not pedagogy, but we tried to make them aware of learners' misconceptions in work, energy and power and how these are accessed is to prior knowledge will be accessed through pre-tests for example, so we did not address curriculum saliency directly, we assumed that the teachers are aware of what is in the curriculum for F.E.T. The aspect of learner difficulties that we addressed was learner misconceptions. The conceptual teaching approach was used in this workshop, and by that I mean they were given problems, I started my session by asking conceptual questions, so I would put up a question and then I had a diagram but I would ask them a conceptual question, and then the workshop will flow from there based on what they had difficult for example.

Participant: Thank you so much for that response, we have touched on this before but I'm still going to ask you again for the last time, do you really think the time that was spend on the entire workshop was enough to achieve the purpose mentioned above?

Participant: I don't think so, because it was too short, and one cannot, I think that a sound understanding of a particular concept like work, energy and power for an example, needs to be covered more than one time and presented material need to be presented in different ways that sort of high light particular difficulties in this topic, that's why I feel like 90 minutes was not enough for covering this topic.

Interviewer: So if resources are available you would recommend that such similar workshops be done.

Participant: Say that again.

Interviewer: I'm saying probably if resources are available and the time is there would you recommend that such kind of workshops be done again.

Participant: I think my personal opinion is there is need to be extended program in which the teachers undergo training in- service. Teachers must undergo some kind of training where they are engaging in this thing throughout the year, for example. That's just my personal feeling, is that it has to be something on going not just like a series of work-shops once in a while.

Interviewer: With the context of South Africa as a country in terms of its education with focus on teachers, do you think the problem lies with the lack of pedagogy or it lies with the lack of content, do they have the sufficient know how to teach or do they lack the content to teach, they might be having the knowhow but they lack the content, or do you think they have the content but they lack the knowhow?

Participant: I think it's a combination; you can have a teacher that has enough content knowledge, but struggles with the pedagogical aspect. The presenting the word perhaps because they are not aware of what the learners feel is difficult, perhaps they are not aware of teaching strategies, for example that help, that are different to traditional teaching strategies, which are known to not help learners overcome difficulties, there is research that shows this right. I think there are teachers that are forced to teach physical science because they are in a school and just because of how the education is in the country, you have schools that are under resourced, and someone who is capable of teaching one subject maybe, or was trained to teach one subject is asked to teach physical science because of this lack of resources and if they lack content knowledge, it's going to be difficult for them to present to teach something to learners that they themselves struggle to understand or do not understand as a result of or because of their lack of content knowledge. I think it is not easy, I think the answer to that question is complex; I think pedagogy and content are the only things that are required to answer that question as completely as one possibly can. I think there is also other factors besides pedagogy and lack of content knowledge that play a role in how teachers teach.

Interviewer: Lastly but not least, this one is of personal opinion but I am going to ask it here, comparatively so South Africa and the developing world not necessarily the developed, for now let's talk about the developing maybe through your own reading and stuff, where do you rank South Africa in terms of science, comparatively with other developing countries?

Participant: I think let's look at how we compare with countries that are producing technology that changes the world for example, not necessarily changes the world. I think there needs to be some kind of change in how physical science is taught in South Africa, I don't know what the answer is to tell the truth, like I said it's a complex question there are many things influencing, and I think it might take there is a social aspects and of cause the knowledge aspects and there is other aspects that affect it. I think that somehow it appears that are we producing enough students, are they able to understand physical science. I don't know if I can answer that question you know about whether where do I rank South Africa, because look at Sandile Ngcobo he works at CSIR and he invented the digital laser, he came through the South African schooling system. So what we want to achieve, I think what we want physical science students to be able to achieve when they write matric exams, they must be able to understand and apply concepts and right now I don't think that the majority of them are able to do that and by understanding and apply, I mean problem solving and I mean being creative.

Interviewer: Okay thank you Doctor I think I have exhausted all my questions, you have been wonderful, and I appreciate your effort and thank you so much.

Participant: You are welcome, I am glad I could be of use to you in your study and good luck.