THE STRATEGY TO ENHANCE TEACHING AND LEARNING OF WORK, ENERGY AND POWER CONCEPTS IN GRADE 12 PHYSICAL SCIENCES CLASS

BY

SIPHO IAN NYEMBE

STD (TSHIYA), ACE (UNIVERSITY OF NATAL) AND B.ED. Hons (UNISA)

A dissertation submitted in partial fulfilment of the

Requirements for the degree

MASTERS EDUCATION

In the

SCHOOL OF EDUCATION STUDIES

FACULTY OF EDUCATION

At the

UNIVERSITY OF THE FREE STATE

BLOEMFONTEIN

Supervisor: Dr M.F. Tlali

DECLARATION

I Sipho Ian Nyembe declare that the dissertation “The strategy for enhancing teaching and learning of work, energy and power concepts in grade 12 physical science class,” submitted for Master’s degree in curriculum studies at the University of Free State is my work and I have never submitted the same work for a qualification in any other university.

I also declare that all the work of other scholars cited in this study has been cited and all sources used have been indicated and acknowledged by means of references.

Signature

Date 30 July 2020

DEDICATION

This study is dedicated to my late grandmother Minah Nyembe (MaMlangeni) and my mother Ntombifuthi who raised and supported me. The dedication also goes to my family Rita (wife) and my children Thokozane Ntokozo and Sinenhlanhla.

ACKNOWLEDGEMENTS

I first want to thank God for carrying and protecting me through this challenging academic journey. I believe it was because of him that this journey was completed. I owe my sincere and profound gratitude to my supervisor Dr M.F. Tlali for adopting me and guiding me throughout this journey. He has been a profound source of information for me. My gratitude to my co-supervisor Dr T.J. Moloi who assisted me to start this journey and guided me. A big thank to Dr B. Dube for his unwavering support during my study, God bless. I would also like to express my words of thanks and appreciation to Prof M. M. Nkoane, Dr Tsotetsi, Dr Sbongile Khumalo and Dr Sibaya for their support. Special thanks to my wife Rita Lamlile (MaDakile) for the unwavering and unconditional support she gave to me. It was a blessing to have a wife of her calibre. A very big thank you to my loving children, my two sons Thokozane and Ntokozo and my daughter Sinenhlanhla, for their unbelievable support and the perseverance they have shown me during my academic journey.

Thanks to the SuLE/SuRLEc family and Newcastle Team, especially Mr Mahaye, Nonhlanhla Shozi, Mpume Mthethwa and Zinhle Bhengu (my sister-in-law). Thanks to all the Nyembe family for their support and encouragement during this journey, especially my late brother Linda, May his soul rest in peace.

ACRONYMS

CDA	Critical Discourse Analysis
CP	Critical Pedagogics
DBE	Department of Basic Education
DoE	Department of Education
KZN	Kwa-Zulu Natal
NSC	National Senior Certificate
PAR	Participatory Action Research
PCK	Teacher Pedagogical Content Knowledge
SA	South Africa
SGB	School Governing Body

ABSTRACT

The study aimed to develop a strategy for the teaching and learning of work, energy and power concepts in the physical sciences Grade 12 class. Different reports from the Department of Basic Education (DBE) and other educational researchers expressed their concern about the poor performance of learners in physical sciences, especially in work, energy and power concepts. It is from the reason mentioned above that I undertook the research to develop a strategy for enhancing teaching and learning of work, energy and power concepts. The study was conducted at Mthavuma high school, which is one of the high schools in Newcastle. The following were selected to participate in my study, two physical science teachers from two different schools, one mathematics teacher who taught physical science in previous years, the school principal, Grade 12 physical science learners, a physical science subject advisor and the chairperson of the School Governing Body (SGB), who was also a motor mechanic. The selection of the co-researchers was based on my intentions to build a hybrid team with different expertise and experience on this topic. Different methods were used to generate the data. These methods included workshops, focus team discussions, Free Attitude Interview (FAI) and teacher presentations. Various factors, which contributed to the poor performance in work, energy and power, were discussed. Bricolage was used as a theoretical framework to achieve the aims of the study. Participatory Action Research (PAR) was used as a research methodology. PAR was preferred for this study because it is democratic and involve co-researchers in finding the solution to the problem. Critical Discourse Analysis (CDA) was used in presenting, analysing and interpreting the data generated from the research field.

Keywords: work, energy and power; teaching and learning, bricolage, physical sciences, teaching strategy, mechanics

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1 CHAPTER ONE:
ORIENTATION AND BACKGROUND

1.1 INTRODUCTION

This study aimed to develop the strategy to enhance the teaching and learning of work, energy and power concepts in the Grade 12 physical science class. This study was based on the proposition that employing appropriate teaching and learning strategies when teaching the concepts of work, energy and power concepts could improve the performance of learners in Grade 12 physical sciences. This chapter gives the background of the study and the literature related to the problem under investigation. The problem statement, research question, aim of the study and the objectives of the study are also introduced. Chapter 2 describes the theoretical framework guiding the study and reviews the relevant literature at length. Chapter 3 considers Participatory Action Research (PAR) as the research methodology for generating data, while Chapter 4 considers the data analysis, and interpretation of results using three-tiered discourse analysis. Lastly, Chapter 5 synthesises the findings to make recommendations.

1.2 BACKGROUND AND REVIEW OF RELATED LITERATURE

Physical Sciences is one of the challenging subjects, which contributes to the high failure rate in South Africa. The Department of Basic Education (DBE) in the 2015 diagnostic test (DBE 2015:175) reports that the general performance in physical science between 2012 and 2015 has declined, with 58,6% of candidates achieving 30% and above, only 36% those learners achieved 40% and above. In addition, the KZN Provincial DBE subject report (DBE 2014:9) reveals that out of 21 855 candidates who wrote the Grade 12 National Senior Certificate (NSC) examination in physical sciences, only 55,8% of candidates achieved 30% and above, while DBE (2018:156) revealed that 74,2% learners achieved 30% and above and 48,7% learners achieved 40% and above. Mnchunu (2012:12) expressed a similar view that learners encounter challenges in solving problems that involve work, energy and power concepts, especially those that involve objects that are on an inclined plane. According to DBE (2016:181), mechanics counts 42% in the final exam and work, energy and power concepts account for approximately 10% of the final examination. These concepts, viz. work, energy and power, permeate other knowledge areas of physical science like chemistry, electricity, light and waves. They also relate science to other disciplines that may be relevant to learners' future interests in other fields like technology, health sciences, life sciences, geography and agriculture. This point to the significance of developing a strategy to enhance the understanding of these concepts.

Learners seem to have the problem of understanding work, energy and power concepts. As a result, they find it difficult to link them to real-life situation (Makgato 2014:3687) in South Africa (SA). This is often attributed to the monological and mimetic traditional teacher-centred approach that promotes rote learning (Ozdemi & Clark 2007:354; Rajmoor 2012:43). According to Sekwena (2014:1), best practices encourage multiple approaches to the teaching and learning of concepts of work, energy and power, where learners' conceptions are used to contextualise the teaching and learning of these concepts (Powner 2006:3).

Following this line of argument, Agommuch (2014:2) in Nigeria argue that inadequate teachers' pedagogical content knowledge (PCK) contributes to the learners' difficulty in understanding work, energy and power concepts. This means the teacher lacks enough knowledge needed for the teaching and learning of work, energy and power concepts (Grossman1990:1; Chinyere 2012:21). Echoing the argument Ding (2006:9) in China reveals that inadequate PCK results in teachers resorting to teacher-centred approaches that make these concepts difficult for the learners. According to the DBE (2015:14), the deficiency in teachers' PCK is prominent when learners are dealing with an object on an inclined plane where they are required to identify forces that do work on an object. Amplifying a notion Prew (2009:4) posited that this is aggravated by the trigonometric ratios that are involved in teaching these concepts. Trigonometric ratios are for calculations, especially for objects on an inclined plane. The symbolic expressions (mathematical representations) used to represent the definitions, originally expressed in words, may add to the complication. It is noted by Heuvelen and Zou (2001:184) that the shortage of knowledge in trigonometric ratios results in learners finding it difficult to interpret and convert scientific statements into mathematical equations to solve work, energy and power problems.

To alleviate the work, energy and power conceptual blockages in learners, Greenlaw (2003:61) and Garnet (2015:70) in South Africa (SA) suggested that the learners should be actively involved in the teaching and learning of these concepts. Alluding to this belief, Gullason (2009:87) posited that in active learning, learners get the chance of exploring ideas and issues under the guidance of the teacher. This assisted the learners to develop deeper understanding of work, energy and power concepts, rather than memorising and being mesmerised by a set of often loosely connected facts (Mchunu 2012:32). According to Whiting (2006:171) active learning promotes collaborative learning where the teacher help and encourage learners to work together in construction of new knowledge in work, energy and power concepts using pre-knowledge.

In the same vein, in SA, Chetty (2014:17), emphasises the importance of linking learners' conceptions to work, energy and power concepts. According to Kiomakech and OSuu (2014:35) in Uganda, this could be achieved by using multiple representations to accommodate the diverse ways in which learners construct knowledge. This calls for the teacher to have adequate teaching methods and content knowledge in to apply a multiple representations approach. This makes it necessary for the teachers to attend subject capacitating workshops and seminars to enhance their PCK (Lanka 2012:14).

Garnet (2015:70) in Australia reveals that insufficient PCK make it difficult to link learners' pre-conceptions to work , energy and power concepts which results in the formation of alternating conceptions. In pursuance of this argument, Rajcoomar (2013:12) in SA reveals that inappropriate staffing can lead to the teachers' insufficient knowledge in work, energy and power concepts. Inappropriate staffing occurs when teachers are given a subject they did not specialise in to teach. Teachers who teach the subjects that they did not specialise in will have difficulty in mastering that subject which reflects insufficient PCK.

The use of learners' conceptions, multiple representations, active learning and adequate PCK has brought some improvement in learners' performance in physics for many countries, including SA (Okbia 2012:15). The NSC report released by DBE (2014:5) indicates an improvement in physical science from 53, 4% in 2011 to 61% in 2014. According to the minister of education DBE (2014:30), teacher empowerment programmes through workshops and seminars have contributed significantly to this improvement. According to the report from The Organisation for Economic Co-operation and Development (OCED) (2012:57), in Singapore the idea of "Teach less, learn more," that is learner-centred learning, was introduced in 2004 and, in 2007, Singapore was rated one of the best-performing countries in physical science in the world. Yamin-Ali and Pooma (2012:15) believes that an improved learner's performance is an indication of an improved teacher's PCK.

1.3 PROBLEM STATEMENT

Learners perform poorly in physical science, especially in work, energy and power concepts (DBE 2015 & Mnchunu 2012:30). According to DBE (2018:156), 65,1% learners got 30% and above and 42,2% got 40% and above in 2017, while in 2018, 74,2% of learners got 30% and above and 48,7% of the learners got 40% and above. This performance is attributed to the teaching strategies that the physical science teachers employed in teaching and learning the concepts of work, energy and power. It is believed that this makes it difficult for learners to understand these concepts. To contribute towards resolving this problem, this study was guided by the research question set out below.

1.3.1 Research question

How to develop a strategy to enhance the teaching and learning of work, energy and power concepts in the Grade 12 physical science class?

1.3.2 Aim of the Research

To develop a strategy to enhance work, energy and power concepts in Grade 12 physical science class.

1.3.3 The objectives of the study

The aim above was unbundled into five objectives to ease its achievement. First, to justify the need for developing the strategy to enhance the teaching and learning of work, energy and power concepts. Data pertaining to this objective was predominantly obtained through a process of situational analysis that involved methods like meetings, analysis of learners' activity books and reflections with the teachers (science teachers). The challenges experienced during the teaching and learning of work, energy and power concepts were indicative of the envisioned need. All the co-researchers shared the same view that learners' (mis)conceptions of work, energy and power concepts, learner-limited involvement in teaching, learning, and inadequate teachers' PCK were among the challenges of learners' misunderstanding of the abstract concepts of work, energy and power. The co-researchers agreed that learners' pre-requisite and or prior knowledge regarding these concepts was not optimally utilised to develop their understanding thereof. Duit and Treaqust (2003:673) also confirm this when they argue that teachers often neglect learners' conception about work, energy and power concepts, and this makes it difficult for the learners to understand these concepts.

The second objective of the study was to investigate the possible solution(s) that could be the critical components of a strategy to enhance teaching and learning of work, energy and power concepts. The data was obtained through observation of teaching and learning–how leaners' prior knowledge was assessed and integrated into the lessons, reflection (post-lesson observations) for areas of weaknesses and possible improvements also comparing with the information from the literature.

During discussions, the team members had common views about the pertinent actions and activities that they believed could enhance learners' understanding of work, energy and power concepts. These actions and activities included using learners' prior conceptions, using multiple representations and involving learners in teaching and learning as well as adequate teachers' PCK.

The third objective was to explore the conditions conducive for developing the strategy to enhance the teaching and learning of the concepts of work, energy and power. When the team members were discussing the strategy, they also identified factors that could enable the success of those strategies.

The fourth objective was to identify the possible threats that could hinder the development of the strategy and find ways of alleviating those hindrances.

The fifth objective of the study was to establish evidence that could point to the success of the strategy. The intentions were to observe if the strategy could be developed to enhance the teaching of work, energy and power.

1.4 THEORETICAL FRAMEWORK

This study was guided by bricolage as the theoretical framework. The word bricolage originated from the work of Claude Levi-Strauss in 1966 (Kincheloe 2004:3). It is derived from the French word bricoleur, which describe a handyperson who use any available tool that is usable to complete the task. This means that bricoleurs are creative and innovative enough to use unutilised and under-utilised resources to create and develop mechanisms that assist in addressing prevalent social challenges. To this end, the evolution of bricolage was discussed over the eight moments of its history with different epistemological and ontological positions. These moments are: the traditional period (1900-1970), the modernist or golden age (1950-1970), blurred genres (1970-1986), the crisis of representation (1986-1990), new ethnographies (1990-1995), post-experimental inquiry (1995-2000), the methodologically contested period (2000-2004) and fractured future (2005 to now).

According to Kincheloe (2005:335), there are numerous dimensions to bricolage with different features and all features of the bricolage come with an elastic clause. These dimensions (formats) are methodological bricolage, theoretical bricolage, interpretive bricolage, political bricolage, and narrative bricolage:

The complex nature of the research problem warranted the use of a theoretical framework that promotes and accommodates multi-perspectives, multi-theoretical positions and multi-methodological approaches to research (Rogers 2012:1). The framework of the study intended to use the co-researchers' multiple perspectives, ideas and knowledge as threads to weave the strategy that could enhance the teaching and learning of work, energy and power concepts in the physical science Grade 12 class. This assisted in helping to change teachers' approaches to teaching and learning of work, energy and power concepts to accommodate learners' diversity (Denzin & Lincoln 2000:291). This assisted the learners to penetrate the complexity of work, energy and power concepts (Aagard 2009:95). This also helped the learners and teachers to collaboratively sharing the way of learning rather than passively receiving it from the teachers (Berry 2003:34).

1.5 RESEARCH DESIGN AND METHODOLOGY

Participatory Action Research (PAR) was used as an approach in this study. PAR is participatory, practical, collaborative, emancipatory, critical, reflexive transformative, and it is a social process (MacDonald 2012:37). In this sense, PAR was considered consistent with the bricolage and would thus enable accommodation of multiple views in an attempt to deal with complex work, energy and power problems. PAR as the research methodology is research with co-researchers rather than on co-researchers (Gaffney 2008:9). It promotes equal and democratic participation of co-researchers

(Miller & Rose 2008:102). This allowed teachers and learners to take an active role in finding the solutions to the teaching and learning of work, energy and power concepts. According to Reason and Bradbury (2008:125), teachers and the learners as people with the problem in work, energy and power concepts are in a better position to understand, explain and address their problem as people with classroom experience to this problem. This allowed teachers and learners to undertake action-oriented research to transform teaching and learning of work, energy and power concepts, to allow learners' a better understanding of these concepts.

PAR's iterative, cyclical steps of planning (preceded by and or inclusive of situational analysis), implementation (action) and reflection, afforded co-researchers opportunities to engage through meetings (planning and reviews of plans), reflection sessions and observation of lessons (collaborative teaching) (Gaffney 2008:9; Sekwena 2014:6). Thus, PAR was chosen as the research methodology for the study to make a collaborative effort to bring about the desired change in teaching and learning of work, energy and power concepts.

1.6 DATA GENERATION

The data was generated through discussion, workshops and meetings with the co-researchers, and the generated data was audio-recorded and subsequently transcribed for ease of analysis and access. Pertinent pictures were also used and were obtained from learners' workbooks and learning environments. To encourage a sense of ownership, an action plan that clearly showed activities, roles, responsibilities and due dates that were involved in the process of data generation, was drawn with all team members. A series of steps were involved in data generation. These steps included a planning stage where different responsibilities were assigned to different co-researchers. During this stage, team members were involved in different activities. This included identifying activities, allocating resources for the execution of objectives, allocation / sharing of roles and responsibilities, identifying the venue making decisions and setting the timelines for these activities. This stage was followed by the development of a common goal reflected in the agreed vision, mission and values. This was done to develop a common understanding of the goal of the study amongst the team members. During this stage, we set ground rules that guided the practice and involvement of co-researchers in the study from the development of the mission to situational analysis, development of the plan and its implementation. The next stage was an action plan where planning sessions and situation analysis, class visits for observation, reflections, and focus on joint lesson planning were done.

The research site was one of the high schools in Newcastle. The team was composed of thirteen members. These members were seven Grade12 physical science learners, a school principal, two physical science educators, the chairperson of the governing body who was a mechanic, mathematics teachers and the physical science subject specialist. Learners and teachers were selected because they were directly involved with the subject and were thus in a better positioned to know, understand and solve their problem. The chairperson, as the motor mechanic, also had some contribution to the research project. As Kalraranga (2008:25) stated, the co-researchers are experts in the topic because of their lived experience in the topic. Pseudonyms were used to ensure anonymity and confidentiality of co-researchers, to avoid undesirable consequences for individuals as a result of the data they provided (Wiles, Crow, Heath & Chales 2006:3).

1.7 DATA ANALYSIS AND INTERPRETATION

The data generated through workshops, meetings, class-teaching observations and reflections was analysed and interpreted using Critical Discourse Analysis (CDA). CDA was used in the study as a multidisciplinary approach to study and analyse written and spoken texts to reveal the discursive sources of power, dominance, inequality and bias (van Dijk 1998:1, 2008:252). The data was organised according to the objectives of the study to ensure the achievement of the aim of the study from which the objectives were developed. The research then identified relevant excerpts (summary of deliberations and observations made) pertaining to each objective and sub-heading. The texts (excerpts) given were corroborated by information from other data sets and subsequently subjected to textual, cognitive/discursive and then social structural analysis. The information was later subjected to bricolage's underpinnings from which the findings were inferred for further discussion and consideration.

In analysing the data, I started by transcribing the data from audio recordings of the focus group meetings discussions into textual form. After organising the data, sub-headings for each objective were decided upon based on the literature read and the empirical data obtained. These headings indicate challenges in teaching and learning of work, energy and power concepts, the solution suggested, conditions conducive for teaching these concepts, the anticipated risk factors involved and the successful implementation of the strategy.

This assisted me as a researcher to analyse opaque and transparent structural relationships of dominance, power and control when discussing the solutions to the teaching and learning of work, energy and power concepts (Sheyholislami 2008:110; Wodak 2008:280). The co-researchers in this study worked together as equal partners in generating the data. CDA in this study was seen as the relevant approach that allowed the co-researchers to work in collaboration to bring change to the teaching and learning of work, energy and power concepts (Tlali 2017: 30). Van Dijk's three layers of discourse analysis were used to analyse the data. These were textual analysis, discursive analysis and social analysis.

1.8 FINDINGS AND RECOMMENDATIONS

The findings are reported in Chapter 4 are further discussed, and recommendations are made in Chapter 5. The findings and recommendations are organised according to the objectives of the study and further sub-divided according to the relevant sub-headings that served as constructs.

1.9 THE VALUE OF THE RESEARCH

The science teachers, physical science specialists and the Department of Education (DoE) will use the findings of the study to enhance the teaching and learning of work, energy and power concepts and physical science in general will use the findings of this study. The findings can also be used by other researchers to improve on their strategies for teaching and learning of physical science where I left off.

1.10 ETHICAL CONSIDERATION

I sought permission from the Kwazulu Natal (KZN) DoE and the school principal where the research was conducted. Consent was obtained from the parents of learners allowing their children to participate in the study, the teachers and SGB chairperson as parents' representative to participate in the study. I also sought permission from the co-researcher to record the data-generating activities and assured them of confidentiality. It was also agreed that pseudonyms would be used to protect their identities and that participation in the study was purely voluntary and they could withdraw from the study at any time if they so wished. I made it clear to the co-researchers that the research project was solely for academic purpose, and it was not sponsored.

1.11 CONCLUSION

This chapter gave the background of the study, and a brief overview of the literature related to the problem in teaching and learning of work, energy and power concepts was provided. This was followed by the introduction of the problem statement and the formulation of the research question. The aim of the study and the five objectives of the study were also explained. Bricolage, as the theoretical framework used for the study, was explained and justification for its use was done. The choice of PAR as the research methodology for the study was explained. PAR cycles were also highlighted. CDA as an appropriate approach for analysing and interpreting data was explained. This chapter also explained how data was generated, analysed and interpreted using the three-layered CDA.

The background to the findings and recommendations, the value of the study and the ethical principles followed were explained.

1.12 LAYOUT OF CHAPTERS

Chapter 1: **Orientation and background**

This chapter outlines the introduction to the study, the research aim and objectives, data generation, research design and methodology, critical discourse analysis, ethical consideration and value of the study.

Chapter 2: **Theoretical Framework and Literature Review**

The chapter begins by discussing the theoretical framework, its origin and objective of the framework focusing on how they influence the strategy of teaching and learning of physical science concepts in a Grade 12 class. I then provide evidence of this collaboration by going through empirical works related to my study. Later, a review of literature is outlined and I discuss the specific challenges that yielded the need to design the framework. This chapter further discusses the conditions conducive for the implementation of the strategy based on the reaction of the stakeholders and envisaged threats that may impede the study.

Chapter 3: Research Design and Methodology

This chapter starts with the presentation of the methods and processes that were used in generating data from the co-researchers to develop the strategy to enhance the teaching and learning of physical science concepts such as work, energy and power in Grade 12 class. Then, it further deliberates the speeches and the plan of action that was done by the chosen coordinating team to classify the need and components of the framework and regulate settings that are conducive for the construction of a framework.

Chapter 4: Data analysis

This chapter deals with the information investigation, as well as the demonstration and interpretation of the outcomes, to develop the strategy to enhance the teaching and learning of physical science concepts such as work, energy and power in the Grade 12 class. The critical discourse analysis methodology had been used to assist the exploration of texts directing the uncover of the significance rooted in the language, taking into consideration the nuances of the school under research and how these influences the status quo.

Chapter 5: Findings and Recommendations

The findings and recommendations are outlined in a chapter where the perceptions of co-researchers are interpreted, and their views are respected to develop the strategy to enhance the teaching and learning of physical science concepts such as work, energy and power in a Grade 12 class.

1.13 SUMMARY OF THE CHAPTER

The chapter began with the introduction and the background of the study. Then the problem statement and the research question, aim and objectives of the study were argued. The research design and methodology used were clarified and also outlined. The study found significant assurance in the principles of the theoretical framework (Bricolage) on which the study is based. The value of the research and ethical considerations were reflected.

2 CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The study aims to develop a strategy that will assist in enhancing the teaching and learning of work, energy and power concepts in the Grade 12 physical science class. In this chapter, I discuss bricolage as the theoretical framework that couches my study. This chapter further presents a review of literature related to work, energy, power concepts, and show how the literature assisted me in developing the strategy that will enhance teaching and learning of work, energy and power in the physical science class. Work, energy and power concepts are a challenge to both teachers and learners. This has led to a decline in Grade 12 physical science National Senior Certificate results.

2.2 BRICOLAGE AS THEORETICAL FRAMEWORK

Bricolage couches this study as a theoretical framework. Denzin and Lincoln (2000:3) define bricolage as the research approach that is multi-perspective, multi-theoretical, multi-methodological, praxis, eclectic and fluid, and open-ended. The multiplicity of bricolage in this study assisted in moving beyond the blinds of the monological approach to work, energy and power concepts and peer through the multiple representations to the problems of teaching and learning of these concepts (Kincheloe 2005:326). This assisted me in avoiding the standard mode of knowledge production that was reflected through the traditional approach to the teaching and learning of these concepts (Rogers 2012:14). Bricolage in this study helps to develop a critical consciousness in learners and teachers where learners become aware of their problem and take an active role in seeking the solution to their problems (Sekwena 2014:11).

2.2.1 The historical origin of bricolage

According to Kincheloe (2004:3), the word bricolage originated from the work of Claude Levi-Strauss in 1966. It was derived from the French word bricoleur, which describes a handyperson who uses any available tool that is usable to complete the task (Kincheloe 2005: 328).This means that bricoleurs are creative and innovative enough to use unutilised and under-utilised resources to create and develop mechanisms that assist in addressing prevalent social challenges. To this end, in this study, this resonates well with the need for teachers and learners as well as other relevant stakeholders to identify and use the resources, knowledge and skills available to address the challenges regarding the learning of work, energy and power concepts. This is pivotal because bricolage encourages the creation of spaces where critical, multi-perspectival theories which use various methods and approaches to enquiry (Rogers 2012:2), can assist me in developing the strategy to enhance teaching and learning of work, energy and power concepts. Thus, multiplicity is why the collaborative work of teachers, learners and other stakeholders was needed in this study where they served as bricoleurs. Denzin and Lincoln (2000:3–17) explained variations and developments in the use of bricolage in research. To this end, the evolution of bricolage was discussed over eight moments.

These moments are, the traditional (1900-1970), the modernist or golden age (1950-970), blurred genres (1970-1986), the crisis of representation (1986-1990), new ethnographies (1990-1995), post experimental inquiry (1995-2000), the methodologically contested (2000-2004) and the fractured futures (2005 to present). Bricolage derives its multiple perspectives and multiple theoretical positions from these moments. Its views about the truth and reality (ontology) and how learning takes place (epistemology) are dynamic and evolve with time. For this study, the preferred ontological and epistemological underpinnings would be decided upon by and according to the nature of relevant empirical data and information. Also, the data consistent with the ontological and or epistemological positions of different moments, was considered for corroboration purposes.

These moments have different ontological and epistemological positions that evolved with time. For this study, the ontological and epistemological positions for the first and the eighth moments are discussed.

2.2.1.1 First moment

The ontological position of this moment is underpinned by the positivist assumption that most phenomena in the world are observable and measurable (Gay & Airasian 2003:8). This means reality is objective and can be measured using scientific laws. This was a the monological approach to the teaching and learning (work, energy and power) which promoted reductionist thinking in learners (Mack 2010:59). The epistemological position of this moment was that knowledge is objective, value-free and inherent in natural science (Schwandt 2001:150). This means empirical data is the only source of knowledge. This approach promotes the teacher-centred approach to teaching and learning where the teacher is the sole source of information (Riegler 2012:8).

2.2.1.2 Eighth moment

The ontological position of this moment is underpinned by multiple reality that is based on moral values (Denzin 2005:42). This means learners' morals, values and ethics should be considered to assist learners in constructing knowledge This emphasises the importance of learners' conceptions in forming the base for the understanding of work, energy and power concepts.

The epistemology of this moment underpinned a sacred existential epistemology that involved the community with common moral values and was grounded in solidarity, care, empowerment, covenant and civic transformation (Denzin & Lincoln 2005:30). According to Cristians 1995 and Hawkins (2008:5), this means all humans are worthy of dignity and sacred status regardless of ethnicity. There is a celebration of difference and diversity to include human dignity (Mahlomaholo 2014:176). This means teaching and learning of work, energy and power concepts should be diversified to cater for different ways in which construct knowledge.

2.2.2 Ontology of bricolage

Ontology is a set of beliefs about the nature of reality (Killam 2013:8). Edward (2015: 16) defines ontology in bricolage as the study of the existence of complexity in the web of reality. This means bricolage respect the complexity of meaning-making hence it uses multiple and diverse ways to come to the understanding of social reality (Rogers 2012:14). Kincheloe (2005:324) adds that ontology in bricolage is based on multiple ways that the researcher should use to come to the realisation of reality (Kincheloe 2005:324).

Based on Kincheloe's (2005:324) argument, the way learners perceive and attach meaning to work, energy and power concepts is based on their diverse views of reality. This means, learners perceive and make sense of work, energy and power concepts in various ways depending on their backgrounds and experiences of physical phenomena (Adeyemo 2010:101). Due to the diverse nature of learners, they attach different meanings to work, energy and power concepts gleaned from their ontology.

It is therefore important that the teacher should understand these contentions and build the teaching and learning of these concepts from learners' view of reality. This means that teachers should build the learners' understanding of work, energy and power concepts on learners' context and cultural experiences. Kincheloe (2005:324) posits that bricolage constructs a more active role in shaping reality. This calls for the teacher to allow learners to take an active role in developing an understanding of concepts. Wibberley (2012:3) concurs that the learners' experiences, as the complex web of knowledge derived from cultural, social interactions, should be used to penetrate the complexity of reality, in this instance of work, energy and power concepts.

2.2.3 Epistemology of bricolage

Bricolage is grounded on an epistemology of complexity (Kincheloe 2005:324). The complex nature of reality, which in this study relates to conceptions of work, energy and power concepts, as well as the teaching and learning thereof, was understood to consider the view that knowledge and how it is created are not monolithic. Epistemologically, bricolage calls for the consideration of multiple views, contexts and theoretical positions when creating knowledge.

Alluding to the notion, Shuster (2012:12) posits that an epistemology of bricolage was based on the diverse, multi-perspectival, multi-theoretical and multi-methodological approaches to knowledge construction process. In pursuance of this argument, Senyard (2012:14) avers that knowledge is multi-perspective and complex, and it is regarded as knowledge when it has been discussed and shared by a particular group.

This means learners' epistemological stance about work, energy and work concepts should be understood by the teacher because they form learners' conceptions (Gagne 2012:55). Learners' pre instructional conceptions form a base in the understanding of work, energy and power concepts. This can help to make changes in learners' underlying epistemic suppositions (Kincheloe 2005:3; Clement 2008:23; Chi 2013:12) so that learning can take place.

This means learners should discuss work, energy and power concepts and come up with different perspectives about the concepts. However, there has to be ways and means through which learners' different conceptions of these concepts are tested for the scientific character. Such means and ways have to extend beyond just concepts but to testing learners' ability to apply them in different contexts, beyond their respective local situations. Bush and Silk (2010:556) further argue that using diverse theories and multiple methods help to transcend learners' reductionism to understand work, energy and power concepts. According to Overing (2014:12), bricolage approaches cater for learners' multiplicity, unpack complex work, energy, and power concepts to enhance understanding of these concepts.

2.2.4 Objectives of bricolage in the study

The bricoleurs' capability to making something useful from materials and resources deemed as useless and of no value (Humphries, Franziska Klaas & Michi Knecht 2016:8), prompted the objective to instil a sense of responsibility and taking ownership to solve own problems using resources available. The purpose is to instil a sense of respect for various ways and modes of knowledge creation and working with others towards achieving a common goal. In addition, the purpose is to instil analytic habits of mind capable of creatively and innovatively unearthing possibilities and opportunities to teach and learn successfully.

It is for this reason that I used bricolage in this study to instil an attitude of improvisation that would create a "do-it-yourself" learner (Wibberley 2012:3). This can be achieved by creating critical thinking, a sense of responsibility and problem-solving skills in learners (Hinrichs 2012:190). An attitude of improvisation makes it possible for learners to use different available methods and incorporate diverse perspectives to create knowledge in trying to understand work, energy and power concepts (De Campos 2016:5). Through this, learners can be empowered, and their self-confidence could increase (Baker & Nelson 2005:331). This could lead to academic growth (Scott 2015:10). The study describes the complexity of the knowledge production process, and through bricolage, account for the complexity of work, energy and power concepts (Kincheloe & Berry 2004:25). Bricolage further assists the learner to use practical and eclectic approaches to meaning-making (Lisa, Kay & Edd 2015:2). This assists the learner in creating knowledge out of the complexity of work, energy and power. In addition, bricolage help the learners to explore meanings, understand and make meaning from the concepts of work, energy and power (Rogers 2012:14). Furthermore, bricolage uses various perspective that leads to new ways of knowledge production and helps the researcher to have a more democratic relationship with co-researchers. To accommodate diverse knowledge like the knowledge that have been subjugated from the marginalised, the researcher came to understand and value the knowledge and the abilities of the co-researchers (Phillimore, Humphries, Klaas & Knecht 2016:12). Therefore, bricolage was regarded as the relevant theoretical framework for couching this study, since it dialogues with the study, and provides opportunities for the articulation of theories, the methodologies of the researcher in the study in a multi-referential scheme of knowledge construction (de Campo 2016:2).

2.2.5 Role of the bricolage researcher

As a bricoleur researcher, my role was akin to that of a handyman (Wibberley 2012:3) who availed his competences i.e. skills, knowledges and values (DBE,2011) necessary for the development of mechanisms to enhance the teaching and learning of work, energy and power to the team, learners, the school (research site) and ultimately other prospective beneficiaries. The competences I refer to were traceable to my 25 years of teaching physical sciences, as well as the knowledge gained from my attendance of numerous in-service physical sciences training workshops.

An attempt to develop a strategy (mechanism) to the enhance teaching and learning of work, energy and power concepts was done in collaboration with the team of co-researchers. It was therefore imperative for me to select a hybrid team with diverse expertise and experiences in these teaching and learning of these concepts.

As a researcher, I allowed co-researchers, teachers and learners, in this case, to take an active role in identifying their problems in work, energy and power concepts and find the solutions to their problems (Delman 2012:231). In this research process, I regard myself as the learner and the co-researchers throughout the research process. Teachers and learners, as people with the problem in these concepts, are allowed to explore the solution to their problem (Kincheloe 2005:3). As Wibberley (2012: 6) pointed out, allowing the co-researchers to take an active role, allows a relatively diverse range of data that allows multiple perspectives. This can be achieved by bracketing my subjectivity as a researcher. Mahlomaholo (2009:226) pointed out that bracketing researcher's subjectivity help to combine researcher's notions with that of co-researchers. This help to accommodate diverse meanings and different ontological perspectives. In addition, this helps me to integrate knowledge from the diverse domains of my co-researchers and understand interconnections shaping this knowledge (Kincheloe 2005:320). According to du Toit (2007:3), this reality should be observed in the same language and culture to create a space for research eclecticism.

2.2.6 The relationship between the researcher and co-researchers

My relationship with co-researchers was a relationship of mutual respect, care and trust that enabled us to work as a team with a common goal of developing a strategy to enhance teaching and learning of physical sciences. Our relationship was further characterised by willingness to learn from one another, As such, the competences and views of all the participants were valued and enjoyed equitably but with robust consideration. This was informed and was consistent with the multi-perspectival nature of bricolage.

It was therefore important for me to act as a participant-researcher and a co-researcher, by allowing the co-researchers to participate actively and equally throughout the research process. This assisted us to diversify our approach to accommodate multiple perspectives and avoid monological approaches to knowledge production (Marlene 2003:44).

As co-researchers, we had an obligation of levelling the critical dimensions of power that emanated from the positions held by the co-researchers in the community (Ortmann 2008:87). This allowed us to avoid monological and the deterministic approaches that would have allowed the dominance of individuals over others in a team (Kincheloe 2005:325). By addressing the issues of power differential realities (e.g. of inequality and injustice), all the team members were afforded the opportunity to participate equitably in the process of knowledge co-construction and production. This helped to create a space for multiple perspectives and diverse forms of meaning making to push the knowledge boundaries (Rogers 2012:14). This further accommodated plurality and diverse dimensions of knowledge from co-researchers during collection and interpretation of data.

Johannisson and Olaison (2007:15) contend that bricolage assists learners in working collaboratively in constructing their knowledge. This helped in cultivating a positive attitude and boosted learners' self-esteem during teaching and learning of work, energy and power concepts. According to Rogers, narrative bricoleurs appreciate how ideologies and discourses shape how knowledge is produced There is much potential to begin developing an understanding of the processes of bricolage through exploring epistemological differences from different life experiences, cultural, religious and other experiences and identities" (Rogers 2015:7).

2.3 DEFINITION AND DISCUSSION OF OPERATIONAL CONCEPTS

This section embarks on the definition and discussion of the key concepts in this study. According to Okeke and Van Wyk (2015:195), understanding concepts helps to identify specific variables that are measured using a set of defined procedures, and this help to come up with the methods that can measure the concept under study. The focus in this is on mechanics; as a result, the other knowledge areas where these concepts find application are irrelevant for this study.

2.3.1 Mechanics

Mechanics is a branch of physical science that deals with energy, forces, and their effect on bodies (Eberhard & Juhasz 2016:3). According to Rogers (2015):

> *it is the area of physics concerned with the motions of macroscopic objects. Forces applied to objects result in displacements or changes of an object's position relative to its environment. During the early modern period, scientists such as Galileo, Kepler, and Newton laid the foundation for what was now known as classical mechanics. It is a branch of classical physics that deals with particles that are either at rest or moving with velocities significantly less than the speed of light. It can also be defined as a branch of science which deals with the motion of and forces on bodies not in the quantum realm.* (Rogers 2015:7).

According to the National Curriculum Statement (NCS), physical science mechanics covers motion in two dimensions and work, energy and power. The study focuses on work, energy and power concepts, and this makes other knowledge areas irrelevant for this study.

2.3.2 Work

The concept of work is defined differently in different disciples, which make people have different perspectives about these concepts. The context in which this concept is used in everyday life is different from the way it is used in other contexts, e.g..

electrical, EM and Fluids (Gases). Example of work definition in other contexts/knowledge areas:

1. W = PV (P: pressure; V: volume) similar to W = FΔx, $may\ contribute\ to\ misconception\ that\ F =$ P and V =Δx; P = F/A and V = Area of base, Δx
2. W=QV (V: potential difference, Q: charge), no visible effects of force as with mechanical perspective, giving the impression that no force is involved, when in fact it is at microscopic level and therefore abstract.
3. W = hf is similarly abstract because of no immediately observable (concrete) movement/displacement of that which experiences force or energy.
4. $W_{net} = \Delta K$, brings the concept of work to energy and may raise many questions like is it only about kinetic energy? What happens when an object's potential energy is changed to its kinetic energy? Etc.

According to the South African Concise Oxford dictionary (2011:1191), work is an activity that involves mental or physical effort done to achieve results for such activity as a means of earning an award. This also shows that the word finds application in many fields /areas. For example, the dictionary meaning includes "mental effort", which may be difficult to explain in terms of distance and force applied (i.e. concretely). This may be another cause of confusion and or misunderstanding. The 'mental effort' represents abstract efforts that are mainly operational at the microscopic level as opposed to the "physical efforts" that may be associated with the concrete aspects of reality.

For the study, the focus is on mechanics, as a result the other knowledge areas where these concepts find application are irrelevant for this study.

Andrew, Ayish and Edward (2003:56) define work as a product of a force applied and distance in the direction of a force. This definition is expressed mathematically as a formula as $W = F\Delta x cos\theta$. Giancoli, (2005:137) defines work done by a constant force on an object as the product of the magnitude of the displacement(d) and the component of the force parallel ($F_{//}$) to the displacement. An equation is written as $W = F_{//}\ d \cos \Theta$, where $F_{//}$ is the same as F$cos\theta\ and\ \Delta$x is the same as displacement 'd'.

When $= 0^0$, Cos $0^0 = 1$ and $W = F\Delta x cos\theta$ = $F\Delta x$, where θ = 90^0, $\text{Cos } 90^0 = 0$ then $W = 0$ thus work done decreases with increase in θ.

$F_{//}$ is the component of the constant force acting on an object which is parallel to the displacement(d) of an object, and Θ is an angle between the force and the displacement.

2.3.3 Energy

According to the South African Concise Oxford Dictionary (2011:3200), energy is the strength and vitality for sustained activity and mental powers as applied to a particular activity. The meaning seems complex and incomprehensible. It refers to energy as:

- Strength and Vitality for sustained activity;
- Mental powers as applied to a particular activity.

Strength may be construed as or may imply force and or power to a person. This could typical be learners' prior knowledge they bring to class. Similarly, "mental powers" as in the second description of energy tend to be abstract by virtue of being a mental activity. Also, it tends to equate energy with power. This may be sensible in everyday language but certainly not in science. Energy is not power, and power is not energy.

The encyclopaedia defines energy as an ability to do work, while Papadouris (2008:14) defines energy as a transfer and transformation that accounts for changes in very different systems. According to Mnchunu (2012:25), "Energy is an ability to do work.'' This is misleading in mechanics, especially when relating work and force, and it ignores the second Law of Thermodynamics, which states that not all energy has the ability to do work. For this study, the perspective of Giancoli (2005:143) of translational kinetic energy ($K = \frac{1}{2}mv^2$) and potential energy ($E_p = mgh$) is adopted. In the equation ($E_p = mgh$), m is mass of an object, g is the acceleration due to gravity and h is the height of an object above the ground. It applies to the equation $K = \frac{1}{2}mv^2$, m is the mass of an object, and v is the speed of an object. This definition helps the learners to understand different principles of energy and its relation to work (Giancoli 2005:137).

2.3.4 Power

According to the Oxford English Dictionary (2011:454), power is an ability to do something or to act in a particular way. This definition does not seem to differentiate between "power" and "energy". The "something" refers to "work", especially when one considers that it is about “acting in a particular way”. This definition does connect, though vaguely so, the concepts of power to those of work and energy.

Andrew et.al. (2015:2) define power as the rate at which work is done, or energy is transferred. with the formula $P = \frac{W}{\Delta t}$. This draws a connection between work and energy and suggests that work done is the same as energy transferred. It prompts one to recall the work-energy theorem, i.e. $\Delta K = W_{net}$.

These two definitions have very different meanings and are confusing to the learners. One definition comes from everyday use of the concept and the second definition comes from the scientific point of view. This makes it difficult for the learners to have a clear understanding of this concept and the formulae that are involved in these concepts (Docktor, Strand, Mestre & Ross 2015:4). Another misconception that emerged from the everyday use of power was that it was confusing for it to mean the same thing as energy. The scientific meaning of power is the rate at which energy was transferred or work was done (Kurnaz & Arslan 2014:630). Energy as a transfer and transformation accounts for changes in very different systems (Papadouris, 2008:14). The definition by Andrew et al. (2015:2) is the one that is scientifically accepted, and it can be expanded to accommodate the formula for average power, $P_{av} = FV_{av}$.

Like work and energy, the concept of power is important in understanding work and energy. Like the two concepts above, this concept is not well understood by the learners. This further deprives the learners’ of an opportunity of understanding work, energy and power concepts.

2.3.5 Teaching and learning

Alber (2014:8) defines teaching as the process of attending to learners’ needs and experiences, and intervening so that they learn particular things, and go beyond the given. According to Prozesky (2000:30), during teaching, the teacher is helping the learners to learn. This means during teaching and learning of the concepts work, energy and power, the teacher uses the learners’ contexts and experiences to facilitate the learning of these concepts. According to constructivism learning theory, learners’ prior knowledge influences what new or modified knowledge an individual construct from new learning experiences (McLeod 2019:10). In this situation, the teacher act as a facilitator, and the learners takes an active role in the process of reconstructing new knowledge about work, energy and power concepts. The work of Fosythe (2002:4), further suggests that by having learners learn through the experience of solving problems, they can learn both content and thinking strategies to solve work, energy and power concepts. According to Hmelo-Silver (2004:236), problem-based learning (PBL) is an instructional method in which learners learn through facilitated problem-solving.

This helps them to develop their critical thinking. The work of Sequeira (2017:3) indicates that during the teaching and learning process, teaching instructions as a set of events outside the learner, are used to support the learner's internal processes of learning to make sense of work, energy and power concepts.

According to Lachman (1997:12) and Vlaev and Dolan (2015:69), learning is the change in behaviour that is due to experience. The Oxford English Dictionary (2011: 811) defines the word "learn" as acquiring knowledge or skills in (something) through study or experience or by being taught. In the same breadth, Nolan (2010:3) defines line of argument; stating that learning can be defined as an active reconstruction of knowledge to assimilate it with new knowledge about work, energy and power concepts. This means during learning, learners work collaboratively and wrestle with ideas to discover meaningful conceptions about work, energy and power concepts. Echoing this argument from the cognitive views of learning, Cahyadi (2007:5) suggested that learning involves a modification of mental structures while the understanding of these concepts are taking place. According to Cahyadi (2007:5), this modification was influenced by learners' active involvement in the process of knowledge construction about work, energy and power concepts.

2.4 REVIEW OF RELATED LITERATURE

In this section, I reviewed the literature about teaching and learning of work, energy and power from South Africa and different countries. This assisted me in identifying challenges that were associated with the teaching and learning of work, energy and power in the Grade 12 physical science class to respond to the objectives of the study. I also reviewed the literature on possible solutions for the development of a strategy, conditions for successful implementation of the strategy, inherent risks associated with the development of a strategy and lastly highlighted possible successes associated with the implementation of the strategy.

2.4.1 Challenges relating to the teaching and learning of work, energy and power

This section focuses on the challenges that can hinder the development of the strategy to enhance teaching and learning of work, energy and power in the Grade 12 physical science class. The following challenges are discussed in this section: Learners' (mis)conceptions of work, energy and power; challenges in teaching work, energy and power, Learner involvement and Teachers' PCK as a challenge.

2.4.1.1 Learners' (mis)conceptions

Learners come to class with their conceptions of work, energy, and power gleaned from previous experiences (Bezen, Bayrak & Aykutlu 2014:391). These conceptions are well fitted in learners' cognitive structures, and are stable; therefore, they pose a challenge to learning in the event their conceptions are not consistent with those that are generally accepted in science as correct (Wenning 2008:11; Yamin-Ali & Pooma, 2012:15). These conceptions lead to opinions that sometimes involve scientifically inaccurate thoughts (Daud, Karim, Hassan and Rahman 2015:39; Sukariasih 2016:483). This makes teaching and learning of work, energy and power even more difficult. Duit and Treaqust (2003:673) pointed out that the teachers aggravate this situation by neglecting learners' conceptions when teaching these concepts. This result in learners defining these concepts in colloquial terms rather than in a scientifically and meaningful way (Wenning 2008:1; Duit & Treaqust 2010:25). One example of learners' pre-conceptions was when they confused the concepts of energy and power. Saglam-Arsalan and Kurnaz (2009:4) in Turkey found that learners defined energy as the total power that was being used to do work. The work of Wong, Poo, Hock and Kang (2014:4) reveals that this definition emanates from the everyday use of concepts like work, energy and power. Alluding to this, Muller and Sharma (2007:12), as well as Baveja (2012:1070), pointed out that this made it difficult for learners to develop a deeper understanding of these concepts. Similarly, Hulan (2005:3) and Viennot (n. d.: 1) added that neglecting learners' conceptions resulted in learners resorting to memorisation. In this case, learners memorise algorithmic execution of the procedures for solving quantitative problems in these concepts at the expense of conceptual understanding (Ozdemir & Clark 2007:23; Tumba 2015:396).

2.4.1.2 Work, energy and power concepts as a challenge for learners

The concepts of work, energy and power are all based on the same basic concepts. They are constructs of concepts like force, change in position (Δx), rate of change in position ($\frac{\Delta x}{\Delta t}$) and the rate of change of velocity ($\frac{\Delta v}{\Delta t}$), as well as the amount of matter in the object (mass) experiencing these effects. Evidently, these concepts (constructs) also have implications for the use of kinematic equations of motion like $v_f^2 = v_i^2 + 2as$; $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$

Work, energy and power are also defined in terms of each other. For instance, these definitions, as discussed earlier, equate work and energy and define power as the rate at which work is done and or energy is transformed (Sefton 2004:3). The following illustrates some of the possible complications:

$W_{net} = F_{net} \Delta x cos\theta = ma \Delta x cos\theta \qquad [F_{net} = ma]$

And the change in displacement caused by $F_{net} > 0$

I.e. the effect of the force that causes accelerated motion as opposed to average velocity, is best described by$\Delta x = \frac{v_f^2 - v_i^2}{2a}$. When substituted in the work equation for this change in position/displacement, the work defining equation changes to show why work and energy are similar/equivalent, even though we say they are equal (i.e. without emphasising equality in value):

$W_{net} = ma \Delta x cos\theta = ma(\frac{v_f^2 - v_i^2}{2a}) \, cos\theta = \frac{1}{2} m(v_f^2 - v_i^2) \, cos\theta$, For $\theta = 0°$, i.e. parallel to the horizontal surface, then $cos\theta = 1$ (Sefton (2004: 2) The resulting work equation shows clear connections with the change in kinetic energy: W_{net}= $\frac{1}{2} m(v_f^2 - v_i^2)$= $\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$=$\Delta E_k$. The situation changes when work is done by the force of gravity, that is when both kinetic energy and potential energy are affected, the formula becomes $W_{nc} = \Delta E_p + \Delta E_k$, which is the work done by non-conservative forces. Hugh, Young, Rogers and Freedman (2012:100); Johnson and Stax (2015:17) defined a non-conservative force as the one for which work depends on the path taken. This include forces like friction, tension and many other forces. Learners have the challenge in stating and applying the formula for both the work-energy theorem and work done by the no-conservative force (Sefton 2004:7; Girep 2008:1). This makes it difficult for the learners to relate work and energy concepts, and solve problems that are related to these concepts. In addition, in Italy, Camarca, Bonanno and Sapia (2007:1181), posited that learners also confused the work energy theorem and work done by non-conservative forces

Evidently, the definitions of these concepts need considerate attention. For instance to say energy is the “ability” to do work and go on to equate the equation of energy with one of work can be confusing. The notion of “ability” may imply “effort”, which in turn can be viewed as a force. However, it will not be correct to say energy is the “force” to do work. It is the meanings originally attached to these words (prior knowledge from our backgrounds) that most likely compromise their scientific meaning as concepts and or constructs.

Yazdi (2017:14) and DBE (2014:152) revealed that, because of this, learners opt to resort to or learn procedures that are involved in solving work, energy and power concepts without understanding them. For example, most learners memorise the definition of the work concept (McCarthy 2010:454; Mnchunu 2012:29). This makes it difficult for learners to understand and apply the formula W=Fnetxcos Θ, to calculate the work done on an object. This results in learners memorising the formula and doing the plug and chug without understanding the process (Cutnell & Johnson 2004:161).

When work is done, energy is transferred, and when energy is transformed, work is done (Sefton 2004:7; Giancoli 2005:137). For example: i. When the energy of an object like EP is transformed to KE, i.e. when it moves (KE) from rest (EP), i.e. energy is transformed from PE to KE (not necessarily transferred), ii. The object traverses / moves (i.e.Δv) and this results in a displacement (Δx), iii. $F_{net} > 0$ causes $\Delta a\ which\ in\ essence\ is\ rate\ of\ change\ of\ velocity\ x$ and ultimately accounts for Δx of an object experiencing it.

The two processes are mutually inclusive and interdependent. Thus, the same examples and or experiments are used to teach the concepts; the only difference may be that they are not necessarily taught at the same time during the same lesson. This has the potential to “harden” the learners’ acceptance that these concepts are different because they all may occur at the same time and the same activity. The concepts of power introduce a variable of time (i.e. rate) it takes to do the work or transform the energy of an object. Practically, what is being observed when work is done, is the rate at which the objects’ position changes (i.e. velocity/speed). Unless clearly explained, the rate of change of position (i.e. ${}^{\Delta x}/_{\Delta t}$) that is observed is likely to be confused with the rate of change of velocity (i.e. $\Delta v/_{\Delta t}$) that happens simultaneously with the change in position.

2.4.1.3 Insufficient learner involvement

According to Sekwena (2014:17), learner involvement in the context of learning refers to the situation in which the learners are motivated to develop meaning about their experience and are willing to expend sustained effort to that end. Learner involvement also means that the learners are the active participants in the construction of knowledge through a range of classroom activities (Doolittle & Hicks 2003:20; Rajmoor 2012:45). According to Duit (1999:270) and Ding (2006:9), insufficient learner involvement that is prominent in the teacher-centred approach deprives the learner of an opportunity to take an active part in the construction of knowledge. Holubova (2008:25) and Bonner (2010:187) pointed out that this approach promotes rote learning and memorisation of laws, theories and principled without a deeper understanding of these concepts. This has the potential for cognitive overload in which the learner has intended cognitive processing that exceeds the learner's available cognitive capacity (Garrett 2008:39; Olusegun 2015:66). According to Mayer and Moreno (2003:5), cognitive overload hinders meaningful learning where learners develop a deep understanding of the material. This includes attending to important aspects of the presented material, mentally organising it into a coherent cognitive structure, and integrating it with relevant existing knowledge (Ramma 2017:2; Macleod 2013:12). The work of Peko and Verga (2014:60) alluded to the belief that this approach makes work, energy and power concepts too abstract for learners.

2.4.1.4 Pedagogical content knowledge (PCK)

Lack of teacher pedagogical content knowledge (PCK) is one of the challenges in teaching and learning of work, energy and power concepts. Kathirveloo, Puteh and Matematik (2014:2) define PCK as a blending of teacher's work, energy and power concepts content knowledge and pedagogical knowledge, to understand how work, energy and power concepts are organised, represented and adapted to match diverse learners' learning styles. According to Hillier (2013:20), PCK involves all approaches, methods and the knowledge that the teacher practices to enhance the understanding of work, energy and power concepts. According to Etkina (2010:4), teachers who lack PCK in work, energy and power concepts, are teachers with gaps in their content and pedagogic understanding (Etkina 2010:4). According to Saglam-Arsalan and Kurnaz (2012:58), teachers who lack PCK in work, energy and power concepts are not at an adequate level in defining the work, energy and power concepts scientifically. This makes it difficult to state the characteristics and explain the situations in relation to their environment (Saglam-Aslan et al. 2009:6). Owing to the lack of PCK, the teachers can select inappropriate teaching strategies and methodologies. This affects learners' conceptual understanding of work, energy and power concepts and demotivates the learners (Linney 1989:1; Heck 2009:5). In support of this Krajcik (2012:58) opines that a lack of PCK might emerge amongst other things when the teacher specialised in one subject and is given another subject to teach.

Sibuyi (2013:10) and Mishra and Koehler (2006:1027) further argue that the teacher who lacks PCK lacks the ability to trace conceptual and procedural knowledge that the learner brings to the class. This makes it difficult for the teacher to identify, misconceptions that might have developed, and the stages the learners need to pass through to develop a deeper conceptual understanding of work, energy and power concepts.

In addition, Mishra and Koehler (2006:1027) posit that lack of PCK deprive the teacher of the knowledge of instructional strategies that connect learners' prior knowledge to a new insight, and eliminates misconceptions. For example, some learners cannot differentiate between the everyday use of the word "work'' and the physics use. According to Chiu and Xihua (2008:10), this can stem from the notion that the teacher is not at an adequate level in defining work, energy and power concepts. This result in the teacher being unable to mention the features and clarifying the conditions in connection to their surroundings. Supporting this notion, Abel (2008; 11), states that the teacher who lacks PCK uses inappropriate analogies and incorrect terminologies. This may result in the formation of an alternative conception in work, energy and power concepts. According to Berry (2008:9), lack of PCK can result in a teacher being unable to understand cultural, political, environmental and social physical settings in which the learner learns. Kleickmann, Richter, Kunter, Elsner, Besser, Krauss, and Baumert (2013:23) express the same view about the teachers that do not feel comfortable about the topic of work energy and power, and tend to confuse the terminology which leads to the learners being discouraged from exploring the topic of work, energy and power. According to Saccardi (2008:18), these teachers are resistant to change and tend to call upon their classroom management strategies and manage the class rather than teaching it.

2.4.2 Possible solutions for the teaching and learning of work, energy and power.

In this section, I discuss the literature review on five possible solutions that could address the challenges in teaching and learning of work, energy and power concepts. These solutions are using learners' conceptions in teaching work, energy and power concepts and multiple representations to teach work, energy and power concepts, utilising learner involvement and PCK.

2.4.3 Using learner's conceptions to enhance teaching and learning of work, energy and power concepts

Learners' conceptions of work, energy and power concepts are earnest attempts by learners to make sense of these concepts (Duit &Treagust 2003:680; Baveja 2012:1070). This means every learner makes sense of the work, energy and power concepts in a unique and personal way (Papadouris 2008; 25). It is therefore imperative for the teacher to use them as a tool available to build on to facilitate learners' learning and understanding of these concepts (Campos 2016:2).

Sometimes learners' conceptions can resonate with work, energy and power concept knowledge (Etkina 2010:4). Conceptions that learners have about the concepts to learn are called paraconceptions and phenomenological primitives (p-prim). Paraconceptions are statements that are either right or wrong depending on specific conditions, while p-prims are general knowledge structures that we all possess because of reflecting on our experiences (Chhabra & Baveja 2012:1070). Refining learners' paraconceptions and p-prims through subsequent learning can gradually develop a deeper conceptual understanding of these concepts in learners (Di Sessa 1988:2 & Wenning 2008:12). For example, the conception that "motion requires force" can be replaced by a deeper understanding of Newton's first law (Wenning 2008:12).

This makes it necessary for the teachers not to eliminate these paraconceptions, rather they must help learners to understand how they fit in with work, energy and power concepts (Wenning 2008:12). One example is when the learner understands that when a non-zero net force is applied on an object, the object will accelerate in the direction of the force. The teacher must clarify to the learner that this statement is true under certain conditions and false under other conditions.

It is for this reason that Duit and Treagust (2003: 680) suggested learners' conceptions as the starting point in developing learners' understanding, in this case of work, energy and power concepts. This means learners' initial knowledge should be considered as a cognitive stepping-stone on their way to the understanding of these concepts (Chhabra & Baveja 2012:1070). Arguing this, Duit and Treaqust (2010:25) and Dunnamah and Danbiyu (2015:396) posit that this helps to develop an interest in much the same way as to develop learners' conceptions towards work, energy and power concepts

Utilising pre-knowledge assists in developing conceptual change in learners' mind (Agiande, Williams, Dunnamah & Tumba 2015:396). According to Agiande et al. (2015:396), conceptual change shall have occurred if learner's pre-instructional conception in these concepts have developed to be congruent with the physics curriculum. According to Agiande et al. (2015:396), this happens when the learner becomes dissatisfied with pre-instructional conceptions, and replacement concepts and knowledge are intelligible, plausible and fruitful to the learner. According to Sands (2014:8), an intelligible conception is the one that makes sense to the learners, is non-contradictory and understandable to the learner. "Plausible" means the learner knows and believes the conception and "fruitful" means the concept is usable for solving problems. Duit and Treagust (2003:23) suggest the use of analogies to stimulate conceptual change in learners during teaching and learning of work, energy and power concepts and accommodation will occur.

Piaget and Vygotsky (1986) and Johnson (2014:5) also noted that cognitive change takes place when previous conceptions go through the process of dis-equilibration in light of new information. Pursuing this further, Mchunu (2012:48) posits that the teacher needs to be aware of these conceptions, to consider explanations, evaluate the competing ideas and adopt the new idea that is more plausible than the misconception. It is for this reason that Friedman, Barbella and Forbus (2012:30) emphasised the importance of using these conceptions as a tool at hand to construct new knowledge. According to Friedman et al. (2012:30), the teacher must integrate the learners' pre-knowledge and the new knowledge to make sense of work, energy and power concepts. Central to this notion is the perspective that the teacher should allow learners to debate work, energy and power concept, so that a clear image of misconceptions may surface and be rectified (Schunk 2012:10). Amplifying this notion, Vosniadou et al. (2007:50) suggested the use of context-specific conceptions to help teachers relate learners' experiences to new knowledge.

Trumper (1997:23) and Tang, Tan and Yeo (2016:4) further suggest that to ensure that the outcomes of teaching are achieved, teachers should determine learners' probable weaknesses and mistakes about conceptual perceptions in advance. According to Zou (2000:20); Mutimucuio (2003:23) and Van der Meij and de Jonh (2006:54), this is helpful in terms of providing learners and teachers with the necessary information to solve and to develop solution strategies for scientific or daily life problems related to energy concepts. In addition, Duit and Treaqust (2010:25) are of the view that this also helps determine what learners know about energy concepts and to what extent they can differentiate it from other concepts (Solbes 2009:35). This can assist in knowing different learners' primary sense of learning so that the teacher will know how to approach teaching and learning and can apply specific methods that will aid different learners to understand the energy concept.

2.4.3.1 Using multiple representations to teach work, energy and power concepts

In an attempt to engage learners and improve their understanding of the work, energy and power concepts, one method of teaching cannot be sufficient, considering that learners have different learning styles and learn from different environments (Van Wyk 2011:183; Sharma 2012:162). It is for this reason that the use of multiple representations was recommended in teaching these concepts. According to Heuvelen and Zou (2001:184), multiple representations, especially the qualitative work-energy bar charts, serve as a useful visual tool to help learners understand work-energy and power concepts, and solve related problems.

This means, in addition to verbal explanations, the teacher can use drawings, bar charts and mathematical representations to assist the learners in developing a deeper conceptual understanding of work, energy and power concepts. As Jewett (2008:41) and Bhattacharijya (2002:19) pointed out, work energy and power represent the amount of energy, work or power possessed by an object by means of the vertical bar. The length of the bar chart is proportional to the amount of energy. That is, the longer the bar, the greater the amount of energy it represents. In pursuance of this, Wong et al. (2014:4) argue that bar graphs help learners to understand the energies that are involved and how they change when work was done on an object. Kurnaz (2007:7) and McCarthy (2010:455) share the same sentiment that qualitative representations of work energy and power concepts through bar charts can play an important role in filling the gap between teacher's verbal explanations and equation.

Olugbara (2008:23) and Etkina (2010:4) further argue that multiple representations help the learners in the modelling of real-world physical phenomena using external representations that range from the concrete to abstract form. In pursuance, Bächtold (2017:2) and Maries (2009:13) aver that multiple representations play a significant role in bringing concepts (in this case work, energy and power) to reality in the classroom and improve learners' understanding of these concepts. According to Doolittle (2002:1) and Naiser, Wright, Capraro (2004:194), learners must learn the format of representation and understand how the representation relates to these concepts.

McIldowie (2004:213-214) argues that energy and work concepts form a duality; hence it is important for learners to have a clear understanding of the work concept to understand the other concepts. In support of this, Warren, (1986:23); Küçük et al. (2005:54) and Kurnaz, (2007:7), posit that this can help to alleviate the conceptual difficulty that learners have about these concepts.

In addition, the work of Ainsworth (2006:10) and Rosengrant et al. (2007:134) revealed that the learning environment based on multiple representations have positive effects to remedy non-scientific learners' ideas. According to Kurnaz and Arslan (2014:629) and Walker (2014:17), multiple representations address learners with richer representations by increasing the variety of external representations that affect the cognitive configuration and gives a more effective result. Sharing the same sentiment, Zou (2000:105); Mutimucuio, (2003:39) and van der Meij and de Jongh (2006:15) posit that multiple representations can help to smooth the transformation of work, energy and power information from one form to another for learners. In addition, Docktor et al. (2015:25), indicated that multiple representation is an effective way strategy for learners' learning and drawing their attention during teaching and learning of energy concept. Following this argument Boyes and Stanisstreet (1990) and Madanoglu (2015) posit that learners' learning should not be limited to the theoretical knowledge they acquire at school, but it should also allow them to draw connections to daily-life instances. According to Jewett (2008:41) and Nyahururu (2015:78) the term "energy change" should be used to describe a change in a system qualitatively and quantitatively when it goes from one state to another.

Alluding to this, Land, Meyer and Baillie (2010:16) posit that this brings about reconfiguration occasions and an ontological and an epistemic shift in these concepts. According to Rosengrant, Heuvelen and Etkina (2009:2) the reconfiguration integration that is accompanied by ontological and epistemic shift in work, energy and power concepts bring about the required new understanding. According to Halim, Yong and Meerah (2014:1036) and Lin and Singh (2016: 30), this understanding helps the learner to cross the conceptual space of work, energy and power concept that is congruent with the physics curriculum. Pursuing this further Heuvelen and Zou (2001:5) posit that in crossing the conceptual boundary into new knowledge during this state both the learning of work, energy and power concepts and the learner are transformed.

Coelho (2010:15) posits that different teaching strategies must be used to present this concept to learners. According to Rajmoor (2012:15) and Mnchunu (2012:47) strategies like verbal explanation, sketches, graphs and concept maps can help to enhance the understanding of the power concept. The concept map can be used to show the learners that when work is done, energy is transferred. This can help to clarify to learners the average power and the force that brings about the average velocity of the object (Sefton 2004:10). According to Rosengrant et al. (2009:2), this can help the learners to understand the concept of power and apply the formula, Pav =FVav. Since the work done is equal to the change in mechanical energy, Wnc= ΔEP+ ΔEK. The power for non-conservative forces can be calculated, for example, the power needed to pump water out of the borehole.

2.4.3.2 Active learning

Karamustafaoglu (2008:28) defines active learning as any instructional method that engages learners in the learning process. This includes the use of discussion, learners' representations, role-plays, flip charts, handouts, laboratory method, problem-solving, project based learning and collaborative methods. This means active learning requires learners to engage in meaningful learning activities during teaching and learning of work, energy and power concepts. This allows them to think about an activity that they are doing.

Bruner (1984) and Peko and Varga (2014:60) pointed out that active learning is based on learners' personal construction and reconstruction of knowledge which takes place in, and is influenced by, learner's socio-cultural context. It is therefore important that the learners take an active part in the construction and reconstruction of knowledge about work, energy and power concepts. Meltzer and Thornton (2012:479) asserted that active learning could assist the learner to make an adequate connection between work, energy and power concepts presented in the class and the real-life application of these concepts. This can help to stimulate learner's interest, and the learner become motivated.

Slavvin (2003:15) further argues that active learning can help to provide learners with an opportunity to come to grasp with work, energy and power concepts that they often struggle to understand. As Garrett (2008:40) pointed out, active learning help to guide learners to construct their knowledge of work, energy and power concepts by direct observation of the world. This helps the learner to enhance interaction between the learner's internal structures and learners outside experience (Greeno, Reder, & Simon 2000:25). This also helps the learners to internalise work, energy and power concepts and make the linkage between theory and practice (Scheyvens, Griffin, Liu & Bradford 2008:53). Arguing this further, Agiande et al. (2015:402) posit that active learning ensures that learning is on the shoulders of the learners where it belongs

2.4.3.3 Importance of teacher's pedagogical content knowledge

Teacher's pedagogical content knowledge plays a significant role in teaching and learning of work, energy and power concepts in the Grade 12 physical science class. According to Shulman (1987:8) and Eralp (2012:2), PCK is the blending of content and pedagogy into an understanding of how work, energy and power concepts are organised, represented, adapted to the diverse interests and abilities of learners, and presented for instruction. According to Etkina (2009:1), knowing work, energy and power concepts and laws that are involved in teaching these concepts and methods of scientific inquiry, can assist the teacher in teaching these concepts. Kiptum (2015:8) adds that teachers' PCK should include knowledge of mathematics, especially trigonometry. Since work, energy and power concepts are mathematically related concepts, this can allow the teacher to transform work, energy and power concepts content knowledge in a more conceptually accessible version for the learners.

According to Olanoff, Lo and Tobias (2014:281), this knowledge allows the teacher to create a learning environment in which learners can construct knowledge about work, energy and power concepts. As the work of Eralp (2012:3) indicated, teacher's pedagogical content knowledge helps the teacher to transform subject matter into content of instructions during teaching and learning. Furthermore, Etkina (2010: 6) posit that relevant PCK can help the teacher to select appropriate methods and teaching strategies that will assist in enhancing the conceptual understanding of work, energy and power concepts. Etkina (2010: 4) echo these sentiments by arguing that the teacher with adequate PCK uses appropriate teaching strategies to create cognitive conflict in learners' mind and this helps to eradicate misconceptions and enhances conceptual understanding of work, energy and power concepts.

2.4.4 Conditions conducive for teaching and learning of work, energy and power

This section discusses conditions conducive for teaching and learning of work, energy and power concepts in Grade 12 physical science class. These conditions relate to the proper use of learners' conceptions to teach work, energy and power concepts, good use of multiple representations to teach work, energy and power concepts, effective involvement of learners during teaching of work, energy and power concepts and Adequate teacher's PCK in work, energy and power concepts.

2.4.4.1 Conditions conducive for integrating learners' conceptions in the teaching and learning of work, energy and power

Chhabra and Baveja (2012:1070) emphasise the importance of integration of learners' conceptions to work, energy and power content when teaching these concepts. Arguing this, Chhabra and Baveja (2012:107) posit that learners' pre-instructional conceptions play a decisive role in constructing knowledge about work, energy and power concepts. Phillimore et al. (2016:12) asserted that integration of learners' conceptions helps to involve the learners in cognitive processes that enable them to retrieve their prior experiences. This helps the learners to use prior knowledge as a tool they have and to combine it with new knowledge to make sense of work, energy and power concepts (Lee 2009:105).

For the teacher to assist the learners in combining their conceptions with new knowledge, Duit and Treaqust (2010;25), suggest that the teacher should allow learners to take an active part. Duit and Treaqust (2010; 25) declare that the teacher must allow the learners to form a hypothesis that fits both their previous knowledge and new experiences. Alluding to this conception, Wenning (2008:11) posits that this helps the learners to get a satisfactory picture that can help them to either discard or modify their conceptions.

Pursuing this further, Wenning (2008:12) posits that more often, learners' conceptions are paraconceptions. This means they should not be eliminated but rather used to help learners to understand how these ideas fit in work, energy and power concepts. This could clarify how to use these ideas in a proper way under different conditions. Mintzes, Wandersee and Novak (1998:23); Strike & Posner (1992) and Southerland, Abrams, Cummins and Anzelmo (2001:329) support the notion that rectifying learners' paraconceptions enhances cognitive restructurings in which learners' work, energy and power concepts and paraconceptions undergo structural modifications or restructuring.

2.4.4.2 Conditions conducive for multiple representation of work, energy and power

Multiple representations of the reality of work, energy and power in the learning situation imply that a single aspect is represented in different modes to cater for the learners' different learning styles (Waldrip, Prain & Carolan; 2010:68; Antwi, Hanson, Savelsbergh & Eijkelhof 20011:56). This means the situation must be adequate in respect of resources for multiple representations, flexible space and time. As a practical subject, for instance, physical science requires a learning space with relevant resources for teaching the concepts of work, energy and power. Some of these resources are expensive while others may be dangerous and as such, require to be handled with great circumspection. The teaching of these concepts, both practically and theoretically, requires more time, especially because teaching must also be tailored according to the needs of the learners (DHET 2015). The learning space should also allow for the possible performance of experiments and or demonstrations, group work /collaborative learning to ensure inclusion of all learners in their learning. The implication of this condition demands that the teacher should be well versed in the different ways of representing the reality and ways of learning and teaching (Lindsay 2011:608; Nixon 2012:8; Olaleye 2012:17) of work, energy and power.

2.4.4.3 Conditions conducive for learner involvement in teaching and learning of work, energy and power concepts

Learner involvement requires mutual respect and care among learners to be successful. Without these values, learner discipline during laboratory/experiment group work may be compromised. These values also enable the realisation of the much-desired learner contribution and actual participation (Thornton & Reynolds 2006:277).

In some instances, learners have to share the use of limited resources and assist one another with responding to questions and or completing worksheets (Fortus, 2014:10). This requires that learners must be encouraged to appreciate that they can also learn from other learners; as such, groups need to be carefully selected to ensure desired equitable representation of learners' capabilities per group.

In addition, learner involvement requires that learners must be willing to work as individuals as well as with others (Anderson 2008:220; DBE 2011, Mchunu 2012:52) to apply and hone their practical skills to solve problems (Scheyvens et al. 2008:53).

2.4.4.4 Conditions conducive for optimal utilisation of teachers' PCK in

Different teachers use different methods and approaches when teaching work, energy and power concepts. Some teachers are more experienced, hold better qualifications and have attended numerous in-service training workshops based on work, energy and power. This variety represents the wealth that teachers have as a collective more than as individuals.

Thus, to derive optimal benefits from teachers' collective knowledge of the content on work, energy and power; the skills and values required form meaningful learning (DHET, 2011), as well as the best possible teaching methods and strategies, require all the stakeholders to work as a collaborative team(s) and or professional working teams (Anderson 2008:220). They should pursue a common goal/vision of improving their disciplinary and pedagogical knowledge regarding work, energy and power concepts.

For these teams to thrive, they also need to adopt a set of values that can bind them together and develop an action plan that clearly spells out activities, responsibilities, and resources needed (Tlali 20013:86). Also, the team may consider drawing up a performance agreement that also indicates teachers' contributions and schedule of engagements (Tlali 20013:90). For purposes of ensuring its sustainability, team members' interests need to be aligned accordingly. The team should be bold to involve external stakeholders to support them, especially in instances where the team lack internal capacity or requires alternative ways of addressing the matter under consideration.

Wittmann and Thompson (2015: 20) suggested the use of teacher development workshops as one of the solutions of improving teachers' PCK where the subject specialist and the teachers will share subject knowledge and methods of teaching work, energy and power concepts. According to Mnchunu (2012:40), through workshops, teachers are connected within the community of peers and that gives the teachers a chance to develop a shared understanding of work, energy and power concepts. Furthermore, Lorenzen (2002:10) suggests the use of scaffolded reflection that must happen throughout the practices and exchange of lesson plans by peers, presentation of ideas and the reflection on their actions. Mishra and Koehler (2006:1027) found that for teachers to understand how the lesson progresses, the teacher must be involved in a mentoring exercise where teachers are given a chance to view their own lesson and learners' work.

2.4.5 Threats that are inherent in teaching and learning of work, energy and power concepts

This section addresses the threats that are inherent in teaching-learning of work, energy and power concepts. These threats include: Risks inherent in learners' conceptions; risks in using multiple representations to teach work, energy and power; risks in learner involvement and risks involved in teachers' pedagogical content knowledge. A variety of literature is are explored in an attempt to identify challenges, find solutions and create a conducive environment for the teaching-learning of work, energy and power.

2.4.5.1 Threats in using learners' conceptions

In as much as this study recommends the use of learners' conceptions in forming the base for the understanding of work, energy and power concepts, this comes with some threats that are inherent in using them. As Duit and Treaqust (2008:43) pointed out, some learners may be reserved and find it difficult to expose their "weaknesses" to others. Other learners may be outspoken and dominant to the extent of suppressing and threatening those who may have challenged self-esteem. Sometimes examples emanating from learners' background may be offensive and or misconstrued with the result that attempts to re-align them with the intended purpose may take a long time at the expense of prescribed teaching time. This may also happen when the learners' erroneous conceptions are deep seated. This makes it difficult for the teacher to identify pre-instructional conceptions that the learners carry about these concepts. According to Chhabra and Baveja (2012:1070), since these preconceptions are well fitted in learner's cognitive structures, and are stable, they can limit the effort the learners invest in learning these concepts. Amplifying this notion, Lee (2009:105) and Muller and Sharma (2007:5) aver that these conceptions can interfere with the memories of recently learned work, energy and power conceptions.

The work of Lee (2009:105) reveals that it is also possible that the teacher could be not well versed with the learners' perspective of work, energy and power. Furthermore, teachers may also have misconceptions about some aspects relating to work, energy and power (Iwuanyanwu 2014:18). This can result in inefficient teaching. According to Chiu and Lin (2008:293), inefficient teaching results in a mismatch between learners' cognitive structures and teachers expectations, and this causes alternative conceptions to be formed. Johnson and Stax (2015:17) aver that this can deprive learners of an opportunity to develop an understanding of these concepts.

In the same breadth Solbes (2009:3) cited some of the conceptions that the learners normally carried in work, energy and power concepts. These conceptions include: learners confuse everyday use of work, energy and power concepts with their use in in physics and leaners confuse the different energy and power concepts. This makes difficult for the learners to amalgamate knowledge from the system of the real-life world and work, energy and power concepts (Chiu & Lin 2008:298). Furthermore, McGregor, (2011:2) posits that preconceptions can also result from learner's axiology. From Wenning's (2008:11) point of view, the concept of work can have different meanings for different cultural groups. Following the same argument, Altan (2009:21) has alluded to the notion that if the new knowledge about work, energy and power concepts delivered is not in line with learners' axiology, conceptual understanding of work, energy and power concepts will not occur.

2.4.5.2 Risks involved in using multiple representations of work, energy and power

Successes in the use of multiple representations in teaching work, energy and power concepts depend on how the teacher uses them. The way the teacher uses representations in teaching work, energy and power concepts can be a threat to teaching these concepts. The work of Naiser et al. (2004:194) reveals that if the teacher is not competent in using multiple representations to teach work, energy and power concepts, it will have a negative effect in learners' understanding of these concepts. Central to Rau and Matthew's (2017:3) perspective is the notion that the use of multiple representations in teaching work, energy and power concepts can confuse the learners rather than helping them to understand these concepts, if not properly used. Nixon (2012:8) went further to argue that if multiple representations are not properly used, it could cause the learners to focus on the surface features of work, energy and power concepts representation, rather than negotiating a deeper conceptual meanings of work, energy and power concepts represented. According to Halim, Yong, Meerah (2014:1036), this is because the way these concepts are represented makes it difficult for learners to identify the shared meaning between representations, and instead, view each representation as separate and distinct in meaning. Ainsworth et al. (2006) and Nixon (2012:8) further assert that if the learner struggles to identify meaningful differences between representations, the learner will struggle to negotiate each separate representation. This will result in one representation constraining the other by limiting the possible meaning of these concepts (Wong & Wee 2014:1). This can also cause the learner to confuse work, energy and power concepts and also to confuse it with other related quantities (Bächtold 2017:2). Pursuing this further Maries (2009:13) posits that incorrect use of multiple representations causes the learners to misinterpret representations and as a result, learners' cognitive load will be increased.

2.4.5.3 Threat inherent in learner involvement

Using learner involvement approaches for the teaching and learning of work, energy and power concepts come with threats that are inherent in using it. Different learners learn differently using different learning styles (Kampwirth & Bates 2016:527), they learn at different paces, some being gifted when others are slow due to several factors like learning barriers and being underprepared for the grade and or content (i.e. work, energy and power). In addition, learners' diverse attributes (e.g. being introverts and or extroverts) may not be divorced from their learning (Davis 20009:132). These factors may significantly influence learning and the facilitation of learning. These concerns require concerted efforts on the part of the teacher to ensure that they do not affect learning negatively (Greenlaw 20003:6). The teachers' thorough and thoughtful consideration of these issues is critical, also noting the limited prescribed time for teaching and learning (Dengler (2008:482).

2.4.5.4 Risks in teachers' pedagogical content knowledge

Science is dynamic (Olaleye 20012:17). The content and methods of teaching science also evolve. Teachers are likely to labour under the impression that the knowledge they have about the content and how to teach it is on point, only to be trapped in ineffective ways of doing things. The demands of the fourth industrial revolution (robotics, artificial intelligence, internet of things) may inherently influence teachers' content and pedagogical knowledge and capabilities on a continuous basis. In addition, in the case of SA, calls for decolonisation of education (Maries 20013:5) that are directed to teaching and learning, are an invitation for teachers to consider including local knowledge in the teaching and learning situation. The call suggests that teachers may still be inconsiderate of this aspect despite them having sound PCK, that might be based predominantly on foreign contexts rather than to those of the learners.

2.4.6 Indications of success in the implementation of a strategy to teach work, energy and power concepts

This section reviews the literature on the success in the implementation of a strategy for teaching and learning of work, energy and power concepts in the Grade12 physical science class. This is done under the following headings: Success in using learners' conceptions to teach work, energy and power concepts; good use of multiple representations to teach work, energy and power concepts, learner involvement, and adequate teachers' PCK.

2.4.6.1 Success in using learners' conceptions to teach work, energy and power concepts

The strategy aims to respond to the problems that affect teachers and learners during the teaching and learning of work, energy and power concepts. The strategy attempts to ensure that learners' conceptions are used as basic knowledge in teaching and learning of work, energy and power concepts. According to Pika (2017:23), learners' conceptions serve as ontological and epistemological beliefs that assist teachers to effect the conceptual change in learners' minds. For this reason, the strategy attempts to use learners' conceptions to transform the teaching and learning of these concepts not only in theory but also in practice (Larkin 2012:930). This assists in developing a deeper conceptual understanding of work, energy and power concepts. It is for this reason that this strategy anticipates the type of learning in which "learners take control of their own learning and engage with active construction and reconstruction of their own meanings for concepts and phenomena" (Chi & Lin 20008:295).

According to Bowden and Marton (2003:69), the advantage of this strategy is that it uses conceptions to increase the learners' desire to learn, which assists in creating an ontological shift that is necessary for conceptual change. This help the learner to develop a deeper understanding of work, energy and power concepts (Sefton 2004:4). According to the strategy, the teacher needs to find which component of learners' conceptions could be beneficial in building a more robust understanding of work, energy and power concepts (Lucariello & Naff 20019:10). The work of Pika (2017:24) reveals that the teacher's instructions should generate a conflict between learners' preconception and work, energy and power concepts by creating a discrepant event. According to Pika (2017:30), this is a phenomenon that cannot be explained using the learner's current conceptions but can be explained using scientific work, energy and power concepts principles and formulae. This helps the learners to spot the inadequacy of their conceptions, and become more open to change (Thornton & Reynolds 2006:277). This further assists them to reconcile the differences between their conceptions and work, energy and power concepts (Chhabra & Baveja 2012:1070). In this situation, the teacher as a bricoleur builds on and innovate learners' conceptions to transform them into a deeper understanding of work, energy and power concepts (Rogers,2012:14).

2.4.6.2 Multiple representations in teaching and learning of work, energy and power concepts

Another positive aspect of the strategy is that it champions the use of multiple representations to teach work, energy and power concepts, which has been a challenge to most teachers (Stokes 2002:12). Through the implementation of this strategy, teachers attain the knowledge of using multiple representations to link an abstract verbal description of work, energy and power concepts to abstract mathematical representations of these concepts. This is done through more intuitive use of diagrams, concept maps and graphs (Kurnaz & Arslan 2014:629). Alluding to this notion, Tall (1988) and Maries (2013:5) posit that the combination of different representations affords the development of a rich work, energy and power concepts image in learners. In addition, the strategy anticipates the learning environment that is based on multiple representations, which could develop learners' understanding of work, energy and power concept (Felder 2002:677). It is for this reason that the strategy deems it necessary that the teacher, as a bricoleur, should use multiple representations for the teaching of work, energy and power concepts to accommodate different learners' learning (Kincheloe 20005:325).

The strategy further develops the problem-solving skills through a qualitative analysis of a problem, which includes the drawing of diagrams to ensure that learners understand the problem in a situation before deciding on the physics principle to be applied (Maries 2013:6). Pursuing this further, Rosengrant (2007:297) avers that the use of multiple representations of knowledge enhances the conceptual understanding of concepts. Central to this perspective is the notion that the human mind relates best to picture-like representations to better understand abstract concepts (Olaleye 2012:17). For the same reason, the strategy suggested using both abstract formulae and picture like representations to teach work, energy and power concepts to enhance the conceptual understanding of these concepts (Ayesh, Qamhieh, Tit and Abdelfattah 2010:505).

2.4.6.3 Promoting learner involvement in teaching and learning of work, energy and power concepts

Another strong aspect of the strategy is that it values learners' involvement as an indication of successful implementation of the strategy for teaching and learning of work, energy and power concepts. It is on this context that Slavvin (2003:12) argues that actively involving learners in teaching and learning through discussing problem strategies in groups and then as individuals has the potential of promoting a more coherent view of work, energy and power concepts problem solving (Doolittle ,2014:55). It is for this reason that this strategy attempts to create a supportive environment where learners practice to solve problems in a mixed-ability cooperative groups (Bull 20009:02). According to Peko and Varga (2014:60), this afford learners an opportunity to share their conceptual and procedural understandings as they solve problems together. Furthermore, the strategy suggests that better problem solutions emerge through collaboration than achieved by individuals working alone (Garrett 2008:40) Following this line of argument, Onwu and Ogunniyi (2006: 131) aver that active engagement in learning stimulates the cognitive development. In the same breadth, Anderson (2014:217) alluded to the notion that actively engaging learners in teaching and learning can promote a more coherent view of work, energy and power problem.

2.4.6.4 Enhancing teachers' pedagogical content knowledge in work, energy and power concepts

The strategy attempts to capacitate the teachers to empower them to address challenging work, energy and power concepts. This component of the strategy is critical because most teachers have shown inadequate PCK in these concepts, and this results in the formation of misconceptions in learners (Sibuyi 2013:10). I agree with Aycan and Yumusak (2003:30) that PCK can help the teacher to transform the knowledge about concepts (work, energy and power) that the teacher is teaching in a way that can be easily understood by the learners. This knowledge could help the teacher to understand learners' conceptions in these concepts, know the cognitive demands that these concepts impose on learners and the teaching strategies required to teach these concepts (Lindsay 2011:608).

The strategy further anticipates that teachers should undergo teacher development and skills programs to enhance their PCK to a level that will assist in dealing with challenging work, energy and power concepts (Tchoshanov 2010:142; Sibuyi 2013:10). The strategy envisages building a knowledgeable and sustainable workforce that can assist in dealing with complex physical sciences problems in a way that will benefit learners (Kelly & Cherkowski 2015:2)

2.5 CONCLUSIONS

This chapter focused on the review of the literature on the challenges on the teaching and learning of work, energy and power concepts in light the objectives of the study. The study is couched on bricolage as the theoretical framework. Bricolage was used because of its principles of multiplicity, eclecticism, emancipatory, diversity, praxis, transformative and empowerment I deemed it relevant for this study. I focused on challenges, solutions, conducive conditions, anticipated threats and indications of successful implementation of a strategy. The focus of Chapter 3 is on the use of participatory research as a research methodology and how is it used to generate empirical data in collaborations with co-researchers.

3 CHAPTER THREE

PARTICIPATORY ACTION RESEARCH (PAR)

3.1 INTRODUCTION

The chapter focuses on the chosen approach for generating data, which is Participatory Action Research (PAR). In conceptualising PAR, I focused on its origin, ontology and epistemology, principles, and rhetoric. Furthermore, the chapter focuses on the role of the researcher and the relationship between the researcher and co-researchers. The chosen data analysis technique, namely critical discourse analysis (CDA), is also discussed in this chapter by tracing its origins and paying attention to textual, discursive and social practice levels. The research sites, profiling of co-researchers and ethical consideration are also discussed. In conclusion, the summary of the chapter is done. Furthermore I identified challenges, solutions, threats, conducive conditions and some indicators that show successful development of the strategy to enhance teaching and learning of work, energy and power. I use PAR as the research methodology when generating data together with the co-researchers. I also used the principles of a free attitude interview as a technique to solicit information. In the following section, I embark on a discussion of the origin of PAR.

3.2 PAR AS RESEARCH METHODOLOGY

PAR as research methodology assisted me to work with the team of co-researchers in developing a strategy that can enhance the teaching and learning of work, energy and power concepts in the Grade 12 physical science class. The members of the team included two physical science educators, Grade 12 physical science learners, a physical science subject advisor, the school principal and the chairperson of the governing body (mechanic) that represented the parents. The aim was to assist the learners in understanding work, energy and power concepts better by empowering teachers with teaching approaches that could accommodate diverse learners. Baum, MacDougall and Smith (2006:854), also confirm this by stating that PAR helps to promote social change and empower the society.

PAR helps to develop a critical consciousness in teachers and learners about their problem in work, energy and power (Freire 1970:28; Ozanne & Saatcioglu 20008:430). In the same breadth, Sadowska and Laffy (2015:2) posit that this brings experience and relevant knowledge because the co-researchers were confronted with this problem every day. The PAR approach helps to solve the problems that the teachers and learners have in relation to work, energy and power concepts by discussing the problems and coming up with solutions. Furthermore, PAR empowers the team members by providing them with the basic skills for solving the problem. These skills involve teachers' use of multiple representations and learners' conceptions in teaching and learning of work, energy and power concepts.

PAR is rooted in critical pedagogies (CP), and as a social phenomenon, it promotes social change and addresses issues of power relations among the team members (Baum et al. 2006; MacDonald 20012:37). This include teachers de-empowering themselves by using an approach that allows them to take an active part in the knowledge constructing process. This helps the learners to relate their class context to their social context in which it is embedded (Wagner 2012:12). Alluding to the notion of social change and teacher self de-empowerment Gillis and Jackson (2002:50) posit that this helps to humanise and empower learners, which in turn transforms their situation in work, energy and power concepts (Aliakbari & Faraji 2020:78).

Like bricolage, PAR uses multiple methods to come to an understanding of social problems and finding solutions to these problems (McDonald 20012:36). Arguing this further, Sekwena (2014:49) posits that this helps the co-researchers to develop the capacity to use their local knowledge to understand their problem better and come up with an effective intervention strategy. I, therefore, hope that amalgamation of PAR and bricolage can be a valuable tool that can assist me during my study to develop a strategy to enhance teaching and learning of work, energy and power concepts.

3.2.1 Historical origin of PAR

PAR is believed to have originated in the olden days during the times of Kurt Lewin between 1940 and 1950 (Kemmis & McTaggard 20000: 243; Zuber-Skerritt, Fletcher, & Kearney 20015:105; Chevalier & Buckles 20019:1). The historical origin of PAR shows that it embraces principles of participation, reflection, empowerment and emancipation (Berg 2004:196; Cordeiro, Soares, & Rittenmeyer 2017:400). This allows the team members to participate freely in the discussion of the challenges that are involved in teaching and learning (in this case, of work, energy and power concepts). It can also help learners and teachers to understand their problem in work energy and power concepts, raise their self-esteem, and improve the underlying conditions. (Grantham, & Ford 20003:20; McDonald 20012:20). Ozanne (2015:13), following Freire's (1970:28) line of argument posit that this helps to develop critical consciousness in teachers and learners. Through critical consciousness learners and teachers come to the realisation of their problem in teaching and learning of work, energy and power concepts, work collaboratively, and apply critical thinking in finding the solution to their problem (Koehler & Mishra 2006:1020; Kleeb 20015:25). Pursuing this further, Muskus (2011:30) argues that through discussions, the team members get involved in the dialectic nature of knowledge construction, come to the realisation of the solution to their problems, and use local knowledge to transform their situation.

3.2.2 Appropriateness of PAR for the study

PAR was believed to be appropriate for this study because, teachers and learners working together can help to produce the knowledge needed to understand how teaching and learning of work, energy and power concepts can be enhanced. This help to contextualise and focus on the real problems that the teachers and learners have in teaching and learning of work, energy and power concepts (Burgess (2006:426; Connolly 2009:16). This could be achieved when I worked in collaboration with the co-researchers to generate the knowledge that would potentially transform teaching and learning of these concepts. PAR also helped to democratise the knowledge co-construction about teaching and learning of work, energy and power concepts and meant that learners contributed to the process of finding solutions to their problems.

PAR is appropriate in this study because it provided us with an opportunity to engage with the co-researchers to explore this problem, seek the solution together, implement the proposed solutions and evaluate the bearing of the suggested solution together.

3.2.3 Challenges in using PAR as an approach

One of the challenges of using PAR is that people may be reluctant to participate in the research process. This was evident during the research process where people from the local community did not want to take part, citing the lack of time as the reason and some further question about their benefits from the research. One of the co-researchers went to the extent of asking if they were going to get their imbursement at the end of the research project. This was an indication to me that they did not understand the importance of the research in their lives and to their community at large. I had to persuade them and explain the relevance of the study in their lives. As Bennet (2004:25); Pothier, Zewge-Abubaker, Cahuas, Klassen, and Wakefield (2019:170) and Tatum (2017:216) indicated, those who were willing to participate were living in the oppressed economies, and they were too busy to participate because each moment they get, they used to secure the necessities of life. Furthermore McDonald (2012:48) amplify what I have experienced as a researcher where the co-researchers failed to maintain their commitment and some of them tended to be absent as the time went on which led to fluctuation in the group. Some members of the team even withdrew from the research project citing the reason that research project has taken longer than they had expected. As Gillis and Jackson (2002:23); Young (2006:32) and Horgan (2017:250) suggested, it is difficult to get rid of power imbalances completely since some co-researchers have a position in their daily work, and they come to the team with an attitude of dominating the discussion. As a researcher, my work was to constantly try to retain the balance of power and establish a democratic relationship among the team members.

3.2.4 PAR ontology

Ontology is the study of how people view reality (Killam 20013:7; Lawson 20019:9; Van Langenhove 20019:63). In PAR, reality differs according to the individual social context (McGregor 20011:423; Greifeneder, Bless & Fiedler 20017:2; Fele 20019:471). Reality is contextual and complex and may not be reduced to a single universally applicable notion (MacDonald 2012:35). For instance, the concepts of work, energy and power are not necessarily and solely applicable to science and in sciences; it depends on the discipline/subject. This called for the team to create an environment that would allow team members to have different views about work, energy and power concepts. This allowed the co-researchers to work harmoniously and collaboratively in an attempt to find the solutions to the problems of teaching and learning work, energy and power concepts. Arguing this Mertens (2007:216) and Baklanov, Baklanova, Erokhin, Ponarina, and Akopyan, (2018:45) posit that due to the multiplicity of realities, we should be explicit about social, political, cultural and economic values that define realities. In pursuance of this notion, McDonald (2012:36) and Sager, (2016:205) add that PAR embraces dialectical shifting of understanding whereby there is a high possibility of subjectivity and multiple shared realities. It was, therefore, important to involve teachers and learner to share their views about teaching and learning of work, energy and power concepts.

3.2.5 PAR epistemology

Epistemology refers to the way different people or groups view knowledge (Killam 2013:8 ; Parviainen 2018:360). In PAR, knowledge is recognised as knowledge when it is socially constructed, embedded within the systems of values and promotes human interaction within the team members (Mertens 2007:216; Rhee & Choi 20017:820). In the study, the team members worked collaboratively, negotiating knowledge through a socially inclusive way to respond to work energy and power problem. This helped the team members to share the knowledge about work, energy and power concepts to accommodate the unique ways in which the team members conceptualise these concepts. In support of this perspective, Irvin and Stansbury (2004:55) and MacDonald (2012:35) argued that people should be actively involved in any activities and in decision making about the issues that involve them. Adding to this notion Berg (2004:19) and Adams (2008:30) posit that PAR is the research approach that embraces the principles of participation, reflection, empowerment and emancipation and it can assist subjugated group to improve their social conditions. It was therefore important that I, as the researcher, allowed the full participation of the co-researchers to maximise the co-researchers' contribution in the process of knowledge co-construction.

3.2.6 PAR axiology

According to Killam (2013:5) and Mertens (2012:20), axiology in PAR addresses the nature of ethical behaviour, and it refers to what the researcher believes is valuable and ethical. McGregor (2011:2) and Schwandt (2014:20) define axiology as the science of enquiry into human values that enable people to identify the internal valuing systems that influences their perceptions, decisions and actions and it helps to clarify their prejudices and biases. Understanding the team members' values helped me to resolve the value conflict between the team members by respecting and comparing them, and this helped me to integrate them into the problem-solving process during my study (Jameson 2007:220; McGregor 2011:3).

3.2.7 Role of the researcher in PAR

PAR facilitates the research process (Kemmis & McTaggart 20000:33) by working collaboratively with all the co-researchers throughout the research process. Since some of the co-researchers were the learners that I taught physical science from grade 10, it was easy for me to develop a trusting relationship with the co-researchers. Using my leadership and communicative skills with the help of some co-researchers as members of the community, I identified and influenced the key stakeholders to take part in the research process to obtain rich information.

As a researcher and participant, I tried to facilitate the creation of conducive condition for every participant to be equally involved and feel free to contribute for us as the team to pool knowledge. According to Roberts and Nash (2009:175) and Juurrjavi and Lundi (2013:5), through this condition, the participants become co-researchers and agents of transformation through participation. This helped me to understand the team members as I was trying to maximise their contributions without the dominance of one by another (Boog 2003:25; Fowler 2018:89). As a researcher, I was thoughtful of the co-researchers' roles, listened to their contributions and acted where necessary. As Zajc and Bednarz (2007:30) and Dhillon and Thomas (2019:445) suggested, the co-researchers and I were constantly checking the process to ensure just practices.

3.2.8 Relationship with the co-researchers in PAR

My relationship with the co-researchers was based on respect and mutual trust, which led our research process to become collaborative partners throughout the research process (Kemmis & McTaggard 2000:33; Vaughn, Jacquez, & Zhen-Duan 2018:682). To earn respect and trust from the co-researchers, I devoted time to interacting with them inside and outside school. Our efforts did bear some fruit, because all the stakeholders I lobbied agreed to take part in the research process.

As Godden (2017:10) and Carl, Kuriloff Ravitch, and Reichert (2018:30) suggested about PAR, we tried to democratise the research process by allowing all the co-researchers to participate equally in discussions and their voices to be heard to empower the co-researchers and transform an approach for teaching and learning of work, energy and power concepts. Through this relationship, participation and contributions of the co-researchers were maximised. As Kemmis and McTaggard (2007:281) and Richards,(2016:371) suggested, the team was engaged in all steps that were involved in reflection and or self-reflecting cycles. These steps involved planning, acting and observing reflecting. At each of these steps, we worked together as a team to guard against power issues. We did this in the realisation of the tenet of PAR as a transformative paradigm that power must be addressed at each stage of the research process (Mertens 2007:213; Gray & Malins 2016:10). Measures were put in place to monitor anticipated artefacts of power differences that could creep in as a result of individual status. It was emphasised that team members should respect each other and their opinions irrespective of their status.

3.2.9 Rhetoric in PAR

The language that the researcher uses contributes to the way the discussion progresses (Sadowska & Laffy 20015:2; Israel, Schulz, Parker, Becker, Allen, Guzman, & Lichtenstein 20017:31). The researcher can objectify the co-researchers by treating them as subjects during the research process. This could create a situation where some co-researchers become reserved. This would then marginalise the co-researchers and contribute negatively to the way they contribute in the process of identifying their problem and developing the strategies that will lead to the solution of their problem. According to Reason and Bradbury (2001:45) and Israel et al. (2017:35), PAR encourages the empowerment of co-researchers by letting them participate fully as collaborators in the construction of a solution to their problem. Tlali (2017:89) believes that the co-researchers must use the language that will show respect and empowerment to the co-researchers. Glassman and Erdem (2014:204) and West Crookes (2017:140) expressed the same view that the researcher must be sympathetic, equally open to all the inputs and use the language that would democratise.

3.2.10 Ethical considerations

Initially, I requested permission from the Ethics Committee and the Committee for Title Registration of the University of Free State to register my topic. After getting permission from the University, I requested permission from the Kwazulu Natal Department of Basic Education (DBE) to access the premises of the school where I chose to conduct my research using the ethical clearance letter that I had received from the University. Permission was then requested from the principal to conduct research in his school. At first, the principal was reluctant to permit me. After I explained to him how the school would benefit from the study, he agreed.

The permission from Kwazulu Natal Department of Basic Education was granted. I explain the purpose of the research to them and how it was going to be conducted after receiving permission from the principal of the school. I contacted those who volunteered to participate in the research project through writing, verbal and telephonic approaches. In my first meeting with the co-researchers, we discussed the purpose of the research and how was it going to benefit them. As McDonald (2012:40-41), Robson and McCartan (2016:10) suggested, I did bring to their attention the fact that the research project was using PAR as such an approach normally took time and I also indicated to them that it was difficult to speculate the time it would take.

3.2.11 Co-researchers

The team was formed from Grade 12 physical science learners, two physical science teachers, a physical science subject advisor, a mathematics teacher, the chairperson of the school governing body and the principal of the school. These participants were chosen to represent large group that was affected by the problem of teaching and learning of work, energy and power. The choice of these participants were based on their credentials. Each of the co-researchers were assigned pseudonyms to protect their identities.

Co-researchers who were willing to take part in the study were invited to a school where the research were to take place. This gave them a chance to introduce each other and clarify the purpose of the team.

3.2.12 Research design

The generation of data was done with co-researchers based on the research design. The vision for us as a team was to develop a strategy that could enhance teaching and learning of work, energy and power concepts in Grade 12 physical science class. I used research design in the context of McKenney and Reeves (2012:9) and Thorne (2016:283) who described research design as a logic structure of inquiry. As Pilot (2001:167) and Glaser and Strauss (2017:23) suggested, we used research design to generate data. This helped us to ascertain that the correct method was used to generate the data, the correct data was generated and it clearly responded to the research question. Furthermore, this helped me to have the correct analysis of the data generated. The team worked for three months in line with the strategy that was formulated by the team members with the team leader constantly monitoring the progress, and the team members constantly reflected on each stage.

3.2.13 Co-researchers' credentials

This section described the credentials of the team members who participated in the process of data generation. The team was composed of different co-researchers with different expertise, who brought rich and diverse knowledge and a variety of experience to the study. Most of the co-researchers have shown an interest in the study of work, energy and power since this section posed a challenge for both learners and teachers in most schools. I contacted the participants personally after they expressed their willingness to participate in the study. A cover letter was attached to the questionnaires informing the participants of the purpose of the study, the confidentiality of the results, and their option to volunteer or decline participation in the study. The participants were assured that their identity would be kept confidential. The names that were used in the section below were not the real names of the team members. This has been done to protect the identities of the team members.

(i) The coordinator of the study

In our first meeting, I was elected as the coordinator of the study progresses. As the study co-ordinator, I conducted the workshop with the team members to empower them about the principles of PAR as our research approach that would guide our activities throughout the study. I explained to the team members that as the study coordinator, I was not the know all, but my duty was to facilitate the process of pooling the knowledge. This knowledge would help in the development of the strategy that would enhance teaching and learning of work, energy and power concepts.

I have taught physical science for many years, and from my teaching experience work, energy and power concepts remained a challenge for many teachers and learners. This contributed to the overall performance of learners in physical science; hence I decided to undertake this research on it

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(ii) Physical science teacher

Mthwasi was a physical science teacher who volunteered to take part in the study. He felt obliged to take part in the study because he has been experiencing this problem where his learners found it difficult to understand these concepts. Mthwasi felt it was important for him to grab an opportunity of contributing towards finding a solution to this problem when an opportunity presented itself. Mthwasi has been teaching physical science in Grade 12 in the neighbouring school for twenty years. He obtained A secondary teacher’s diploma and furthered his studies with an advanced diploma in physical science. He taught physical science for twenty-five years, and he was a good teacher who produced good result in the NSC physical science in Grade 12. As an experienced teacher, he brought a lot of experience, knowledge and expertise about the topic of work energy and power concepts to the table since he has been teaching these concepts for a long time and he has been to many physical science workshops during his career. He also marked NSC physical science papers for many years.

(iii) Physical science subject advisor

Jabhi was a physical science subject advisor in the FET band in our district, and she worked as a subject advisor for ten years. She holds a secondary teacher’s diploma in mathematics and physical science, an advanced diploma in physical science and a B.Ed. Honours degree in natural science. She taught physical science in Grade 12 for eight years before she became the subject advisor. She has been a subject advisor for ten years. She has conducted many pedagogical and content knowledge workshops in different circuits empowering physical science teachers for many years. Since she took over as the subject advisor, physical science results in the district have shown great improvement. She made a huge contribution during our discussion about the topic of work, energy and power. She made us aware of some common mistakes and the misconceptions that the learners usually held about work, energy and power concepts. She also made us aware of some policies and diagnostic tests that we must consult to find more information about these concepts.

(iv) Learners

There were forty learners in the Grade 12 physical science class. Most of these learners were from the local underprivileged community. They attended this school from Grade 8, and they understood the culture of the school. Most learners were willing to take part in the study because they had a problem with the topic. Apparently, they hoped that by participating in the study, their problems in work, energy and power would be solved. Six learners participated in the study, three girls and three boys. These learners were Bhamu, Doski, Boyi, Ruth, Luyi, Chazi and Tozi. The ages of learners who participated in the study ranged from 17 to 19 years. According to the learners, they felt obliged to participate in the study because they felt they were directly affected by this challenge. Van Dijk (2008:353) and Kennedy (2006:190) expressed the same opinion that people who are directly affected by the problem and who feel obliged to contribute in finding a solution to their problem should be given a chance to participate. Those learners who participated in the study were asked to request permission from their parents, and they were given consent letters to complete. These learners contributed a lot to the study by indicating all the problems they encountered during teaching and learning of work, energy and power. They even went to the extent of suggesting the solutions that they thought could help to enhance their understanding in work, energy and power concepts.

(v) Mathematics teacher

Slova is a mathematics teacher who has been teaching mathematics for 15 years. She holds a BSc and Further Diploma in Education in mathematics. She has been producing good results in mathematics continuously for ten consecutive years. Slova showed an interest in participating in the study, citing that she once taught physical science in Grade 12. As a mathematics teacher who taught mathematics for many years, she knows and understands which part of trigonometry and geometry is required by the learners to understand work, energy and power concepts. She brought a lot of experience and knowledge about mathematics, especially trigonometry and geometry, which contributed to the understanding of work, energy and power concepts.

(vi) Principal

Spesheli a school principal who had nine years' experience in the principal's post at the time of research. He had good leadership skills, and he was a hard worker. He believes that teachers and learners should work hard, and they must work for extra hours to produce good results. He is very active, and he always takes part in organising extra classes for learners on weekends and holidays. He demonstrated some qualities of being a good leader by showing interest in the teachers' problems and involved parents who were necessary for solving some school problems.

(vii) Chairperson of the school governing body

Kapa is the chairperson of the school governing body and a motor mechanic. He is a well-known person and active in politics, and he is a member of many committees in the community, including the youth committee. Kapa represents the parents since he knows the problems and the needs of the community. He brought his knowledge and experience about the community expectations to the study and his knowledge of mechanics. He was interested in the study because he knew from the community meeting that physical science was always viewed as a difficult subject that was supposed to be done by a chosen group of intelligent learners.

(viii) Physical science teacher

Ndevu is another physical science teacher who has taught physical science for 11 years in Grade 12, and he was teaching in one of the schools in the area. He holds a secondary teacher's diploma in mathematics and physical science and an advanced diploma in physical science. At the time of the study, he was a Grade12 physical cluster coordinator in his circuit. As a cluster coordinator, he works with the subject advisor in organising physical science workshops, and he is responsible for the moderation of teachers' physical science scripts at the cluster level. He was known for organising and teaching in winter classes in the community. Ndevu was regarded as a good science teacher in the area because she usually produces good year-end results in Grade 12 physical science.

3.2.14 Pseudonyms

I opted to use pseudonyms in my research to protect the identity of the co-researchers. The aim was to avoid undesirable consequences that may occur for individuals because of data that was given. As Wiles, Crow, Heath and Chales (2006:3) suggested, in the process of anonymising the co-researchers, I allowed the co-researchers to pick their own pseudonyms. According to Wiles et al. (2006:10), allowing the co-researchers to pick their names helped to avoid the awful coincidence where a chosen pseudonym is similar to their nicknames or one of their family member's names. Wiles et al. (2006) further warned that the researcher should avoid disclosing identifiable information about the co-researchers.

I obtained informed consent for my research as the researcher. I then consulted all relevant persons, committees, and authorities. As Heath and Chales (2006:3) indicated, I also made sure that the principles guiding the work were accepted before commencing the research. All the co-researchers were allowed to influence the work, and the wishes of those who did not wish to participate were respected.

3.2.15 Voluntary withdrawal

As a researcher, I explained to my co-researchers about their right to withdraw voluntary from the research project any time they felt like withdrawing and for whatever reason. If there were anyone who wanted to withdraw, as Bera (2011:6) suggested, I would change my approach in trying to persuade the withdrawing co-researchers to re-engage with the research project and do self-reflection to identify the course of dissatisfaction.

The section below discusses the process and steps of data generation.

3.2.16 Process and steps of generating data

The study took place in the community school. The co-researchers were first invited telephonically to arrange an appointment. Later one on one discussions were held to seal the deal where the aim of the study was made known to the people who were going to participate in the study. The study was accepted because most of the schools had the problem of poor performance in physical science, especially in these concepts of work, energy and power. Several meetings with the co-researchers were convened to generate the data that was relevant for the study. The co-researchers were learners, parents, teachers, the subject advisor, and the chairperson of the governing body.

3.2.17 Research site profile

This study was conducted at Mthavuma high (not its real name of the school), that is situated in Kwazulu Natal under Amajuba district in Newcastle. Most of the learners were from the same location in Newcastle. The school had 1500 learners.

3.3 CYCLE ONE OF THE PARTICIPATORY RESEARCH

Echoing this sentiment of Kemmis and McTaggart (2007: 276-277) and Banks, Herrington, and Carter (2017:545), to achieve the meaningful change, the PAR process should involve engaging with the co-researchers in a series of self -reflective cycles. These cycles involve planning the change, acting and observing the process and the consequences of change, reflecting on these processes and consequences, and repeating these steps again.

3.3.1 Pre-planning stage

In this stage, I started by contacting physical the science teachers from different schools to get their views about the teaching and learning of work, energy and power concepts in the Grade 12 physical science class. Most teachers indicated that they had the problem of teaching these concepts to learners and showed interest in the topic. They also indicated that these concepts were challenging and abstract for most of the Grade 12 learners. The teachers said that this problem was compounded by the teaching approaches that they used when teaching these concepts. The mathematics concepts involved in teaching these concepts were cited as one factor that made the situation worse. According to the teachers, the teaching approaches that the teachers used in teaching these concepts impeded the learners' understanding of these concepts. I also contacted the subject advisor who expressed the same view about the difficulty that the learners and teachers encountered in the teaching and learning of work, energy and power concepts. She also indicated that poor performance in work, energy and power concepts contributed to the general poor performance of learners in physical science National Senior Certificate (NSC) examination. Suggestions were made by other teachers to involve the mathematics teacher, one of the principals, some members of the school governing body and the learners because they believed they could all contribute to the construction of knowledge.

3.3.2 Building the PAR team

It was clear from the discussion with the teachers that it was necessary to build a PAR team to discuss the challenges of work, energy and power and power concepts, share ideas and come up with the solutions where necessary. The participants who formed the team brought their diverse perspectives and theoretical positions (Fuller, Hodkinson, Hodkinson, & Unwin 20005:50; McDonald 20012:36) to resolve the problematic issues. From my meetings with individual physical science teachers from different schools and with the district subject advisor, it appeared that there was a need to involve a mathematics teacher, the principal, some members of the SGB and the learners, so that we could pool our knowledge. We felt that it would help us to develop a strategy that could help to enhance the teaching and learning of work and energy concepts. We then established a small PAR team of co-researchers who were willing to participate in the study and had a common interest. The team was composed of two physical science teachers from different schools, one mathematics teacher, the school principal, one member of the governing body and Grade 12 physical science learners.

After that, we arranged our first meeting with the team to request them officially to take part in the study as the co-researchers in the process, transforming the teaching and learning of work, energy and power concepts in Grade 12 physical science class. At this stage, a workshop on PAR was held for the team, since some team members were not conversant with PAR. The rights of the team members were explained to all, including the right of withdrawing from the study whenever they felt like doing so. This stage was also important for developing trust and a good relationship with the co-researchers, as McDonald (2012:45) indicated. According to McDonald (2012:45), a good relationship should be based on the principles of trust and respect. It was also important for the co-researchers to understand that the study was also intended to transform their lives so that they could feel free to contribute during the discussions.

3.4 CYCLE TWO OF PAR

3.4.1 Planning stage

During the planning stage, different responsibilities were assigned to different co-researchers. During this stage, team members were involved in different activities. This included identifying activities, allocating resources for the execution of objectives, allocation/sharing of roles and responsibilities, identifying the venue, making decisions and setting the timelines for these activities. These activities were undertaken in an attempt to respond to the research question. During this stage, provision was also made to accommodate contingencies that not anticipated but which could emerge as the research activities unfolded. This involved possible threats that might hamper the project and reflect on the development of the research project. There was also a need in the process to accommodate new and diverse ideas that could emerge from the co-researchers. This was a period of sense-making where the diversity of the co-researchers negotiated and synchronised. This was done to level the ground for pooling the knowledge. The co-researchers were also motivated to own the study. Following this argument, Mahlomaholo and Netshandama (2012:8) posit that for the co-researchers to be fully immersed in the study, they should own and make sense of the study.

3.4.2 The development of a mission and vision for the team

It was important at this stage to develop the mission and vision of the team. The team members did this through the development of a common understanding of the goal of the study. This was done so that all the co-researchers would be committed to the attainment of that goal. It was also important that the co-researchers should have a clear understanding of the goals of the study at the beginning of the study. According to Mahlomaholo and Netshandama (2012:8) and Grimble and Chan (1995:115), if the co-researchers understood the goal of the study clearly from the beginning of the study, they would be able to make sense of the study and immerse themselves fully in the study. This helped them to design a practical and effective participatory study. This assisted them in developing the mission statement using strategies that would help them to attain their goals as to what the study was trying to achieve. We set ground rules that guided the practice and involvement of co-researchers in the study from the development of the mission to situational analysis, development of the plan and its implementation.

In one of the meetings, we engaged in the process of developing the mission statement of the study as a team. We were guided by the research problem of the study. The mission statement of our study was to develop a strategy that could enhance teaching and learning of the concepts of work, energy and power. The study was based on two major goals. This goals were to alleviate the problem of abstract work, energy and power concepts through the use of multiple representations and to encourage active participation of learners in the teaching and learning of work, energy and power concepts. Teacher centred learning and the difficulty and abstractness of the concepts are among the factors that contribute to the poor performance of learners in work, energy and power concepts. We had the same belief as the team members that working collaboratively as a team could help us to learn from each other and empower each other in our attempt to address the research problem.

Several meetings were held by the team members of the focus group to generate the data on the research problem and to share views and knowledge. These meetings aimed at finding the solution to the problem to transform teaching and learning of these concepts. The vision of the team was to create a framework that could assist in the development of the strategy to enhance the teaching and learning of these concepts in the Grade 12 physical science class. This was done to attain the research goal of the study.

3.4.3 Developing the policy for the research team

The team members drew up policies and rules to facilitate the smooth running of the research process. The group members discussed the times of meetings. The group members unanimously agreed to have meetings every Tuesday at 15h30. This was done to allow time for other group members like the subject advisor and the chairperson of the SGB who had other commitments. The meetings were held in one school that was chosen as the research site. A total twelve meetings were held. .Respect and keeping time was emphasised by the group members, and the group members were requested to send an apology in time when they could not attend the meeting.

We agreed as team members to seek information about the research problem from any resource that they could secure to obtain rich and diverse knowledge from the different resources. It was also agreed that the generated data in this research would be kept in a safe place and it would be used solely for the research, and the anonymity of the co-researchers would be preserved.

3.4.4 SWOT analysis of the study

A SWOT analysis to assess our strengths, weaknesses, opportunities and threats and to guide our activities in terms of our goal of solving our research problem was done. This was done using skills, knowledge and expertise that was accumulated during discussions with the co-researchers. This helped us to reinforce our strengths, to adventure our opportunities and use them to counter the threats and understand our weaknesses. This made us aware of the potential problems or challenges that needed to be addressed and to decide what areas needed serious attention. The SWOT analysis was going to help us as team members to work collaboratively in dealing with the problem of teaching and learning of work, energy and power concepts in the Grade 12 physical science class. The SWOT analysis helped us to understand and match our strengths to our opportunities and try to eliminate the threats while we tried to overcome weaknesses.

3.4.4.1 Strengths

The multiple and diverse strengths which our team members possessed were inherent in the knowledge, experiences and the expertise possessed by individual members. Two teachers had years of experience in teaching physical science in Grade 12 and marking NSC examination in physical science. The mathematics teacher had majored in both physical science and mathematics and had once taught physical science. He had years of experience teaching mathematics and had a deep knowledge of mathematics concepts, especially trigonometry and geometry that are involved in work, energy and power concepts. The subject advisor had ten years of experience as the physical science subject advisor and taught physical science for five years in Grade 12. Learners were exposed to physical science in Grade 8 as natural science, and they chose physical science as one of their major subjects in Grade 10. Some of these learners were repeating Grade 12, and this made them understand this problem better. Teachers, learners and the subject advisor had experience that enabled them to make valuable contributions in an attempt to develop a strategy that would enhance teaching and learning of work, energy and power concepts. The principal of the school had years of experience as the principal, and he had knowledge of some of the factors that contributed to the poor performance of learners in physical science. The chairperson of the governing body was also a mechanic. He contributed some experience and expertise about mechanics and the community problems that could contribute to this problem, and this created an inclusive and cohesive society where all of us as team members were equal and had equal opportunities.

We had other resources like writing materials, books, information from the internet from those who had access to it, and data capturing instruments like a voice recorder and video recorder. Even parents contributed to the study by allowing learners to stay behind after school on the days when the meeting was to be held and further consented to them participating in the study. The principal of the school where the research was based took part in the study and gave permission for the study to be conducted in his school.

3.4.4.2 Weaknesses

As human beings, we had some weaknesses in our team. It was the first time some team members were involved in a research project, and they had no knowledge of it. We also had financial constraints since our research project was not funded. This made it difficult for other team members who were staying far from school and who had no funds. This resulted in some of them sometimes absenting themselves from other sessions. The limited time for the research after school was also a challenge because some co-researchers were staying far and they had the problem of transport if they left late. Some co-researchers also had some duties to perform after hours, like teachers and learners who sometimes had extra classes to attend after school and some co-researchers who were involved in community projects and sometimes had an obligation to attend to community meetings. Time constraints posed a challenge to our research study since the collaborative problem solving process requires time for planning and coordinating, implementing strategies and reflecting on the progress made.

3.4.4.3 Opportunities

The principal and the chairperson of the school governing body had an opportunity to contribute directly in finding the solution about teaching and learning of physical science, which was considered as one of the most challenging subjects in the community. The teachers, the subject advisor and the learners had an opportunity to work together with the common goal of developing a strategy that could enhance teaching and learning of work and energy. They also had the opportunity to work with the mathematics teacher in integrating mathematics and physical science to solve challenging work, energy and power concepts. During this process, learners had an opportunity to voice their concerns about the challenges that they came across during teaching and learning of work, energy and power concepts as a collective. Arguing this Dickens and Watkins (1999:127) suggested that co-researchers could be empowered by being given a chance to research their own lives and generate knowledge that would lead to the solution of their problem. The co-researchers had opportunities to work collaboratively with the common goal in mind of finding the solution to their problem. This helped to empower the co-researchers and develop their capacity by becoming the partners in social change. The co-researchers had an opportunity to share knowledge, and this strengthened their beliefs in their abilities and resources, and helped to develop their skills in collecting and utilising information (McDonald, 2012:40; Ridsdale, Rothwell, Smit, Ali-Hassan, Bliemel, Irvine, & Wuetherick 20015:10). This gave the co-researchers some opportunities to learn from each other in their mission to better understand abstract work, energy and power concepts.

To the teachers, this was an opportunity to nurture the development as they were introduced to different and diverse approaches to the teaching and learning of work, energy and power concepts. This occurred through teachers' engagement in the series of cycles of reflection, debating, action and learning. The teachers also had an opportunity to grow and develop, which led to improved classroom practice (Park & So 20014:98; Sekwena 2014:59).

3.4.4.4 Threats

One of the threats that emerged during the research process was the issue of power play that existed between the teachers and learners due to the African culture that emphasised respect for an elderly person. Another threat that could emerge from the everyday teacher-learner relationship that was based on respect was that the teachers were always considered as superior and had power over the learners based on their content knowledge. The work of Mertens (2007:216) and Kincheloe (2012:10) emphasised the importance of respecting the culture and being aware of power relations during the research process. This was reflected when learners as co-researchers constantly mentioned words like ''yes sir'' when talking to teacher co-researchers. Another threat was the lack of funding, and some co-researchers had to leave before we finished because of the transport problem.

Some learners showed a lack of motivation on some days because of hunger and fatigue as they had to stay behind after school during the days of discussions. They were staying far from school and some were travelling for long distances to get to their homes.

Another threat that emerged during discussions was the domination of some co-researchers by others due to the knowledge they possessed about the topic that was discussed. This manifested itself when physical science teacher, learners and the subject advisor tried to dominate the discussion due to the knowledge they possessed about work, energy and power concepts. This is in contrast with PAR that emphasises multiple ways of knowing through equal involvement of all the co-researchers throughout the research process (Lykes & Coquilon 2007:333; Heron, & Reason 2008:370).

When the team members were satisfied that they had identified their strengths, their weaknesses, opportunities as well as the threats that could hinder the development of the strategy to enhance teaching and learning of work, energy and power concepts, another day was set for the development of a strategic plan.

3.5 THE THIRD CYCLE OF PAR

During the third cycle, the team members worked together in developing a strategic plan that had to be followed to attain the goal that was set collaboratively by the group members. During the development of the action plan, different members of the team were entrusted with duties to perform, resources that would be required to perform those duties, the indicators that would show that those duties were successfully performed, and the time frames that were set for those duties to be completed. In this cycle of PAR, all the team members were involved and worked together to achieve the common goal. Alluding to this notion, Young (2006:499) indicated that PAR was a process of engagement that opened a space for inquiry. PAR is an inclusive, educational, transformative and empowering process, wherein researchers and co-researchers work together to co-create knowledge (Bragg 20007:32; Wilhelm 20016:22). It also helped to create consciousness and social change by working together with the co-researchers to achieve the agreed-upon goal, which is the overall goal of the action cycle of PAR (Kelly 20005:70; Horgan 20017:250).

Different team members had some inputs on the actions that they regard as appropriate. The team members ultimately agreed on the following action plan: Defining work, energy and power concepts, designing the teaching and learning strategy for work, energy and power concepts, drawing an up action plan for the implementation and observation of activities in a class, identifying conducive conditions and address challenges for the implementation of a strategy, identify the components of work, energy and power concepts in teaching strategies.

3.5.1 Defining work, energy and power concepts

Learners find work, energy and power concepts abstract and difficult to understand in a physics context, especially because they are also used in everyday language. For this activity, three groups were formed, each with a few learners and one teacher. Each group was given a sub-topic in work, energy and power concepts as classified in the Physics Curriculum and Assessment Policy Statement (CAPS) to prepare using different sources of information. One week was allocated for this task.

In the following meeting, a different groups was given a chance to present the sub-topics, and give the definitions of these concepts from different sources like textbooks, dictionaries and everyday use of these topics to reflect the way each group understand these concepts. After each presentation, another group was given a chance to ask questions.

3.5.2 Designing a teaching and learning strategy for work, energy and power– the sub-topics

Each group was required to do a research teaching and learning strategy that they preferred for each of the sub-topics presented, discuss it with other groups, and select a classroom activity that they felt was suitable for a particular topic. This activity aimed to develop a learner-centred teaching and learning strategy that would emphasise the active involvement of learners in the knowledge construction process during teaching and learning of work, energy and power concepts.

Consequently, each group was given a chance to demonstrate what they had designed. They had to tell us about the activity, the resources they required, and the knowledge that learners would gain from that activity. These demonstrations and presentations were recorded. This process was allowed to run for two weeks.

The team met again to reflect on the presented activities, and suggestions were made to improve the activity.

In the following presentation, each different each group was given a different teaching strategy to explore. This approach was followed so that every team member would be well versed in the different teaching strategies to allow a vibrant discussion and opportunity to effect the improvements suggested by the team members. One week was allocated to the activity. After this activity, team members reflected on the aptness of the improvements.

3.5.3 Action plan for implementation

A bigger group was formed that would create a classroom-like situation and each teacher was allowed to present a particular work, energy and power concept topic using the teaching strategy of their choice. Amongst the team members who were observing the presentation, there was at least one teacher present. The teacher who was to present was supposed to provide the lesson plan before starting the lesson. Notes and videos were used to record the presentations. This presentation permitted the teachers and the team members who observed to compare the actual and the prepared lesson. The observers took notes to use during the reflection session. After the presentation, the team members embarked on reflection on the impact of the presented strategies. The team members had some inputs on the lessons presented.

3.5.4 Identification of conditions and challenges for the implementation of strategies

After the presentation of lessons using different teaching strategies, each strategy was analysed to determine the conditions that enabled the successful application of these strategies in the class. These presentations involved the capacitation of the teachers, and definition of the roles of teachers and learners during the implementation of each of these strategies. Possible barriers to the successful implementation of each strategy were also analysed.

Afterwards, team members were making every effort to ensure that ideal conditions for implementing the strategies for teaching and learning of work, energy and power concepts were met, and possible measures were taken to overcome the barriers that could hinder the implementation of these strategies.

The teachers were again given a chance to present in the groups formed to put suggestions in place for creating an enabling environment for the various work, energy and power teaching and learning strategies. Measure to improve the challenges that could hinder the implementation of these strategies were added. At the end of the presentation, their progress in ensuring that these strategies were successful was reported. Lastly, the teachers reported on progress in dealing with challenges in using these strategies.

3.5.5 Identification of components for work, energy and power concepts teaching strategies

The group members presented findings and perceptions on the use of work, energy and power teaching and learning strategies that seemed appropriate were recommended. A decision was made on the strategies that the team members felt should be included in the components of the strategies they wanted to develop.

The group members provided more information on different teaching and learning strategies relating to work, energy and power concepts. The teachers were given a chance to formulate tasks to be completed by learners to assess the impact of the strategies used to bring about the envisaged change. The team members suggested actions to ensure the sustained use of proposed work, energy and power teaching strategies.

3.6 CYCLE FOUR OF PAR

Implementation (ACTION) of the plan

In this cycle, a meeting was held where the team members started to discuss the development of the strategy that could enhance the teaching and learning of work, energy and power concepts. During the meeting, I reminded the co-researchers that as the team members, we were all in mutual relationship, we should all work together as equals, and throughout the research project, we were all decision-makers, and the contribution of each of us was of great value in the study. I also emphasised to them that they should see me as a partner in an attempt to develop a strategy that would enhance teaching and learning of work, energy and power concepts not as an expert who knew everything.

The team members deliberated on the challenges that teachers and learners faced during the teaching and learning of work, energy and power concepts. In the discussion, the team members pointed out that some of these challenges emanated from the approaches that teachers used to teach these concepts. It also arose that mathematics concepts that were involved in work, energy and power concepts were problematic to both learners and teachers themselves. Some of the solutions that were suggested during the discussions included the use of learners' conceptions, multiple representations, learner involvement and teachers' pedagogical content knowledge. The team members suggested that mathematics and physical science teachers should work together. According to the team members, this could alleviate the problem of mathematics concepts that are involved in work, energy and power concepts.

It was important at this stage to develop the trust of co-researchers to maximise their participation and their commitment to the study. It was, therefore, imperative that different perspectives of the co-researcher were respected and valued. This helped to develop the sense of ownership of the research project in the co-researchers.

The co-ordinating team discussed the development of the strategy to enhance teaching and learning of work, energy and power concepts. The FIA was also used to find more information from the individuals, the focus group and from the rest of the class. We were explaining the components of the strategy, delegating duties to respective team members and highlighting the steps to be taken in developing the strategy and identifying strengths, weakness, and opportunities and anticipated threats (SWOT) in relation to the study.

This stage was in line with bricolage because multiple inputs from all the co-researchers were accommodated since all the co-researchers participated equally in all the processes of this stage. Pursuing this, Miller and Rose (2008:102); and Linville, (2009:23) posited that to support the flourishing of team members in PAR, the research should allow the co-researchers to participate freely in the research activities, and it should embrace different types of knowledge and self-expression. As Kemmis and McTaggard (2007:281) and Richards, (2016:371) suggested, the team was engaged in all steps that were involved in reflection and or self-reflecting cycles. These steps involved planning, acting and observing reflecting which was repeated.

The discussion below shows the steps of data generation that followed during discussions.

3.6.1 Stages of data generation

In the section below, I discuss the stages of data generation with the team that was composed of different team members with diverse knowledge, experiences and expertise. The data that was generated through discussion, observations and workshops was used to respond to the research question and problem statement. Different stages that were used to generate the data which helped in the development of a strategy are shown below..

3.6.1.1 Stage 1: Explaining the problem and planning

This was a stage for clarifying the problem to all the team members. It was a very important stage for the team members to understand the problem of learners' failure to understand work, energy and power concepts. This stage also involved the planning of the discussions and the workshops. According to McGregor (2011:2) and Dickens and Watkins (1999:130) this helped the team to scaffold the value differences to diffuse the conflict among the team members. Team members were engaged in the issues related to physics to foster an understanding to team members like some parents who might not be well vested with physics. At this stage, the team met to verify if there indeed was a problem in teaching and learning of work, energy and power concepts.

The co-researchers were at liberty to use the language of their choice when expressing their views. All the co-researchers did agree to abide by the rules. The learners and teachers agreed that there was a problem in the teaching and learning of work, energy and power concepts. The team members believed this could lead to the generation of a strategy that could help to enhance the teaching and learning of work, energy and power concepts. As the team, we set times and dates for the next meetings.

3.6.1.2 Stage 2: Challenges in teaching and learning of work, energy and power.

The team members discussed various challenges in teaching and learning of work, energy and power in response as the first objective of the study. These challenges included the conceptions, teaching approach, learner involvement and teachers' PCK in work, energy and power concepts. The team members noted generally that these challenges made it difficult for the learners to understand these concepts.

This means the ways that learners used these concepts in everyday life was different from their use in the physical science curriculum. From the discussions, it emerged that learners had difficulty in integrating their conceptions from their daily experience with those of the physics curriculum. This resulted in learners forming alternative conceptions about these concepts. The team members proposed that the teachers should use the learners' conceptions as the basis for the development of a deeper conceptual understanding of work, energy and power concepts in learners' minds.

3.6.1.3 Stage 3: Common conception about work, energy and power.

Each of the co-researchers was given an opportunity to talk about the conceptions that they have in work, energy and power concepts. Throughout the discussion, the co-researchers constantly reminded each other not to deviate from the ground rules. Free attitude interview (FAI) was also used to solicit the data that was generated. This included the interviews with individual team members and with the focus group. These interviews helped the team members to identify the common conceptions that they had about work, energy and power concepts. It further helped the team members to develop the solution that would assist in the alleviation of this problem. The subject advisor took the team through the common conceptions that the Department of Basic Education stipulated in DBE diagnostic in 2015. Most of the conceptions that the subject advisor mentioned were similar to those that the learners held. From the team members' point of view, these conceptions impeded the learners' understanding of work, energy and power concepts.

3.6.1.4 Stage 4: Discussing challenges that learners and teachers encounter during teaching and learning of work, energy and power.

The team also discussed the challenges that the learners encountered during teaching and learning of work, energy and power concepts. The learners, as the people who were directly affected by the problem, were given a chance to take the team through the challenges they came across during teaching and learning of work, energy and power concepts. Amongst the challenges that the learners mentioned were the approaches that the teachers used to teach these concepts, insufficient learner involvement during teaching and learning of these concepts and inadequate teachers' pedagogical content knowledge in these concepts. When some of the team members probed learners on the challenge about teachers' approach, the learners explained that some of the approaches used by the teachers to teach work, energy and power concepts made it difficult for them to understand these concepts. The learners explained that they have different ways in which they understand the content that is taught by the teachers. They, therefore, deemed it necessary for the teacher to use a teaching strategy that would accommodate them. The teachers and the subject advisor alluded to the learners' notion that teachers should accommodate learners' diversity when teaching work, energy and power concepts. According to them, the teacher could do this by using different teaching strategies to cater to learners' diversity.

Another challenge that emerged during the discussions with the team members was the insufficient learner involvement during teaching and learning of these concepts. When the team members were discussing the challenge of learner involvement, there was a general feeling that teachers do not adequately involve learners when teaching work, energy and power concepts. The discussions from the team members revealed that teacher imparts the knowledge to the learners without involving them fully in the teaching and learning of these concepts. According to the team members, this disadvantaged the learners by marginalising them from the knowledge co-construction process.

There was also a discussion about the challenge of inadequate teacher pedagogical content knowledge in work, energy and power concepts. All the team members agreed that sometimes there were deficiencies in the teachers' pedagogical knowledge that led to inappropriate teaching strategies. The team members concurred with the notion that inadequate teacher pedagogical content knowledge deprives learners an opportunity to develop an understanding of these concepts.

3.6.1.5 Stage 5: Discussing a possible solution

The workshop was held in a school where the research took place. This focus was on what should be done to address the challenges of the teaching and learning of work, energy and power concepts. The team members reflected on various solutions that could be implemented to enhance teaching and learning of work, energy and power concepts. Learners, as the people who were directly affected by the problem, had a lot to contribute about the solutions they thought could work to improve their performance work energy and power concepts. The team members had already discussed the challenges that were involved in teaching and learning of work, energy and power concepts, and they were seeking for some way of transforming teaching and learning of these concepts. These are some of the solutions that were suggested by the team members: using multiple representations to teach work energy and power concepts, involving learners when teaching these concepts and adequate teacher pedagogical content knowledge.

The teachers and learners agreed that the use of multiple representations could help in enhancing learners 'understanding of work, energy and power concepts. According to team members, the use of multiple representations accommodated different learners in the class. This increases the number of learners that understand these concepts.

The next solution suggested by team members was the involvement of learners in teaching and learning of work, energy and power concepts. From the team members' perspective, involving learners in teaching and learning of these concepts helped to stimulate interest in learners and further developed a deeper understanding of these concepts.

The last solution that was suggested by the team members was ensuring adequate teacher's pedagogical content knowledge. In this workshop, it emerged that the teachers with adequate teacher pedagogical knowledge are in the position of developing a better understanding of these concepts. The team members were well vested with challenges of work, energy and power concepts, and this helped them to transform the teaching and learning of these concepts. The solutions that were suggested by the team members led to the formulation of a strategy to address the challenges of work, energy and power concepts.

3.6.1.6 ***Stage 6: Discussing conditions conducive for the development of the strategy for work, energy and power***

The team also discussed the conditions that they regarded as conducive for the successful development of a strategy for teaching and learning of work, energy and power. The team members deemed it necessary to discuss the conditions because they had the notion that the compilation of the conditions for success was important. It had emerged from discussions that lack of teacher content and pedagogical content knowledge have contributed negatively to the teaching and learning of work, energy and power. One of the conditions that was considered conducive for the successful implementation of the strategy was to improve teachers PCK through workshops and other related seminars that could boost teacher content knowledge and the teacher pedagogical knowledge. According to the team, teachers should work as a team with other physical science teachers and maths teachers to boost the teachers' PCK and maths content knowledge.

3.6.1.7 Stage 7: Threats to the development of the strategy

Through the workshop that was held by the team members, the threats that could hinder the implementation of the solutions were discussed. It emerged from the discussions that there is always a possibility of the threats that could jeopardise any attempts to improve the conditions for the teaching and learning of work, energy and power concepts, if not properly managed. Various threats that could hinder the implementation of the solutions were identified. These threats included learners' conception, multiple representations, learner involvement and teachers' pedagogical content knowledge. After identifying some threats, different avenues of dealing with these threats were suggested.

3.6.1.8 Stage 8: Indication of successful implementation of the work, energy and power strategy that was anticipated by the team.

Through the discussions among the team members, different suggestions emerged about the strategy that can enhance teaching and learning of work, energy and power concepts. It became clear from the discussions that the use of learners' conceptions, the use of multiple representations and active l some of the anticipated successes of enhancing teaching and learning of work, energy and power concepts.

3.6.1.9 Stage 9: Formulation of a strategy for enhancing teaching and learning of work, energy and power concepts.

Points that emerged during the discussions and workshops with team members were used to draw the strategy. This strategy incorporated some points that emerged from the discussions. Some of these points were used to formulate the strategy outlined in Chapter 5. In developing the strategy, the team members focused on some constructs. These constructs are learners' conceptions, multiple representations in teaching work, energy and power, learner involvement and teachers' PCK. The team members had the notion that if these issues could be addressed, the teaching and learning of work, energy and power concepts would have been addressed.

3.6.2 Concluding research discussions.

In conclusion, the team members concluded by reflecting on discussions and workshops that were done during the past three months. I then thanked all the team members for their participation in the research project, their time and dedication. S agreed as the team that teaching and learning of work, energy and power concepts could be enhanced through cooperation and collaboration work when we are engaged in discussions that allow multiplicity and diverse methods of knowledge production informed by bricolage.

3.7 DATA ANALYSIS

As the main researcher, I took the responsibility to analyse the data that we generated as a team. I used Critical Discourse Analysis (CDA) to analyse the data generated through discussions and workshops. I used CDA to understand how the co-researchers' written and spoken texts functioned when knowledge about work, energy and power concepts was transmitted, as del Vecchio (2015:55), Bakker and Heimbrock (2007:10) propounded. According to Sheyholislami (2001:2), language is social, and is ideologically driven. As Wodak and Meyer (2008:4) and Wodak (2009:9) suggested, CDA helped me to de-mystify ideologies and power that were embedded in spoken and written texts (language) during the discussions with the team members, through the systematic and reproducible investigation of the co-researchers' spoken and written words. As a researcher in this study, one of my aims was to depower myself to empower the co-researchers. In defining CDA, van Dijk (2001:352, 2008:467) posits that CDA is a discourse analytical research tool that mainly studies the way social-power abuse and inequality are enacted, reproduced, legitimated and resisted by text and spoken words in the social and political context.

Wodak (2002:11) added that CDA aims to investigate social inequality critically as it is expressed, constituted and legitimised by language. This helped me understand and critique the power relationship embedded in teacher-learner relationships, which can sometimes marginalise the learner's knowledge construction process during teaching and learning of work, energy and power concepts .CDA is in line with bricolage since it requires an interdisciplinary approach, which practises a multi-method approach (Wodak 20002:10). In developing a strategy to enhance teaching and learning of work, energy and power concepts in Grade 12 physical science class, this study aimed to assist and empower learners to contribute to the development of the strategy. The study also wanted to expose how those with power derived from their access to knowledge dominate and enact their hegemony on the less powerful co-researchers and how the less powerful researchers succumb and naturalise these hegemonies (Wodak 2002:8).

3.8 CONCLUSION

Chapter 3 focused on PAR as an approach used to generate the data with the co-researchers in a collective attempt to find the solution to the problem of teaching and learning of work, energy and power concepts. PAR was used as an approach because it is associated with the marginalised, and it allowed me to work collaboratively with the co-researchers to find a solution to their problem. PAR also helped to parallel the power relations and made it possible for me to adopt the position of a facilitator and a learner instead of an expert in a research process. Discussion of PAR's origin, ontology, epistemology, ethical considerations and profiling of the co-researchers were done. Lastly, the chapter discussed CDA.

4 CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION OF RESULTS

4.1 INTRODUCTION

The study aims to develop a strategy to enhance teaching and learning of work, energy and power in Grade 12 physical science class. This chapter addresses the analysis of data that was generated through Participatory Action Research using the focus group. The five objectives of the study were used to organise the data. Critical Discourse Analysis, which are textual, discursive and social practices, were then used to make sense of the data. The CDA technique for the analysis of data was chosen because it is problem-orientated and it addressed the issues of power relations and social inequality amongst the team members during the development of the strategy to enhance teaching and learning of work, energy and power.

4.2 CHALLENGES IN THE TEACHING AND LEARNING OF WORK, ENERGY AND POWER.

The objectives and or constructs developed from them were used as the headings according to which data was organised. I then considered the best practices that emerged from the work of other research studies, educational policies and other relevant literature that related to the heading. Following that, I gave the context to introduce the data generated regarding the heading and used the best practices to determine the extent to which the data was in line with the data generated. The analysis was then concluded by interrogating the data for deeper meaning and making sense using CDA before couching the analysis in relation to the framework and methodology. The challenges that were encountered by the teachers and learners during teaching and learning of work, energy and power were discussed with the team members. Some challenges noted were: The learners’ conceptions in work, energy and power concepts, confusion associated with the different work, energy and power concepts, challenges in work, energy and power concepts, learners’ involvement in work, energy and power concepts, and teachers’ PCK in work, energy and power.

4.2.1 Learners’ conceptions as a challenge in work, energy and power

Learners’ conceptions play a crucial role in the teaching and learning of work, energy and power concepts. Constructivism theory pursues this further by stating that knowledge develops iteratively within the minds of individual learners (Taber 20014:2).

Following this argument, Ausubel assimilation theory states that what the learner already know is the most important factor that influences the process of learning positively (Ausubel 2000:101). DOE (2003:5) shares the same sentiment that linking the content and the learners' context helps the learner to transfer their skills from familiar to unfamiliar situations to comprehend the abstract situation. The work of Denis, Williams, Dunnamah, Tumba (2015:396) indicates that if learners' conceptions are neglected they have the potential to block proper cognitive development of concepts and principles, thus making it difficult for learners to develop the conceptual understanding of the concepts.

The use of learners' conceptions is one of the challenges in teaching and learning of work, energy and power concepts. According to Meyer and Land (2003:420) teachers have a tendency to neglect learners' conceptions, which make it difficult for the learners to make sense of work, energy and power concepts.

When the team members were discussing the challenges in the use of learners' conceptions in teaching work, energy and power concepts, Jabhi, the subject advisor, Ndevu the physical science teacher and Bhamu the Grade 12 learner had some conversation.

> *Jabhi (Physical science subject advisor): "Sometimes the teachers themselves make the understanding of these concepts difficult by neglecting learners' pre-knowledge."*
>
> *While Jabhi was talking, Bhamu interjected.*
>
> *Bhamu (Learner): "Most of us confuse concepts of energy and power. I also knew that when you are running you put more power, which is energy."*
>
> *Thabo (Learner): "I also take energy and power are the same thing."*
>
> *Ndevu (Physical science): "Using learners' conceptions is our problem as teachers."*

The word, "neglect" from Jabhi's statement in this context suggests an inclination towards "uncaring", "carefree", and take-for-granted of learners' understanding of work, energy and power as if it were insignificant. In the same vein, pre-knowledge refers to the knowledge that learners, in this case, bring to class from their diverse backgrounds like cultures, previous grades, different subjects, homes, social engagements to mention a few. This might mean some teachers know that learners have preconceptions about work, energy and power concepts, but they deliberately neglect it or others are not aware of these conceptions. By neglecting, the learners' pre-knowledge, teachers may be excluding some learners from the process of knowledge construction. Jabhi's (subject Advisor) statement, points to the belief that the teacher needs to use learner's preconceptions to develop a deeper understanding of these concepts. Bhamu uttered the phrase," Most of us confuse concepts of energy and power" "Us" in Bhamu's view/context might include other teachers, parents or learners. This statement suggests that Bhamu is not the only one with the problem of work energy and power concepts.

The words of Jabhi "teachers themselves make the understanding of these concepts difficult by neglecting learners' pre-knowledge" suggest that Jabhi believes that learners' conceptions are important in forming the basis for the understanding of work, energy and power concepts. Jabhi uttered the words,"…teachers make the understanding of these concepts difficult." Since Jabhi works with the teachers almost every day, this could mean she knows that neglecting learners' conceptions has become a social practice for the teachers. Centrally to Jabhi's words, is the notion that the teacher should refrain from taking learners as the blank slates to write on. Instead, find out what the learners already know about work, energy and power concepts and build on it.

Bhamu uttered the phrase," when you are running you put more power, which is energy." In this phrase, Bhamu compares running and walking. "Running" compared to "walking" involves more power and more energy but that does not make energy the same as power. For instance from, $P = \frac{W}{\Delta t} = \frac{F\Delta v}{\Delta t} = F\Delta v$ meaning the faster (as in running) or the higher the value of Δv the higher will the product $F\Delta v$, i.e. power, in the same way, $EK = \frac{1}{2} m\Delta v^2$ brings us to the conclusion that energy also increases. To address the differences and assist Bhamu and others in the same situation as Thabo and Ndevu, we may compare the parameters $m\Delta v^2$ in energy and $F\Delta v$ or $(ma\Delta v)$ in power. Further analysis of dimensions (dimensional analysis) will also show that the two concepts do not have the same SI units.

The phrase,'' it is true" from Bhamu, suggests that Bhamu shares the same sentiment that the teachers neglect the learners' pre-knowledge when teaching work, energy and power concepts. Bhamu's utterances, "most of us confuse energy and power concepts,'' show that most learners lack a deeper understanding of work, energy and power concepts hence they confuse them. The word “us” by Bhamu indicates that the problem concerns not only him but also most of the learners.

This point is confirmed by Thabo saying “energy and power is one thing.” This suggests that the learners confuse the concept of energy and power. This statement indicates that most learners do not understand the physics definition of energy and the power concept; hence they resort to a colloquial definition that was used in their society.

Given Bhamu and Thabo’s confusion, one may argue that little or no attempt was made by the teacher to link learners’ conceptions to physics knowledge. The words of Thabo, “Power and energy are the same thing’’ indicate that learners cannot differentiate between the concept of energy and power. This indicates that they lack the conceptual understanding of energy and power, such that it becomes too difficult for them to see the difference between them. This means they struggle to make sense of these concepts.

Ndevu (physics teacher) was quoted as saying “Using learner’s conceptions was one of our problems’’ shows that the problem was known by most of the teachers and they have accepted it. From the words of Ndevu, there was no indication that they have attempted to alleviate the problem. Jabhi (subject advisor) also confirmed the challenge of preconception as one of the common features among learners, which indicates that preconceptions were not identified and used as pre knowledge. From what was said, it is evident that there was no collaborative learning and no prior knowledge was considered.

These preconceptions, when it relates to work, energy and power are also confirmed in literature by Duit and Treaqust (2008:43) and Chiras (2008:70) who noted that learners have preconceptions about work, energy and power concepts which emanate from previous experiences, materials and inappropriate teaching methods (See 2.4.1.1).

The literature confirmed that there are general misconceptions relating to work, energy and power (see 2.7.1.1). Pendrill (2012:243) suggested that there is a need for the teachers to identify work, energy and power conceptions, and take them as hypotheses based on everyday experience to rectify them.

Neglecting learners' pre instructional conceptions indicate the exclusion of learners from the teaching and learning process. This makes it difficult for the learners to make sense of work, energy and power concepts.

Jabhi is quoted saying, "make understanding of these concepts difficult by neglecting learners' conceptions." From a bricolage point of view, this phrase indicates that Jabhi sees learners' conceptions as the tools that the learners have to assist them in the construction of knowledge about work, energy and power concepts (Kincheloe 20005:323). Jabhi, from the subject specialist point of view, sees the neglect of learners' conception as detrimental to the understanding of this concept. This indicates that Jabhi has moved beyond the blinds of the traditional approach that views the learners' conceptions as misconceptions instead of pre-experience to build on (LaForce, Noble & Blackwell 20017:2). From the word "neglect" one can deduce that the teachers often neglect learners' conceptions and this deprives the learners from a chance to dialogue with work, energy and power concepts under their conceptions (Campos 20016:2). This deprives the learners of the chance to make use of their conceptions as the tool at hand to make sense of work, energy and power concept.

4.2.2 Confusion associated with the concepts of work, energy and power

The words "work, energy and power" have various applications and meanings that relate to the contexts in which they are used (Bhattacharijya 20002:19). For instance, people will always indicate that they go to work; they have no energy, or have power to do things on a daily basis when they refer to the daily use of these concepts. Yet the unemployed will indicate that they have no work, no energy and no power when in essence they may be involved in several chores and activities including thinking about their situations. Work involves the transfer of energy at a certain rate (power). This means work has invariably been closely connected with energy and power, which in turn have various applications (Sirait, Hamdani & Mursyid 20017:2) and as such need to be taken seriously and understood thoroughly. Work and therefore energy and power are the essence of life and living (Rosengrant et al. 2009:5). Work, energy and power are often associated with change and transformation of things, systems and processes. Mechanically, work may be defined as the change in position caused by a net force applied on an object ($W_{net}=F_{net}.\Delta x \cos\emptyset$). Energy is the ability to do work ($E_m=E_p+E_k$) and power as the rate at which work is done ($P=\frac{W}{t}$). It is for this reason that special attention should also be given on the work, energy and power concepts. Due to the use of work, energy and power concepts in different spheres of life, it becomes difficult for the learners to develop a deeper conceptual understanding of these concepts (Iwuanyanwu 20014:18).This results in learners developing a colloquial understanding of the these concepts, which is in contrast with the physics curriculum (Sefton: 2004:8), (see 2.4.1.2.).

Learners have the problem in understanding work, energy and power concepts. This means learners find it difficult to relate these concepts and the theory that they were presented in class with the real scientific world (Alonzo & Steedle 20009:129) (see 2.4.1.2.) This results in learners being unable to develop a conceptual understanding of these concepts, and failing to apply them in solving problems related to these concepts (Tang et al. 2011:10) (see 2.4.1.20.

Luyi and Bhamu had the following conversation during the meeting that we had in the school where the research was conducted

> *Luyi (learner): "We have a problem in understanding work-energy theorem and work done by non-conservative forces. It is difficult for me even to recall these concepts. I only memorise them for the test."*

Bhamu added:

> *I also have a problem with these concepts, especially if I use their formulae to calculate work done on an object. These, formulae are almost the same, they confuse, me. Even last year, I think the way we were taught make us memorise this concepts.* (Bhamu)

Analysis shows that most learners have a problem in understanding work-energy theorem and work done by non-conservative forces concepts. Luyi was quoted saying. "It is difficult for me to recall these concepts. I only memorise them." This phrase shows that learners have difficulty in comprehending these concepts; as a result they resort to memorising them. The pronoun "we" that is used by Luyi indicates that most of the learners have this problem. The statement from Luyi shows that most learners cannot even state work-energy and theorem. Those who can have only memorised it.

Bhamu made the statement, "I also have a problem with these concepts, especially when I have to use their formulae to calculate the work done on an object. These formulae are almost the same, and they confuse me."

Learners' conversation show that most have problems with these concepts.

From Luyi and Bhamu utterances, it is clear that most learners confuse Work-Energy theorem and the work done by non-conservative forces. These formulae are as follows: Work-Energy Theorem ($W_{net}=\frac{1}{2}mv^2 - \frac{1}{2}mu^2$) and work done by non-conservative forces ($W_{nc}= \Delta \frac{1}{2}mv^2 + \Delta mgh$). Looking closely at some formulae one can deduce that it is easy for learners to confuse these formulae if learners did not develop a deeper understanding of these concepts.

Bhamu is quoted saying,"… I think the way we are taught make us memorise this concepts". This phrase suggest that these learners were taught in a traditional approach that emphasise the memorisation of the concepts without understanding.

From this statement one can deduce that these learners are deprived the right of understanding concepts of work energy theorem and the work done by non-conservative forces. According to Aasland and Flotten (2000:1027) deprivation is another form of social exclusion where people are deprived opportunities in particular spheres. In this case learners are deprived the opportunity to understand work, energy and power concepts by using the teaching approach that does not that accommodate all the learners. This means some learners are excluded from the process of knowledge construction.

From the bricolage point of view the approach that promote learners' memorisation of work-energy-theorem is constraining to learners' thinking about these concepts (Mahlomaholo 20014:175). This situation deprive the learners an opportunity to adapt or respond the problems related to work-energy theorem and work done by non-conservative forces.

4.2.2.1 Energy concept

Energy is one of the most important concepts in science. It is a multidisciplinary topic covering interaction of physics, chemistry and biology (Mesic, Muhmutovic, Hasovic & Erceg 20017:54). The learning of energy concept in different disciplines poses a challenge to learners because it is defined differently in different disciplines (Hewitt (2002:106-107)

The traditional way of defining energy is "the ability to do work" (Mnchunu 20012:30). As the definition of work, this energy definition was not very precise, nor valid for all types of energy (see 2.4.1.2.2) (Papadouris et al. 2008). It is, however, valid for mechanical energy, which is a part of the discussion in this study. This implies energy is a more abstract concept than work. It was, therefore, important for the learners to understand the nature and the role of energy in their lives (Coelho 20009:2650). These explanations help learners to apply this understanding to answer questions and solve problems in their daily lives. Current national and global issues such as the fossil fuel supply, climate change, and load shedding highlight the need for energy education.

The everyday use of energy concepts make it difficult for the learners to develop the scientific understanding of this concept (Giancoli 20000:120). This result in learners defining energy concept in a colloquial terms (Tarın 20009:269). For the same reason, learners have difficulty in understanding and applying the principle of conservation of energy in relevant situations (Takaoğlu 20018:655). For example, in the pendulum, learners have a challenge in finding potential energy or kinetic energy at any point.

> *During the discussion with the team members, this is what the team members discussed:*
>
> *Qondi: "The issue of energy is confusing because the way we use this term in our societies is different from its use in physics."*

Tozi added:

> *I think that is one of our biggest problem as learners. I also think that the way teachers teach the concepts of energy make the things worse. Sometimes we are only required to memorise the definition of energy and the formulae that are involve in calculating the energy concept.* (Tozi)

Bhamu commented:

> *Another problem we have is the understanding of principle of conservation of energy. I know it by heart, but I do not know when to apply it. I do not understand the term conservation. To my knowledge, conservation of energy is the saving of energy.* (Bhamu)
>
> *Mthwasi: "I think this make it difficult for the learners to calculate mechanical energy of an Object.] For example, potential energy or kinetic energy at any point of a pendulum."*

In the discussion, Qondi indicated the energy concept was confusing for them. In her statement Qondi states that "the way we use this term in our societies is different from its use in physics." The statement from Qondi shows that the way the concept of energy is defined in their societies is different from the way this concept is defined in physical science curriculum. This statement shows that the social definition of the energy concept makes it difficult for the learners to develop a definition of the energy concept that is in line with the physics curriculum.

Another problem that the learners have about the energy concept is the method that the teachers use to teach this concept. This emerges from Tozi's statement when she said, "the way the teachers teach the concept of energy". This means the method that the teachers use in teaching this concept makes it difficult to be understood by the learners. Tozi is further quoted as saying "we are only required to memorise the definition of energy and the formulae that are involved." This statement points to the traditional teacher-centred learning that relegates learners from knowledge construction (See 3.4.1.2) (Hewitt 20002:106-107; Sefton; 2004:2). This traditional and monological method excludes the learners and deprives them from the chance of developing a deeper conceptual understanding of the energy concept.

In another case, Bhamu pointed out the problem of the principle of conservation of energy. Bhamu is quoted as saying "Another problem we have is the understanding and application of principle of conservation of energy. In the statement made by Bhamu, the phrases," I have memorise it by heart ….do not know when and how to apply it." This phrase shows that learners have a problem in understanding this concept and they have to memorise it. This poses a challenge when learners are supposed to apply the principles in solving problems related to the energy concept. Bhamu puts it clearly that he does not even understand what conservation means. Bhamu uttered the words, "conservation of energy is the saving of energy." This phrase demonstrates that Bhamu has a colloquial understanding of this concept. This can emerge from the social use of this concept. This leaves him with the notion that energy can be used up, (see 2.4.1.2) (Papadouris et. al 2008:120)..

Sharing the same sentiment, Mthwasi articulated the words, "this makes it difficult for the learners to calculate mechanical energy of an object." This adds to the notion that if the learners did not develop the conceptual understanding of the principle of conservation of energy, it is difficult for the learner to calculate the mechanical energy of an object.

From a bricolage perspective, the monological approach and neglect of social and cultural experiences that link learners' content to the context make it difficult for them to understand the energy concept, (Kincheloe 20004:48; Berry 20015:88). According to Campos (2016:8), this removes the teaching and learning phenomenon from its context and impasses recognition of the multiplicity of the teaching process. This result in a poor understanding of the energy concept.

4.2.2.2 Power as a challenge

The concept of power in the context of this study refers to the rate at which work is done or energy is transformed from one form to another (Arslan & Kurnaz 20014:629). This means that the faster one performs work, the more powerful one is. The principles of power are applied, for instance, in machines and cars where an attempt is made to generate or perform more work in the shortest possible time. The purpose is generally to increase productivity and to lower the costs of goods and services provided (i.e. economical). In this sense, power potentially and immensely influences businesses. Employment tends to target persons who are powerful in the sense of influencing and producing desired services in a short space of time. The relationship between power, and work may be traced from the following:

$$P = \frac{W}{\Delta t} \text{ ; } W = \Delta x \cos \emptyset \text{ ; } P = Fv$$

The concept of power in the context of this study refers to the rate at which work was done or energy was transformed from one form to another (Amir & Yazdi 20017:4). This means that the faster one performs work, the more powerful one is. The principles of power are applied, for instance, in machines and cars where an attempt is made to generate or perform more work in the shortest possible time. The purpose is generally to increase productivity and to lower the costs of goods and services provided (i.e. economical). In this sense, power potentially and immensely influences businesses. Employment tends to target powerful persons in the sense of influencing and producing desired services in a short space of time. The relationship between power, energy and work may be traced from the following definitions of power, mechanical work done on an object and work-energy theorem respectively:

$$P = \frac{W_{net}}{\Delta t} \text{ ; } W_{net} = F\Delta x \cos \emptyset ; W_{net} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2;$$

$$P = \frac{\left[\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right]}{\Delta t} = \frac{m(v^2 - u^2)}{2\Delta t} = \frac{F_{net}\,\Delta x \cos \emptyset}{\Delta t}$$

Learners have the challenge of understanding the concept of power. Learners become confused about the concept of power and energy (see 2.4.1.2.4) (Kurnaz 20009:2).

This makes it difficult for learners to develop an understanding of this concept. The learners end up memorising definitions and the formulae for this concept (see 2.4.1.2.4) (Walker 20014:17).

This emerged from the discussion that we had with the team of co-researchers during our meeting. Chazi and Ruth had some discussion. The following are some of the comments received from our (co-researchers') reflection sessions and from our engagement with learners on what they understood about the concept of power:

Kapa: (a parent, mechanic) commented:

> *The power of a car engine has to do with its ability to enable transportation of heavy load like the one a heavy-duty truck compared to a mini cooper. The power of a car also determined by how fast it reaches a certain high speed.* (Kapa)

Kapa, from the mechanics perspective, compares the power of a heavy truck with the power of a mini" A phrase show that Kapa associate the power of a truck to its ability to carry a heavy load." Kapa further uttered the phrase, "The power of a car …how fast it reaches the high speed." Kapa associates the power of a car with its rate of attaining the higher speed. This can mean that centrally to Kapa's notion is the definition that" Power is the rate at which the truck carry the heavy load", or Power is the rate at which the car attain the high speed." This brings us to the formula P=$\frac{W}{t}$. During the discussion, Chazi uttered the statement,

Chazi: (enquired): Does it mean the small car has more power than a truck?

While Chazi was speaking, Tozi interjected.

> *Tozi (learner):"I know power to be like the force with which work was done, like moving that stone (pointing at the nearby stone) to another position."*

Bhamu added,

> *Bhamu: "I know power as force or energy to do work, or ability to influence change. What about the saying that electricity is power? I heard people saying that."*

Chazi's questions if the small car has more power than a truck. Tozi understands power as a force and Bhamu attributes it as ability to influence change. In the discussion about the power concept, the team members had different ways in which they understood the concept of power. Each perspective reflected how each member defined the power concept.

4.2.3 Learner involvement as a challenge

Learner involvement is crucial during teaching and learning of work, energy and power concepts. According to the theory of social constructivism, for learning to occur, there must be social interaction between the teacher and the learner and between the learner and the learner's peers (Bull 20009:1). DoE (2003:3) emphasises the importance of shifting from teacher input to learner's outcomes to enhance the learner's understanding of new concepts. According to Benjamin (2015:6), if the teacher wants to improve the conceptual understanding of work, energy and power concepts, the teacher should allow active participation of the learner in the teaching and learning process. Furthermore, Antwi et al. (2011:46) posit that active learning gives the teacher a chance to identify and acknowledge conceptual blockages. This helps the teacher to find a way of alleviating them. It is noted by Rogers (2012:1) that learner involvement embraces a multiplicity of learners' epistemologies through inquiry.

Lack of learner involvement is one of the challenges in teaching and learning of work, energy and power concepts. According to Rajmoor (2012:45), the teacher-centred approach that the teachers use during teaching and learning deprives the learners of the chance of taking an active part in the process of knowledge construction. This makes it difficult for the learners to develop a deeper understanding of work, energy and power concepts. This result in learners memorising these concepts (see 2.4.1.3.)_ (Holubova 20008:25).

This was evident in the conversation below. Jabhi commented:

> *What I have been observing all these years is that in most of physics classroom teacher-centred approach is dominant. Teacher's uses lecture method that was based on transmission of knowledge with little or no learner involvement when teaching work, energy and power concepts.* (Jabhi)

While Jabhi was talking, Chazi interrupted

> *Chazi: "That is true mhloli, this make us to memorise these concepts without understanding them."*

In the discussion with the team members Jabhi articulated the words,

> *"in most of physics classes, teacher-centred approach is dominant."*

The words from Jabhi demonstrate that in most physics classes teachers are using the teacher-centred learning where the teacher is a dominant figure as the transmitter of knowledge. In these classes, the voice of the learners are rarely heard because the learners seldom take part in teaching and learning. From the statement, the word “dominant” indicates that the teacher does everything in the class, and the learner remains the passive recipient of the information. Jabhi further uttered the words, “no learner involvement.” This means the learners are not involved in knowledge construction about these concepts. From Jabhi’s point of view, the teachers do not involve the learners when teaching work, energy and power concepts. According to Jabhi, this makes it difficult for learners to understand these concepts. Jabhi’s words demonstrates that the act of marginalising the learners from the teaching and learning process is the known practice. This means viewing learners as empty vessels has become a social norm.

Chazi pronounced the phrase, “*this make us to memorise these concepts*”. This means if learners are not involved in the construction of knowledge, they resort to memorising these concepts.

The literature indicates that a lack of learner involvement is a challenge in the teaching and learning of work, energy and power concepts. Rajmoor (2012:45) expresses the same view that when teacher-centred learning was used during teaching and learning of work, energy and power concepts, learners were deprived of an opportunity to take an active role in the construction of their knowledge.

What was happening in this situation was not in line with bricolage, my theoretical framework that encourages multiplicity in knowledge creation through the involvement of all stakeholders in the process of knowledge creation. Rogers (2012:1), in his work confirms that active learning embraces a multiplicity of learners’ epistemologies through inquiry. The teacher, in this case, does not recognise the learners’ input and marginalises the learners from the process of knowledge co-construction.

4.2.4 Pedagogical content knowledge (PCK) as a challenge

The teacher’s PCK seems to be more important in the teaching and learning of work, energy and power concepts in a sense that it contributes to the learners’ performance in these concepts. Teacher’s PCK is the teacher’s knowledge of the subject content and pedagogy (Shulman 1986:4; Kathirveloo et al. 2014:2). This involves the knowledge of learners’ conceptions, the cognitive demands that these concepts have and the knowledge of the curriculum (Sibuyi 20013:10).

Insufficient teachers' PCK is one of the challenges in the teaching of work, energy and power concepts. According to Saglam-Arsalan and Kurnaz (2009:6) teachers with insufficient PCK are not at an adequate level of explaining the concepts to the learners, which makes it difficult for learners to understand (see 2.4.1.4). Etkina (2010:4) noted that the shortage of PCK in teachers creates a gap in their teaching knowledge, which makes it difficult for the learner to understand work, energy and power concepts. Mishra and Koehler, (2006:1027) noted that this could lead to the formation of alternative conceptions in work, energy and power concepts (see 2.4.1.4).

The team members discussed teacher's pedagogical content knowledge:

Slova (maths teacher) commented*:*

> *Teachers' knowledge of the content and methods of teaching was important in teaching work, energy and power concepts. Especially because this concepts are abstract.* (Slova)

Mthwasi (physics teacher) added:

> *"I also believe so; I think that knowledge can assist the teacher to explain these complex concepts well using the proper teaching strategy*."

During the discussion, Slova commented:|

> *"Teachers' knowledge of content and methods…is important in teaching."*.

The statement from Slova showed the importance of PCK in learners' understanding of work, energy and power concepts. From this statement, one could deduce that PCK assists the teacher to explain work, energy and power concepts in a way that is easy for the learners to understand. Slova went on, "*these concepts are abstract*" Slova used the concept "abstract" to explain the degree of difficulty of work, energy and power concepts. The dictionary meaning of this word is, "existing in thought or as an idea but not having a physical or concrete existence." The fact that these concepts do not have physical existence demands that the teacher should have sufficient knowledge and teaching strategies to explain these concepts to learners. Mthwasi quoted, saying, "*that knowledge will assist the teacher to explain these complex concepts.* "This statement demonstrated coherence as it builds on Slova's explanation on the importance of teachers' PCK in enhancing learners' understanding of work, energy and power concepts. This means the teacher with insufficient PCK is unable to match his/her teaching to the learners' learning styles. This excludes learner from constructing the knowledge about work, energy and power concepts, and derails learners' understanding of these concepts. This means that the lack of PCK minimises the learners' chances to develop a conceptual understanding of work, energy and power concept.

The statements from Slova and Mthwasi indicate that the teacher with insufficient PCK does not possess enough teaching strategies to assist the learners in penetrating the complexity of work, energy and power concepts (Kincheloe 20005:326). This might further mean the teacher lacks appropriate knowledge of overcoming challenges in work, energy and power concepts and turn them into opportunities (Campos 20016:2).

4.3 SOLUTIONS IN TEACHING AND LEARNING OF WORK, ENERGY AND POWER CONCEPTS

This study aimed to enhance teaching and learning of work and energy concepts in Grade 12 physical science class. To respond to the challenges, the team members came up with suggested solutions. In this section, the solutions that were suggested by the team are discussed. These solutions were:

1) Linking learners' conceptions to teach work, energy and power concepts, 2) Teaching work, energy and power concepts using multiple representations, learner involvement and the teacher's PCK as the solution for the teaching and learning of work, energy and power concepts.

In the discussion we held with the team, the team members suggested some additional solutions that they thought could respond to the objectives of the study during the development of the strategy to enhance teaching and learning of work, energy and power concepts in the Grade 12 physical science class. The following are some of these solutions.

4.3.1 Linking learners pre-knowledge to work energy and power concepts.

For teachers to address the challenges of alternative conceptions in learners, the teacher should link learners' conceptions to work energy and power concepts (Duit & Treagust 2003:680), (see 2.4.2.1). Cognitive theories posit that learner's knowledge should be linked to the new knowledge to make the new knowledge meaningful to them (Ertmer & Newby 2013:54). This emphasises the importance of a teacher knowing learners' pre-instructional conceptions to help learners to develop conceptual understanding of work, energy and power concepts (Agiande et al. 2015:396) (see 2.4.2.1.)

The team members were discussing the possible solution that could be used alleviate the challenges facing the teaching and learning of work, energy and power in Grade 12 physical science class when Jabhi, Tozi and Slova remarked:

> *Jabhi: "I think it is important to find out what learners know about work, energy and power concepts and build on that knowledge."*

While Jabhi was talking, Tozi intervened:

> *Tozi (learner): "I agree with you inspector, sometimes you find that what you know is very close to the right thing, when the teacher correct it, you become happy."*
>
> *Slova (physics teacher): "It is not easy for the learner to forget that because it is his /her knowledge, you just rectify the small mistake in his /her knowledge."*

From the discussion above, it is clear that there is a need for the teacher to use learners' pre instructional conceptions to enhance learners' understanding of work, energy and power concepts. Jabhi, in her statement pronounced the phrase, *"find out what learners know.* 'This emphasises the need for teachers to know their learners' conceptions. From Jabhi's words, one can deduce that Jabhi is of the notion that some of the learners' conceptions might resonate with work, energy and power concepts hence, it is important to know and use them to enhance learners' understanding. Jabhi's words "build on that knowledge,'' show that Jabhi recognises the learners' conceptions as the knowledge that is based on learners live experience (Duit & Treagust 2003:680) (see 2.4.2.1). According to Jabhi, it is easy to build the understanding of work, energy and power concepts on learners' conceptions. This means Jabhi does not take the learners as the blank slates given that she trusts learners' conceptions in developing the understanding of work, energy and power concepts.

The words uttered by Tozi, "close to the right thing,'' shows that these conceptions are deeply rooted in learners minds and are resistant (Duit, & Treagust 20012:48). This calls for the need for the teacher to link learners' context to the content to develop learners' conceptions into intended work, energy and power concepts (see 2.4.2.1) (Agiande et al. 2015:396).

From the comments made by Slova, “It is not easy for a learner to forget,’’ indicated that Slova shared the same sentiment with Jabhi and Tozi that learners, conceptions can help to enhance an understanding of work, energy and power concepts. The words uttered by Slova suggest that using learners’ conceptions help the learners to retain work, energy and power concept knowledge for longer. This means Slova believe that using learners’ conceptions can help to move information to the long-term memory (Schweppe & Rummer 20013:287). From utterance above, one can deduce that the use of learners’ conceptions empowers the learners by including them in the process of knowledge construction.

The words from the team members above suggest that the teacher should help the learner to retrieve and recombine pre-knowledge with new work, energy and power concepts knowledge (Klaas & Knecht 20016:20). This calls for the teacher to use learners’ conceptions as a tool to build an understanding of work, energy and power concepts (Etkina 20010:10).

4.3.2 Teaching work, energy and power concepts using multiple representations

The use of multiple representations can assist the teacher to enhance teaching and learning of work, energy and power concepts. The theory of multiple representations, which Diene named “Perceptual Variability Principle,” states that the same conceptual structure should be presented in as many perceptual equivalents as possible (Cikla 20004:15). This can help to develop the scientific essence of an abstraction in learners’ minds (Dubinsky 20002:980; Kramer 20007). The use of multiple representations can enhance the understanding of work, energy and power concepts in learners (see 2.2.2.2) (Sharma 20012:162). Multiple representations include the use of qualitative representations like pictures, graphs, diagrams, simulations videos, concept maps, and other representations (see 2.4.2.2) (Heuvelen & Zou 20001:184). There were discussions about the use of multiple representations in teaching work, energy and power concepts

4.3.2.1 Teaching the concept of work

It is imperative that multiple representations should be used to teach the work concept in order to accommodate different learners’ learning styles (Nixon 20012:8).

It was difficult to find a single definition of the work concept that befits all contexts because this concept was applied in many disciplines. For this study, I have adopted a definition of work extracted from Grade 12 physical science books, the mechanics part. Papadouris, (2008:34) define work done on an object by a constant force as the magnitude of the displacement (d) times the component of the force parallel ($F_{\parallel}$) to the displacement. Writing this in an equation form it becomes $W = F_{\parallel} d \cos \theta$, where $F_{\parallel}$ is the component of the constant force F parallel to the displacement d of the object, θ is the angle between the directions of the force and displacement. According to Jewett (2008:38), this definition may lead to a conceptual difficulty when the force like friction act on an object.

It is for this reason that multiple representations were used to enhance learners' understanding of the work concept.

The work-energy theorem and the work done by non-conservative forces are among the abstract concepts that are difficult to understand when only verbal descriptions are used to teach them.

When the team members were discussing the work energy theorem and work done by nonconservative forces, Chazi, Jabhi and Ndevu had the following contributions.

> *Ndevu: "Because of the complexity of the work-energy theorem and work done by non-conservative forces, multiple representations should be used to teach these concepts in order for learners to understand them better."*
>
> *Jabhi commented:*
>
> *I also think that in addition to verbal explanation, pictures and diagrams, bar graphs can make learners' understanding of the work energy theorem and work done by non-conservative forces better. From my experience this concept are understood better by learners if bar graphs was used as one of the descriptions.* (Jabhi)

Jabhi drew bar graphs representing work energy theorem and work done by non-conservative forces. She then explained work energy theorem and work done by non-conservative forces using bar graphs on the board. She used different colours for each bar graph. Jabhi commented:

> *The] work energy theorem and work done by non-conservative forces relate work and energy. We can use bar graphs to show this relationship. The length of the bar graph is proportional to the amount of energy or work. For positive energy or work, the graph is going up. For negative work or energy, the graph goes down. Remember that the sum of bar graphs on the left must always equal to the ones on the right.* (Jabhi)

She continued explaining using bar graphs until she finished.

Chazi: "This thing is now crystal clear.

Ndevu: "You simplified it."

Jabhi selected the problem and write on the board as follows:

> In a physics lab, a Hot Wheels car starts at an elevated position, moves down an incline to the level ground, strikes a box and skids to a stop. Consider three positions for the car: State A is the top of the incline; state B is the bottom of the incline before striking the box; state C is after the car has been brought to a stop. Use the diagram at the right and your understanding of the work-energy theorem to construct bar charts for the motion from A to B and from B to C.

She then drew the diagram to show what was said by the question.

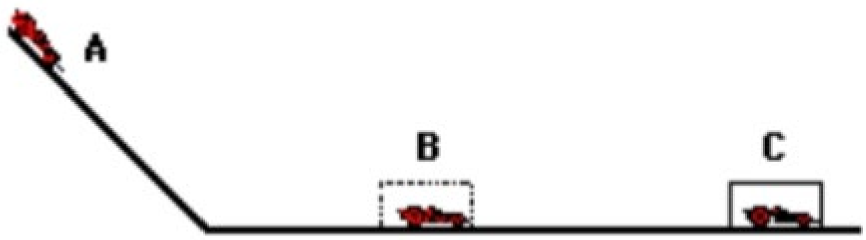

FIGURE 4.1: THE EFFECT OF FORCE ON AN INCLINE.

After some discussions with the team members, Jabhi took out the picture of the bar graphs to represent the solution to the problem and explain the steps that are involved.

The picture of the bar graphs that were used by Jabhi to explain the work-energy theorem and work done by non-conservative forces is depicted below.

Ndevu uttered the phrase, "multiple representations should be used to teach these concepts."

This statement suggested that teachers should not only rely on verbal descriptions when teaching the work-energy theorem and work done by non-conservative forces but use multiple representations. This statement suggests that teachers' instructions that involve multiple representations of the work concept can assist the learners in relating the work concept to the real physics world; as a result learners are able to Fig

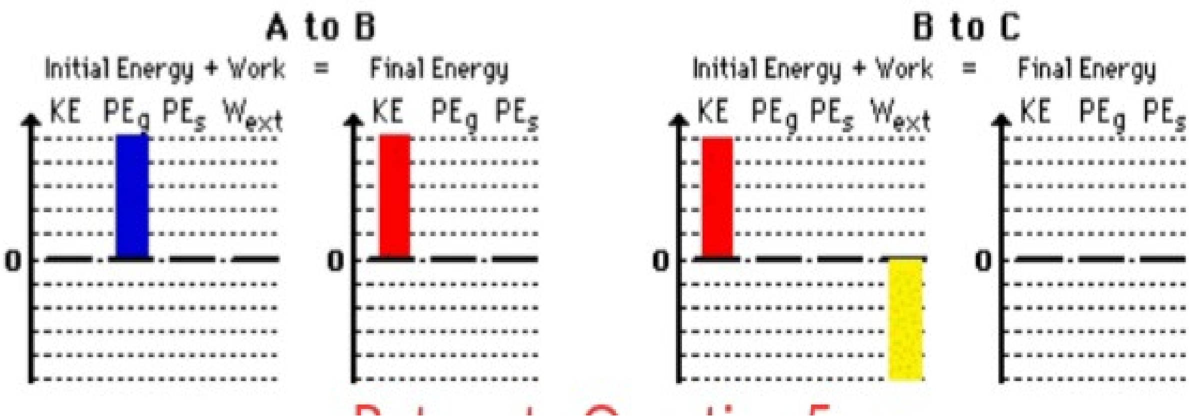

FIGURE 4.2: BAR CHART ILLUSTRATIONS TAKEN FROM CLASSROOM PHYSICS

develop a deeper understanding of this concept (Ruffle 20003:123; Rosales & Journell 20012:58).

Jabhi suggested that the bar graph should be among the descriptions that are used to explain the work and energy theorem and work done by the nonconservative forces. According to Jabhi, the bar graphs help learners to understand these concepts better. During discussion Jabhi uttered the statement, "in addition to verbal explanation, pictures and diagrams, bar graphs make the understanding of …better". From the statement uttered by Jabhi, it was further suggested that the learners understand these abstract concepts better when using the bar graphs, looking closely at Jabhi's presentation. The words, "*from my experience*", uttered by Jabhi indicated that she was familiar with the usage of the bar graphs in teaching these concepts. These words suggest that she has had an opportunity of teaching these concepts using different approaches and has found that the bar graph approach yielded better results. The statement by Chazi, "this thing is crystal clear," suggested that Chazi understood the way Jabhi explained these concepts using bar graphs. Pursuing this further, Ndevu's words, "you simplified it," also indicated that he was impressed by the way Jabhi presented these concepts using verbal description, sketches and bar graphs. This means that the team members well understood the concepts of the work energy theorem and work done by nonconservative forces. From the above statements, one can conclude that verbal descriptions, pictures and bar graphs as qualitative descriptions can help learners to enhance an understanding of work-energy theorem and work done by nonconservative forces. This makes it easy for learners to understand the formulae of these concepts.

4.3.2.2 Energy and power concept

Like work, energy concepts have different applications and meanings that were related to the contexts in which these concepts were used (Murray, Skene, & Haynes 20017:370). It is a multidisciplinary concept covering the interaction of physics, chemistry and biology (Mesic et al. 2017:54). Energy concepts were also used in everyday life. For example, when someone was tired, he or she said " I am running out of energy" (Coelho 2009:2650). Learners need to understand the nature and role of energy in the universe and their lives (Arroio 20010:135; Coelho 20010:15). This will help them to apply this understanding and solve problems related to energy in their lives (Camarca et al. 2007:1181). Mechanical energy can be defined as the ability to do work (Kurnaz 2009:4). This implies that the energy concepts were more abstract than the work concepts. It was for this reason that energy concepts and energy conservation were discussed. Learners often encounter a problem in understanding energy concepts. The way this concept is used in everyday life makes it difficult for learners to understand this concept. Learners confuse the concept of energy with force, power and electric concepts (Kurnaz & Sağlam Arslan 20009:4). It was therefore important that the teacher uses multiple representations to enhance learners' understanding of the energy concept. According to Bezen et al. (2016:110), multiple representations allow learners to draw the connection between the energy concept that were used in everyday life and the one that is accepted by the physics curriculum. According to Coelho (2010:15), multiple representations accommodate the diverse ways in which different learners make sense of the energy concept. Alluding to this notion, Lucy (2012:15) posits that multiple images integrate learners' old perception with new and scientific perceptions about energy concepts (see 2.4.2.2). In pursuance of this notion, Savian and Gonsalves (2008:1443) indicated that this brings about an ontological and epistemic shift in the energy concept that brings about a new understanding of this concept.

This emerged when the team members discussed the energy concept.

Jabhi: "It is important for the teachers to use as many representations as possible when teaching energy concept. Multiple representation accommodate the diverse way in which the learners learn."

Bhamu commented:

I agree with you mhloli, this also help to remove non-scientific ideas that we have about this concept. Some associate energy with force and some with power. (Bhamu)

Ndevu added:

I agree with you, most learners take energy and force as meaning the same thing. I also recommend the use of multiple representation in teaching this energy concept. Since it involve qualitative approach, where pictures and diagrams are used and quantitative approach where formulae are used to explain energy concept. It make it easy for learners to understand this concept. (Ndevu)

Jabhi believes that it is important for the teachers to use multiple representations in teaching the energy concept. Jabhi uttered the statement, "multiple representations accommodate the diverse ways in which learners learn." This statement points to the necessity for the teachers to use different teaching strategies to teach the energy concept. From Jabhi's point of view, this allows each learner to relate to the energy concepts in a way that suits his/her learning style (see 2.4.2.2) (Van Wyk 2011:183). The statement from Jabhi suggests that since learners have different contexts, which makes them have different ways in which they construct knowledge about energy concepts.

This makes it necessary for the teacher to use multiple representations to teach energy concepts. Bhamu agrees with Jabhi that multiple representations can help the learners to develop an understanding of the work concept. Bhamu adds that multiple representations can also help address learners' misconceptions, Bhamu is quoted as saying, "this also help to remove non-scientific ideas that we have about this concept." The statement from Bhamu points to the presence of alternative conceptions in learners about the energy concept. The pronoun "we" in Bhamu's statement demonstrates that the problem of misconceptions does not just concern him or individual learners, but most of the learners. Ndevu, who made an example of learners confusing energy and force concept, confirms this point. Adding to this notion, Ndevu adds that the qualitative and quantitative approaches that are inherent in multiple representation help in developing a deeper conceptual understanding of the energy concept. Doolittle (2002:1) shares the same sentiment that both recall and memory are improved when information is presented in multiple ways to learners.

There is coherence in the statements from Jabhi, Bhamu and Ndevu in their emphasis on the use of multiple representations in enhancing learners' understanding of the energy concepts. As in bricolage, multiple representations use multiple approaches to cope with the complexity of the energy concept. This allows both the learner and the energy concept to be transformed.

Discussion were also held about the teaching of power concepts. Ndevu, Mthwasi and Bhamu discussed the teaching of power concepts:

> *Using multiple approach can help learners to understand the concept of power. I think we must use qualitative approach by using descriptions like words, picture, diagrammatic, graphic before engaging ourselves to mathematical descriptions like the formulae.* (Ndevu)
>
> *Bhamu: I also believe that like in other concepts, multiple approach to the teaching and learning of power concept can help the learners to understand these concepts.*

The phrase, "using multiple approaches can help learners to understand the power concept," from Ndevu's statement show that Ndevu believes that multiple representations can be the solution to the representations of work in developing the conceptual understanding of other concepts. He has now developed confidence in the use of multiple representations; hence he supports Ndevu about the teaching of power concepts. Ndevu's statement shows that the teacher should first use both qualitative and quantitative approaches to the teaching of power concepts. Ndevu, in his statement, suggests, "we must use qualitative approach …before engaging ourselves to mathematical descriptions like formulae." This statement shows that Ndevu supports the idea that the use of multiple representations can help learners to understand the concept of power better.

Bhamu shares the same opinion that multiple representations can assist the learners in making sense of the concept of power. The phrase, "I believe" from his statement shows that he supports Ndevu in his notion that multiple representations can enhance the understanding of the power concept. From the phrase, "like in other concepts" it is clear that Bhamu understood how the use of multiple representations could benefit learners.

4.3.3 Learner involvement as the solution in teaching and learning of work, energy and power.

Learner involvement plays a vital role in the teaching and learning of work, energy and power concepts. Learners should be given a chance to be actively involved in the construction of the knowledge about work, energy and power concepts (see 2.7.2.5). The theory of constructivism states that the learners should be given a chance to take an active role in the construction of their knowledge (Doolittle 2014:55). Slavvin (2003:15) further suggests that peer teaching can help the learners to discuss and find the solution to their problem, and the teacher should act as a facilitator and scaffold the learning process.

During the team members' discussion, Qondi said:

> *I think the teacher should make us part of teaching and learning. The teacher can do that by giving us a chance to say something about the about work, energy and power concepts. That can help the teacher to find out what we know is right or wrong, if wrong, the teacher will rectify it*. (Qondi)

While Qondi was talking, Ruth interrupted:

> *That is true, Qondi, this topic of work, energy and power need to be discussed. It became easy when you discuss it with other learners and it becomes better when the teacher is closer, so that the teacher can help us where we have confusion. If we are actively involved, things become easy.* (Qondi)

Qondi suggests that the teacher should give the learners the chance to be actively involved in the process of teaching and learning of work, energy and power concepts. In her statement Qondi uttered the words, "*should make us part of teaching and learning."* These words indicate that Qondi believes that the teacher should give them a chance to participate actively in the teaching and learning of work, energy and power concepts. Central to Qondi's notion was the perspective that the more they discussed these concepts, the more they develop the conceptual understanding of these concepts. This means the teacher should give learners the chance to discuss and talk about these concepts. In addition, when the learners were given a chance to talk about these concepts, they remembered these concepts for a long time. This approach also helps to promote collaborative learning where the learners work together and explain the concepts amongst themselves. Learner involvement also helps to include the learners in the teaching and learning process as a result, the learners will be empowered.

The phrase by Qondi, “can help the teacher to find out what we know,” indicates that the learner believes that if the learners are given a chance to discuss the learning, the teacher will come to know the learners’ conceptions. As Lee (2009:105) pointed out, this will assist the teacher in using these conceptions in developing a more profound understanding of work, energy and power concepts.

The phrase, “this topic of …need to be discussed,” from Ruth’s statement indicates that Ruth shares the same sentiment as Qondi, that for work, energy and power concepts to be understood by learners, they need to be discussed by the learners. Alluding to a notion of Sekwena (2014:94) that if learners were given a chance to discuss concepts, they transferred it to their long-term memory. This helps the learners to develop an understanding of these concepts and retain them in their minds for a long time. Involving learners in the teaching and learning of work, energy and power concepts help to deal with the issues of power and inequality that manifest itself when the teacher uses the traditional and monological approach to the teaching and learning of work, energy and power concepts. In this approach, the teacher is feeding learners with information, and learners are passive receivers of information. In the traditional approach, the teachers are using the power that is embedded in their knowledge to control and manipulate teaching and learning of work, energy and power concepts. This deprives the learners of their right of taking an active role in the construction of knowledge about these concepts.

4.3.4 Teacher’s pedagogical content knowledge in teaching work, energy and power concepts

Pedagogical content knowledge plays an important role in the teaching and learning of work, energy and power concepts. The teacher with adequate PCK can describe learners’ alternative conceptions and have the skills of making content accessible to learners (see 2.4.2.4) (Ngo 2012:84). In pursuit of this, Olanoff et al. (2014:281) argue that the teacher with adequate PCK knows the content in the context of their teaching, for lesson design, analysis of learners’ work and for their learners’ learning. Following this argument, Eralp (2012:3) posits that PCK includes an understanding of learners’ preconceptions and what makes the learning of work, energy and power concepts easy or difficult (see 2.4.2.4).

During the discussion with the team of researchers, Slova, Mthwasi, Jabhi and Bhamu had the following discussions about the importance of teacher's pedagogical content knowledge in work, energy and power concepts. Mthwasi said:

> *Teacher's pedagogical content knowledge is very important in learners' understanding of these concepts. There is no way you can expect the learners understand these concepts if the teacher does not have enough PCK in these concepts.*

Slova added:

> *I think teacher should also possess trigonometric knowledge. It is important for the teacher to develop that knowledge in these concepts. This help to enhance their knowledge in these concepts and their teaching methods.* (Slova)

> *Bhamu: "I agree with you teachers, if the teacher have the knowledge of these concepts, the teacher can teach better and is able to see if learners do not understands."*

Jabhi added:

> *I think you have raised an important point meneer. Teachers should develop themselves in these concepts. I think that by attending departmental workshop, seminars and enrolling in related courses, the teachers can develop themselves in these concepts.* (Jabhi)

The phrase, "teacher's pedagogical content knowledge is very important" from Mthwasi's statement demonstrates how he values teacher's PCK in an understanding of work, energy and power concepts. The words of Mthwasi show that it is important for the teacher to possess enough pedagogical content knowledge in work, energy and power concepts to help learners to understand these concepts. Following this line of argument Smith (2010:540) and Deng, (2007:513) alluded to the notion that a teacher with enough PCK knows the conceptions that the learners hold in these concepts. This makes it easy for the teacher to alleviate learners' misconceptions. This means that the teacher with enough PCK can transform the knowledge about work, energy and power concepts to learners in a way that can easily be understood by the learners (Chick 20014:60).

Slova agrees with Mthwasi's statement. Slova commented, "I agree ….the teacher should also possess trigonometric knowledge." These words demonstrate that Slova agreed with what Mthwasi was saying. In addition to what Mthwasi proposes, Slova suggested that the teacher should find ways of developing pedagogical content knowledge. Slova articulated the statement, "it was important for the teacher to develop knowledge in these concepts." This statement shows that Slova deems it necessary that the teacher should develop their knowledge in these concepts.

Bhamu agreed with both Mthwasi and Slova. He also added that PCK helps the teacher to see if the learners understand these concepts. The phrase, "teaches better and was able to see if the learners do not understand," shows that Bhamu believed that the teacher with enough PCK could detect if the learners had problems with the concepts.

This assists the teacher to tailor teaching strategies according to the learners' learning styles. This also helps to accommodate the learners' diversity. This further empowers learners and even includes learners that were marginalised by the teacher's teaching strategies from the knowledge construction process.

Jabhi agreed with Slova that the teacher should develop knowledge in work, energy and power concepts. This included attending workshops and enrolling in relevant courses. Jabhi uttered the statement, "attending departmental workshops, seminars and enrolling in relevant courses." This statement demonstrates that Jabhi deems it important for the teachers to empower themselves. According to Jabhi, teacher empowerment was necessary for enhancing their knowledge in these concepts. Teacher development helps the teacher as a bricoleur to peer through a conceptual window to knowledge and knowledge production about work, energy and power concepts (Kincheloe 20005:323).

4.4 CONDITIONS CONDUCIVE FOR SUCCESSFUL IMPLEMENTATION OF THE STRATEGY.

This section addresses the conditions that the team members suggested as conducive for the successful teaching and learning of work, energy and power concepts in the Grade 12 physical science class. These conditions are: Using learners' conceptions in the teaching and learning of work, energy and power concepts, good use of multiple representations; learner involvement and adequate attention for work, energy and power concepts.

4.4.1 Learners' conceptions in teaching work, energy and power concepts

The use of learners' conceptions to enhance teaching and learning of work, energy and power concepts was one of the conditions that was considered conducive for teaching and learning of these concepts. In support of this, Baveja (2012:1070) from India alluded to the notion that learners' conceptions play an important role in forming the base for the understanding of these concepts (see 2.4.3.1.). Arguing this further Wenning (2008:11), posits that using learner's conceptions give learners satisfactory initial pictures of these concepts. This helps the learners to either discard or modify their conceptions (see 2.4.3.1). There was a discussion by the team members about using learners' conceptions to improve the understanding of work, energy and power concepts. In the discussions between Ndevu, Kapa and Chazi, Ndevu said:

> *I think it is good if the teacher link learners pre knowledge to work energy and power concepts. This can help the learner to compare their pre-knowledge to the new knowledge about work, energy and power concepts.* (Ndevu)

Kapa added:

> *Teacher, I also agree with you because we use the words work, energy and power every day in our communities. I think every learner knows something about these concepts. Maybe some learners' knowledge can help understand this problematic topic.* (Kapa)

Chazi commented:

> *Yes chairman, that is true, somewhere these concepts meet with the way we use in our communities, but somewhere they differ and the teacher need to clarify in order for us to understand.* (Chazi)

There was a general feeling from the Ndevu, Kapa and Chazi that teachers should build from learners' conceptions when teaching work, energy and power concepts. According to them, the use of learners' conceptions can help to develop the conceptual understanding of these concepts. This was reflected in the statement uttered by Ndevu. Ndevu uttered the words "*it is good if the teacher link learners' pre-knowledge to work, energy and power concepts*." From this phrase, it is clear that Ndevu believes that by using learners' conceptions the teacher will be able to help learners to develop a more profound understanding of these concepts. Kapa attested to this notion. Kapa uttered these words, "we use words work, energy and power every day in our communities." Kapa added, "*maybe some learners' pre-knowledge can help in understanding these {Sic] problematic topic."* Chazi agreed with both Ndevu and Kapa and added the phrase, "and the teacher need to clarify." The words uttered by Ndevu, Kapa and Chazi make it clear that learners use these concepts more often in their communities. It is then obvious that learners do hold some conceptions about these concepts. Sometimes these conceptions can be wrong, and some can be right under certain conditions (Wenning 20008:11). It is therefore that the teacher is required to identify learners' conceptions and use them to develop the understanding of work, energy and power concepts.

4.4.2 Use of multiple representations

Using multiple representations to teach work, energy and power concepts can be considered as one of the conditions that is conducive for learners to understand these concepts. Elucidating this Nixon (2012:8) posits that multiple representations are a powerful tool in enhancing the understanding of concepts if correctly used (see 2.4.3.2). Stokes (2002:12) emphasises the importance of varying instructional materials and teaching styles to match with different learners' cognitive styles. This will help to span the conceptual space associated with work, energy and power concepts (see 2.4.3.2) (Waldrip et al. 2010:68). From the discussion that the team members had about the use of multiple representations during teaching and learning of work, energy and power concepts, Jabhi, Spesheli and Qondi had the following to say:

> *Jabhi: "This thing of explaining work, energy and power concepts using verbal description, pictures, graphs force diagrams and other descriptions works if you use it well. "*
>
> *Spesheli: "The use of teaching aids is an old thing. I also believe that learners can remember better if they see the picture of what they are learning about."*
>
> *Qondi: "I agree with you Mr Principal, we learn better by seeing things."*

The statements from the co-researchers above show that they all believe that the use of multiple approaches can assist the teacher in boosting the understanding of work, energy and power concepts. This was confirmed by Jabhi in her statement, "*explaining work, energy and power concepts using verbal descriptions, sketches, graphs and other descriptions works if you use them well*." This statement shows that Jabhi was of the view that using multiple representations can help learners to understand work, energy and power better. Spesheli shares the same notion when he articulates the statement, "I also believe that learners can remember better if they see the picture of what they are learning about." Qondi also shares the same sentiment in her phrase, "I agree with you… we learn better by seeing things."

The statements above show that they all agree that the use of multiple representations can help to enhance the conceptual understanding of work, energy and power concepts. Amplifying this notion (Nixon 20012:8) posits that multiple representations complement each other resulting in a more complete representation of the concept than a single source of information. Doolittle (2002:1) pursued this further by stating that the use of multiple representations helps to compensate for any weakness associated with one particular strategy of representation. From the information above, it emerges that the use of multiple representations can assist in accommodating learner's diversity. This can be achieved using different instructional strategies to cater for different learners' learning styles. This approach to teaching and learning of work, energy and power concepts helps to accommodate the diverse and multiple ways in which learners develop an understanding of these concepts.

4.4.3 Learner involvement in teaching work, energy and power concepts

The involvement of learners was one of the conditions that is conducive for effective teaching of work, energy and power concepts. According to Astin (2014:519), the theory of involvement refers to the investment of learners' physical and psychological energy in the teaching and learning process. Kim (2013:2) argues that through learner involvement, strengths that students already have can be highlighted and nurtured. Weimer (2012:168) further adds that learner involvement results in learners, cognitive investment in active participation and emotional commitment to their learning, which can result in high-quality learning. During discussions with team members. Boyi, Slova and Ndevu had the following to say about learner involvement during teaching and learning of work, energy and power concepts:

> *Boyi: "If the teachers can involve us in teaching and learning of work, energy and power concepts, we can understand better".*
>
> *Slova: "I think what Boyi is saying does make sense. I think effective involvement of the learners can enhance their understanding of these concepts."*
>
> *Ndevu: "I am also of the same opinion that learner should be involved during teaching to know their thoughts about the topic, but I doubt if it used every day because it is time-consuming."*

When discussing learner involvement during the teaching and learning of work, energy and power concepts, Boyi, Slova, and Ndevu had the common belief that it can improve the understanding of the concepts. The words articulated by Boyi, "If the teacher can involve us…we can understand better" show that Boyi believes that learner involvement can improve the understanding of work, energy and power concepts. Slova also shares the same view that learner involvement can enhance the understanding of the concepts. They used the statement,” I think effective involvement of learners can enhance their understanding of these concepts.” Although Ndevu is in agreement with what Boyi and Slova believe about active learning, he is sceptical that it can be implemented every day. He used the phrase, “I am of the same opinion, but …,I … doubt it can be used every day.” Ndevu cites time constraints as having a damping effect on the implementation of active learning. The words uttered by Boyi, Slova and Ndevu emphasise the importance of learner involvement in developing a deeper understanding of work, energy and power concepts. This promotes collaborative learning where the learners work together in the process of knowledge co-construction. Collaborative learning makes it easy for the learners to assist each other and ask questions from more able peers without fear of being scorned. As Wattanakasiwich (2010:502) pointed out, learners who work in collaboration may be able to achieve cognitive results together that they will not be able to accomplish as individuals. This means the learners need to participate actively in teaching and learning of work, energy and power concepts for them to be cognitively involved with these concepts. Arguing further Sekwena (2014:97) suggested that the teacher should relinquish his power in the class and become a facilitator to promote active learning.

4.4.4 Sufficient PCK

Sufficient teachers’ PCK was one of the conditions that are conducive for the successful teaching of work, energy and power concepts. Kathirveloo et al. (2014:3) pointed out that the teacher with sufficient PCK can transform the knowledge of the concepts in a way that learners could easily understand it. In support of this Chinyere (2012:21) argues that a teacher with sufficient PCK can identify learners’ conceptions and help them to change or modify them where necessary (see 2.4.3.4.). This means it is important for the teacher to possess sufficient PCK to develop learners understanding of work, energy and power concepts.

Mthwasi, Ndevu and Slova had some conversation about teachers’ PCK. Mthwasi said:

> *Teacher’s PCK does contribute to the way learners perform in work, energy and power concepts. I think, if the teacher is having sufficient PCK on these concepts, learners can perform better in this concepts.* ()Mthwasi)

Hi colleagues added:

Slova: "I also have the same belief that learners' performance does depend on teacher's PCK."

Ndevu: "I also have the same view. Teacher's PCK also help to identify learners' alternative conceptions, which are very problematic and have some strategies to deal with them."

Mthwasi articulated the phrase, "*If the teacher is having sufficient PCK, learners can perform better*." This statement show that teachers' PCK contributes to the learners' performance. That means if the teacher has sufficient PCK, the teacher will be able to help the learners to understand work, energy and power concepts. Slova in the phrase, "learners' performance does depend on teacher's PCK," demonstrates the importance of PCK in teaching work, energy and power concepts. Ndevu articulates the words "help to identify learners' conceptions…and have some strategies to deal with them." Analysis of these words shows the importance teachers' PCK in teaching and learning of the concepts. Alluding to this, Jones and Moreland (2003:78) report that PCK helps the teacher to understand learners' conceptions, how the learner learns so that the teacher can select appropriate teaching instructions. This means the teacher will be able to synthesise all the knowledge needed for the teaching and learning of work, energy and power concepts.

4.5 THREATS IN TEACHING AND LEARNING OF WORK, ENERGY AND POWER CONCEPTS

This section discusses the threats that are associated with the teaching and learning of work, energy and power in the Grade 12 physical science class. These threats include risks in using the learners' conceptions, risks in using multiple representations to teach, inherent risks associated with learner involvement and risks associated with PCK

4.5.1 Risks in using learners conceptions

The use of learners' pre-instructional conceptions is known to be good in enhancing learners' understanding of work, energy and power concepts. Still, there are risk factors that are inherent in using them. Since learners are from diverse backgrounds, they hold different epistemic beliefs (McGregor 2011:2). This causes different learners in the class to have different behaviours. Some learners may, for some reasons, be too shy to talk in the class, as a result, it becomes difficult for the teachers to identify their conceptions (Duit & Treaqust 2008:43). This can hinder the learners' conceptual understanding of work, energy and power concepts.

When the team members were discussing the risk factors that involved in using learners' conceptions, Tozi, Mthwasi and Jabhi commented:

> *Tozi (learner) "The problem is that we sometimes become shy to talk in the class."*
>
> *Bhamu (learner): "That is true, because some laugh at our answers."*
>
> *Mthwasi (physics teacher): "That is a big problem because it becomes difficult for us to know the learners' pre-knowledge. This makes it difficult to select the correct teaching strategy."*

Tozi (learner) uttered the phrase "shy to talk in the class". This phrase from Tozi indicates some learners are reserved for various reasons. As a result, they are too shy to take in the class. This makes it difficult for the teacher to identify some misconceptions that they hold about work, energy and power concepts. Bhamu shares the same sentiment with Tozi that some learners are reserved. Bhamu said, "some laugh at our answers". This statement indicates that some learners are reserved because they are afraid to be scorned by other learners. The word "our" for Bhamu's statement suggests that he was not the only one who was reserved because of being afraid to be scorned. Mthwasi, the physics teacher, agreed with Tozi and Bhamu that for various reasons, some learners are reserved in the class. According to Mthwasi, this makes it difficult for the teacher to know and understand the conceptions that learners have about work energy and power concepts. Bhamu's believed that it was important to know and understand learners' pre-knowledge. Bhamu pronounced the statement, "this makes it difficult to select the correct teaching strategy". The statement from Bhamu demonstrates that teachers find it difficult to tailor the teaching strategy to accommodate different learners in the class who had pre-instructional concepts (Chhabra & Baveja 20012:1070).

4.5.2 Risks in using multiple representations to teach work, energy and power concepts

The use of multiple representations can pose a threat to the teaching and learning of work, energy and power concepts. Arguing this, Rau and Matthews (2017:5) posit that the use of multiple representations may confuse learners rather than aid their learning (see 2.4.4.2.). Nixon (2012:8) concurs, arguing that if different representations are not properly interpreted and no connection is made among the multiple representations and the information they intend to convey, then learners can be confused by them (see 2.4.4.2). During the conversation between the team members about the threats posed by the use of multiple representations in the teaching and learning of work, energy and power concepts, Luyi and Jabhi commented:

> *Jabhi: "We need to be careful when using multiple representations because learners can be confused if they are not properly used."*

Luyi added:

> *It is true mhloli. Sometimes you can find that there is no connection between what the teachers is teaching and the pictures and diagrams that the teacher uses. This make us more confused.* (Luyi)

The statements from Jabhi and Luyi show that the use of multiple representations can pose a threat to the teaching and learning of work, energy and power concepts. Jabhi's statement, "we need to be careful when using multiple representations," demonstrates that the teacher should be careful when selecting the representations of work, energy and power concepts. This means the teacher should be well prepared and choose the correct representations before teaching. The phrase, "learners can be confused" from Jabhi's statement show that if representations are not correctly selected before teaching these concepts, they can confuse the learners. Luyi agreed with what Jabhi was saying. Luyi issued the statement, "sometimes …there is no connection between what the teacher was teaching and pictures and diagrams he/she uses." This statement demonstrates that the representations that the teacher uses do not link the content with the learners' context. This makes it difficult for learners to share the meaning between representations used by the teacher. This will result in the representations confusing the learners instead of aiding the development of a deeper understanding of these concepts (Waldrip et al. 2010:68). Arguing this further Tang et al. posit that this will result in learners constructing work, energy and power concepts understandings that are not congruent with the physics curriculum.

4.5.3 Inherent risks associated with learner involvement

Some traits displayed by learners could be seen as risks. As an example, some learners may display and express their dominant character over the other learners, especially when learning in teams (during collaborative learning). The teacher needs to be sensitive to this and find ways of helping learners deal with this situation.

Slower learners may derail the learning progress of other learners who may be gifted and swift in learning the concepts and even the application of the concepts of work or energy. This means the teacher has to ensure that neither the slow nor the gifted learners are disadvantaged in the learning process.

Learning barriers may also hinder progress when learners get involved in their own learning. Such barriers need to be identified and dealt with appropriately.

Clearly the active involvement of learners in their learning during the teaching process requires time. Unfortunately, the prescribed times during which these concepts have to be taught is limited. Thus, teachers may find themselves having to rush for compliance with the time as prescribed at the expense of involving learners accordingly. Also, see 2.4.4.3.

As the discussion with the team members about risks factors that are involved in teaching and learning of work, energy and power concepts progressed, Mthwasi, the physics teacher and Spesheli, the principal, commented:

> *Spesheli (principal): "Involving learners can also be risky because you may find that only few learners participate in the class."*
>
> *Mthwasi (physics teacher): "That is true Mr Principal, more often few learners dominate discussions. The other thing is time factor. Involving learners consume a lot of our time at the expense of completing the syllabus."*

The discussions between Spesheli and Mthwasi demonstrate that usually a few learners tend to dominate the class when the learner involvement approach is used to teach these concepts. Spesheli said , "you may find that only few learners participate in the class". This phrase demonstrates that a few learners can dominate the teaching and learning process if learner involvement is not monitored properly by the teacher. This could make it difficult for other learners like the slow learners and the learners who are naturally too reserved for participating in the teaching and learning process. Therefore, these learners could be excluded from the teaching and learning process. Mthwasi agreed with Spesheli on the issue of learner dominance and further cited the time factor as another risk in using the learner involvement approach. Mthwasi was quoted saying, "involving learners consume a lot of time at the expense of the syllabus." This statement demonstrates that Mthwasi sees the learner involvement as time-consuming. The words "our time" show that it is not only Mthwasi who sees the learner involvement approach as time-consuming but other teachers carry the same notion.

4.5.4 Risks associated with PCK

Despite the teachers having sound PCK, learners can still have a problem in understanding work, energy and power concepts. If the teacher is inconsiderate of the learners' context during the teaching and learning of these concepts, this can pose a threat to the teaching and learning of these concepts (see 2.4.4.4) (Maries 2013:5). This was illuminated during the discussion with the team members, when they commented:

> *Jabhi: "I think another problem that contribute to the learners' difficulties in understanding these concepts is that teachers neglect their context."*
>
> *Tozi: "I agree with that sometimes you may find that the teacher is making an example of an aircraft that you have never seen."*

Analysis shows that most teachers do not contextualise their teaching when teaching work, energy and power concepts. This makes it difficult for learners to make sense of these concepts. This was also reflected in a comment from Jabhi: "problem that contribute to the learners' difficulties…teachers neglect their context.". Neglecting in this context might mean the teacher disregarded the learners' local knowledge when teaching these concepts. Disregarding learners' pre-knowledge might mean the teacher is ignoring their conceptions that can assist in building the foundation to their understanding of these concepts. According to Jabhi, this makes it difficult for learners to make sense of these concepts.

Tozi agreed with Jabhi, saying, "the teacher is making an example of an aircraft that that you [have] never seen." This means teachers even go to the extent of using the examples that are out of the learners' context. This act excludes the learners from teaching and learning processes, and this deprives the learners' of an opportunity to develop the conceptual understanding of work, energy and power concepts.

4.6 INDICATION FOR SUCCESSFUL TEACHING OF WORK, ENERGY AND POWER CONCEPTS

This section is about the empirical data that was collected concerning some indicators that show successful implementation of a strategy that can enhance the teaching and learning of work, energy and power concepts.

4.6.1 Good use of learners' conceptions

Through the implementation of this strategy, according to DBE (2012:3), teachers can use learners conceptions successfully in developing their understanding of work, energy and power concepts. The use of learners' conceptions is profound to ensure that the teacher is building upon learners' understanding of these concepts to form a solid foundation and transform the teaching and learning of these concepts (Larkin 2012:930). The literature substantiates that successful use of learners' conceptions assist in preventing the formation of alternative conceptions, and helps to develop a more profound understanding of these concepts (see 2.4.5.1) (Chi & Lin 20008:295).

During the team discussion, Ndevu and Jabhi commented.

> *Ndevu: "The use of learners' conceptions to teach work, energy and power concepts is of great success. It help to build a solid foundation in understanding these concepts."*
>
> *Jabhi: "Yes Mr Ndevu, using learners' conceptions is a very good approach to the teaching and learning of this concepts. It also help to prevent the formation of alternating conceptions in learners' minds."*

Ndevu sees the use of learners' conceptions as a fruitful endeavour in forging learners' understanding of work, energy and power concepts. According to Ndevu, learners' conceptions allow the teacher to build a solid foundation on learners' understanding of these concepts. Ndevu is quoted as saying, "The use of learners' conceptions …is of great success." This statement indicates that Ndevu sees the use of learners' conceptions as ensuring the success in teaching these concepts. Jabhi also believes that the use of learners' conceptions is a very good approach in the teaching and learning of these concepts. Jabhi is quoted as saying , "It help [sic] to prevent the formation of alternating [sic] conceptions". Normally, alternative conceptions are formed if there is a mismatch between learners' conceptions and the intended scientific concepts. This can help to create a link between learners' conceptions and the intended scientific concepts, and this results in conceptual change. This means learners' conceptions should be given the rightful space in teaching and learning of these concepts to develop the conceptual understanding.

4.6.2 Promoting multiple representations in teaching work, energy and power concepts

The use of multiple representations to teach work, energy and power concepts serve as an indicator of success for this strategy. The learning environment based on multiple representations has positive effects to enhance learners' understanding of these concepts and remedy non-scientific learners' ideas (Felder 2002:677).

As the team members discussed indicators of success, Mthwasi and Ndevu commented:

> *Using multiple representations is very much successful in improving learners' understanding of work, energy and power concepts. If for an example you first explain work energy theorem verbal and then draw the bar graphs, learners understand better.* (Mthwazi)
>
> *Ndevu added: "I also know that if you use different representations like sketches, graphs, concept maps, learners understand better."*

The team members see the use of multiple representations as an indication of successful teaching and learning of work, energy and power concepts. According to the team members, multiple representations have the potential to accommodate learners' diversity by catering to different learners' learning styles. During the discussion with the team members, Mthwasi commented. "Using multiple representations is very much successful in improving learners' understanding." This statement demonstrates that Mthwasi shares the same notion that the use of multiple representations indicate the success in the teaching and learning of these concepts. In this argument, Mthwasi explained that in addition to verbal descriptions that the teacher uses, the teacher should include representations like sketches, graphs and concept maps. Ndevu has the same belief that multiple representations can enhance learners' understanding of concepts.

4.6.3 Learner involvement in teaching work, energy and power concepts

Involvement of learners can enhance learners' understanding of work, energy and power concepts. As it has been shown, devoting a considerable amount of physical and psychological energy to the learning improve learners' understanding (see 2.4.5.3) (Slavvin 2003:12). Learner involvement is a critical indicator in the sense that the traditional chalk and talk methods have failed to produce visible improvement in learners' performance. Teachers and learners who participated in the study indicated that traditional chalk and talk approach has failed them in their attempt to develop an understanding of work, energy and power concepts. This means an indicator for success is when the teachers involve learners successfully during teaching and learning of these concepts.

When participants were discussing involvement as an indicator for a successful strategy, Slova and Mthwasi commented:

> *Slova (maths teacher): "The involvement actively engage learners in an abstract learning process."*
>
> *Mthwasi: "Any teaching approach is deemed to fail if it does not involve learners in teaching and learning process. Learners' success lies in learner involvement."*

Devoting a considerable amount of physical and psychological energy to the learning of work, energy and power concepts is a condition that is conducive for the learner to understand these concepts (Astin 20014:518). According to Paosawatyanyong and Wattanakasiwich (2010:502), learners who are involved and work together during learning can achieve cognitive results that they cannot achieve when they are passive and work as individuals (see 2.4.5.3).

Analysis shows that learner involvement is an indication of successful teaching and learning of work, energy and power concepts. Slova uttered the statement, "The involvement actively engage learners in an abstract learning process." According to Slova, learner involvement has the potential to involve learners actively in the learning process. This further assists them to remember and apply work, energy and power concepts in real-life situations. According to Slova, in learner involvement learners find an opportunity to put into practice the theory; they learn and engage with these concepts to find their deeper meaning. This statement indicates that Slova sees learner involvement as an indication of success in teaching these concepts. Mthwasi agreed with Slova on the issue of learner involvement. Mthwasi is quoted as saying, "Any teaching approach is deemed to fail if it does not involve learners." According to Mthwasi, the success in the teaching of these concepts lies in learner involvement. This statement indicated that Mthwasi believes that learner involvement is a good indication for successful teaching and learning of work, energy and power concepts.

4.6.4 Maximising teachers' Pedagogical Content Knowledge

To maximise the functioning of the teachers' PCK teachers need to work as a collaborative team(s) (see 2.4.3.4) (Anderson 20008:220). This helps to derive optimal benefit from their collective knowledge of the content work, energy and power. Working collaboratively is the condition that is conducive in the sense that it empowers the teacher. When the team discussed the issue of maximising teachers' PCK to benefit learners, Jabhi and Kapa commented:

> *Kapa: "The collaboration of various teachers' PCK can assist teachers to improve their teaching strategies and content knowledge in order to meet learner' needs."*
>
> Jabhi: *"*That is true*;* our strengths as teachers lies in collaborative work*."*

Teachers have an important role to play to ensure that learners develop a deeper conceptual understanding of abstract concepts. Jabhi believes that this can be achieved through the pooling of their knowledge. Kapa is as quoted saying "The collaboration of various teachers PCK can assist to improve their teaching strategies and content knowledge." This statement demonstrates that working collaboratively and sharing pedagogical and content knowledge is an indication of successful teaching of work, energy and power concepts. This means the teachers must work together. Also, the teachers must share their teaching knowledge to improve their teaching strategies. Jabhi shares the same notion that teachers should work together and share their knowledge. Jabhi is quoted as saying, "our strengths as teachers lies in collaborative work". This phrase indicates that Jabhi believes that if the teachers work together and share the knowledge, their PCK is enhanced. This means if the teachers' PCK is stronger, they have the power to control their pedagogical space.

4.7 CONCLUSION

Chapter 4 focused on the presentation, analysis and interpretation of data generated through the focus group meetings in the research of the teaching and learning of work, energy, and power concepts. CDA was used to analyse the data at three levels, namely the textual level, discursive level and social level.

5 CHAPTER FIVE

FINDINGS AND RECOMMENDATIONS

5.1 INTRODUCTION

In this chapter, I have presented the findings from the data generated through participatory action research (PAR) as a research methodology. I further make some recommendations that assist in developing a strategy that will assist in teaching and learning work, energy and power concepts in the Grade 12 physical sciences class. I have classified my findings and recommendations under the five objectives of the study.

5.2 NEED FOR THE USE OF LEARNERS CONCEPTIONS

5.2.1 Findings: Teachers often neglect learners' conceptions when teaching work, energy and power concepts.

Findings from the literature review revealed that learners' conceptions were still neglected by the teachers when they were teaching work, energy and power concepts. One of the reasons for neglecting learners' conceptions that emerged during the discussion was that they made no sense and were not in line with the physical science curriculum. Centrally to the teachers' perspective is the notion that these conceptions were wrong and needed to be removed.

The study found that teachers did not see any link between learners' pre-knowledge and work, energy and power concepts. This made it difficult for learners to link real-life situations to these concepts. This resulted in learners struggling to develop the correct conceptual understanding of these concepts.

Recommendations

There was a recommendation from the team members that the teachers should determine learners' conceptions and build an understanding of work, energy and power concepts on them. This means the teachers should refrain from taking learners conceptions as misconceptions to be eradicated but rather view them as knowledge that is based on lived experience. The learners' pre-knowledge should benefit them during teaching and learning process.

5.2.2 Findings: Teachers still use a single traditional approach to teach.

The literature study revealed that teachers were still using a single and traditional approach when teaching work, energy and power concepts. This makes it difficult for learners to develop a deeper understanding of these concepts. The data that was generated through the focus groups revealed that the single and traditional approach that the teachers used to teach these concepts seemed to be too abstract and had no relevancy to their daily experience. This resulted in learners resorting to memorisation of these concepts. This also resulted in surface learning which led learners to fail to develop a deeper understanding of these concepts.

Recommendations

The recommendations are that teachers should use multiple representations to teach work, energy and power concepts. These representations include qualitative representations like pictures, sketches, concept maps and quantitative representations like equations and graphs. It is suggested that a qualitative approach that utilise pictures and sketches, should be used to clarify the concepts rather than a quantitative approach that use calculations. This will help to accommodate different ways in which the learners learn. This means that in addition to verbal descriptions that the teacher uses to teach these concepts, qualitative and quantitative descriptions of the concepts should be used to enhance the understanding of these concepts.

5.2.3 Findings: Inadequate learner involvement during teaching and learning of work, energy and power concepts.

Learner involvement is crucial in enhancing learners' understanding of work, energy and power concepts. Empirical data shows that there is inadequate learner involvement during teaching and learning of work, energy and power concepts. The findings show that teachers' involvement of learners during teaching and learning of these concepts was minimal. This excluded learners from taking an active role in constructing knowledge about these concepts. According to the empirical data collected, this results in learners memorising these concepts without understanding them. This result in learners failing to develop a deeper conceptual understanding of work, energy and power concepts.

Recommendations

The team members agreed that the teachers should allow the learners to take an active role in constructing knowledge about these concepts. During the discussions, it emerged that involving learners helped the teacher to trace the conceptions that they have about these concepts and how to rectify these concepts where necessary. Team members suggested that the teacher should give the learners the chance to discuss these concepts. According to the team members, this can help to eradicate the misconceptions that the learners have about these concepts.

5.2.4 Findings: Pedagogical content knowledge as a challenge in teaching and learning of work, energy and power concepts

The team members agreed that most teachers have a challenge in teaching work, energy and power concepts. Team members attributed this to the insufficiency of teachers' pedagogical content knowledge in these concepts. According to the team members, due to inadequate PCK, teachers have some gaps in their content and pedagogical understanding of these concepts. This makes it difficult for the teacher to explain work, energy and power concepts in the way that is understandable to the learners. This was also confirmed by the literature, as reflected in Section 2.4.1.4. Some team members suggested that the mathematics involved in this topic makes this topic even more challenging to both the teachers and the learners.

Recommendations

It emerged from the team members that most teachers lacked adequate pedagogical content knowledge of these concepts. The team members suggested that teachers should develop their knowledge of these concepts. According to the team members' workshops, seminars, and other relevant courses, can help to enhance teachers' knowledge in these concepts.

5.3 COMPONENTS THAT ENHANCE LEARNERS' UNDERSTANDING OF WORK, ENERGY AND POWER CONCEPTS

5.3.1 Findings: Learners conceptions

The study found the use of learners' conceptions to be effective in enhancing learners' understanding of work, energy and power concepts. It was found to be beneficial where the teacher used the learners' conceptions as knowledge that is based on experience and built learners' understanding on it. Learners' conceptions helped the teacher to link the learner’s context to the content. This helped to develop a deeper understanding of work, energy and power concepts.

5.3.2 Findings: Multiple representations

Multiple representations were also found to have a positive impact in enhancing learners’ understanding of work, energy and power concepts. Multiple representations helped to accommodate different learners’ learning styles. This helped to cater for the diverse way in which learners construct knowledge.

5.3.3 Findings: Learner involvement

The study showed that learner involvement has the potential of improving learners’ understanding of work, energy and power concepts. According to the study, when the learners are actively involved in the teaching and learning process, they get a chance of engaging with the concepts and make sense of the concepts. Findings show that since active learning was based on learners’ personal construction and reconstruction of knowledge, it gives learners the chance of linking the content of these concepts to their context.

5.3.4 Pedagogical content knowledge (PCK).

The study revealed that pedagogical content knowledge played a significant role in learners’ understanding of work, energy and power concepts. PCK assisted the teacher. allowing the teacher to transform work, energy and power concepts content knowledge to a more conceptually accessible version for the learners. This knowledge allows the teacher to create a learning environment in which learners can construct knowledge about work, energy and power concepts.

5.4 THE STRATEGIES TO ENHANCE TEACHING AND LEARNING OF WORK, ENERGY AND POWER CONCEPTS

5.4.1 Findings: Usage of learners’ conceptions

The study found that usage of leaners’ conceptions during teaching and learning had a positive impact on learners’ understanding of work, energy and power concepts. It emerged from the study during the discussion that this approach has the potential to bring abstract work, energy and power concepts to the classroom level. It was also found that this approach could help learners to develop a deeper conceptual understanding of these concepts.

5.4.2 Findings: Multiple representations in teaching work, energy and power

The co-researchers during the discussions agreed that multiple representation could assist learners in developing a better understanding of work, energy and power concepts. The study showed that since multiple representations use different instructional materials and teaching styles, it assists to match different cognitive styles for the greatest learner benefits, helping to accommodate many learners with different learning styles.

5.4.3 Findings: Active learning enhance understanding of these concepts

Findings from the study showed that if learners were actively involved in the teaching and learner process, their understanding of work, energy and power concepts is enhanced. The study also found that active learning emphasises the development of learners' skills and their exploration of their attitudes.

5.4.4 Findings: The importance of PCK in teaching

The study found that PCK plays a significant role in learners' understanding of work, energy and power concepts. In the study, it emerged that PCK helped the teacher to identify the problems that the learners had about work, energy and power concepts. This assisted the teacher in securing the teaching methods that accommodated different learners with different problems in these concepts.

5.5 CONDUCIVE CONDITIONS FOR THE IMPLEMENTATION OF A STRATEGY

5.5.1 Findings: Necessity for teachers' use of learners' conceptions

The study found that since learners' conceptions were based on their experiences it was deeply rooted in their minds. The conducive condition is that teacher should know and understand the conceptions that the learners have about work, energy and power concepts. This assists the teachers to use them as bases to scaffold the understanding of work, energy and power concepts.

Recommendations

Through discussions, the teacher can allow the learners to voice out their conceptions on work, energy and power concepts. This can be done by allowing learners to define these concepts. The teacher can then explain the concepts in a manner that is understandable to the learners. This will help the learners to develop the conceptual change in these concepts.

5.5.2 Findings: Multiple representations require teachers' knowledge.

The study found that multiple representations were helpful in enhancing learners' understanding of work, energy and power concepts. The condition that was conducive for this approach was when the teacher had knowledge of different teaching approaches and was able to apply them correctly for the benefit of all the learners.

Recommendations

It is recommended that teachers use a variety of representation techniques to help the learners interact with learning materials they are provided with to accommodate learners' diversity. This increases the chances that instructional material and teaching styles match with different learners' cognitive styles for maximum learner benefit.

5.5.3 Findings: Necessity to involve learners in teaching and learning

It was found in the study that most learners had become used to the traditional way of learning where the teacher transmits the knowledge to them, the learners listen to the teacher and take notes where necessary. The study, therefore, recommends that the teachers should create conditions that are conducive for the learners to take an active part in the process of knowledge construction during teaching and learning of work, energy and power concepts. This could be done through group discussion, peer teaching and other approaches that allow active involvement of learners.

Recommendations

The teacher should create a space where learners are actively involved in discussing and sharing ideas about work, energy and power concepts. This means the teacher should sometimes redistribute some powers and control to learners. This could help to develop learners' curiosity and make them responsible for their own learning.

5.5.4 Findings: The need for the teachers to possess adequate PCK

The study showed that there is a need for the teachers to possess adequate pedagogical content knowledge in work, energy and power concepts. This knowledge includes, amongst other things, teaching strategies, conceptual and procedural knowledge, cognitive and affective demands of work, energy and power concepts and other demands of these concepts.

Recommendations

The teacher should read extensively to develop a deeper knowledge of work, energy and power concepts. It is further recommended that the teacher should attend seminars and workshops that are related to their subjects to enhance their content and pedagogical knowledge in work, energy and power concepts.

5.6 CHALLENGES IN THE DEVELOPMENT OF THE STRATEGY

5.6.1 Findings: Learners preconception

The study has shown that learners' pre-instructional conceptions proved to be the barrier in learners' understanding of work, energy and power. This result in learners defining these concepts in a colloquial way. This problem emanates from the way these concepts are used in everyday life, which contrasts with the physics use of these concepts. The study revealed that these preconceptions were well fitted in learners' cognitive structures and were stable. These preconceptions, therefore, posed a challenge to the learners; understanding of work, energy and power concepts.

Recommendations

The teachers are encouraged to identify the preconceptions to find out if they are in coherence with the physics curriculum. This helps the teacher to design the teaching strategies that will help the learners to discard or re-construct them to match those that are accepted in the physics curriculum.

5.6.2 Multiple representations

Another challenge that was found by the study was that when multiple representations were used to teach work, energy and power concepts, in the learner's mind the representation can just be represented as a representation rather than negotiating deeper conceptual meanings. This will make it difficult for the learners to identify shared meaning between representations when they view each representation as separate and distinct in meaning.

Recommendations

The study recommends that multiple representations should be taught in such a way that the learners properly interpret each individual representations. It is also recommended that when using multiple representations, the teacher should make connections among the different representations and the information they are supposed to convey.

5.6.3 Learner involvement

Another challenge that the study found was that it is often difficult to practice the many activities that involve learner involvement because of the large number of learners that we often have in our classes. Large class sizes makes it difficult for all learners to participate in the activities given to them. This will make it difficult for the teacher to achieve the results that were desired.

5.6.4 Teachers' pedagogical content knowledge

The study showed that inadequate teachers' pedagogical content knowledge poses a challenge to the teaching and learning of work, energy and power concepts. The study found that the teachers do not possess the capacity to transform the knowledge to be taught to learners in a way that could be easily understood.

Recommendations

The recommendations from the study are that teachers should undergo empowerment through workshops, and enrolling in seminars to further the studies in physics and other empowering activities.

5.7 CONCLUSION

The study aimed to develop a strategy to enhance the teaching and learning of work, energy and power in the Grade 12 physical science class. Chapter 5 presented the findings of the study concerning the teaching and learning of work energy and power in the Grade 12 physical science class. The findings showed that despite the teachers' attempts to teach these concepts, most learners found it difficult to understanding work, energy and power concepts. The study also found that the teaching approaches that teachers used to teach these concepts made it difficult for the learners to develop a deeper understanding of these concepts. It emerged from the study that approaches like using learners' conceptions, multiple representations and learner involvement have the potential to improve the understanding of these concepts.

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7 APPENDICES

7.1 APPENDIX A: PERMISSION TO CONDUCT RESEARCH IN KZN DoE INSTITUTIONS

education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Phindile Duma Tel: 033 392 1041 Ref.:2/4/8/1303

Mr S Nyembe
PO Box 12379
Newcastle
2940

Dear Mr Nyembe

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"THE STRATEGY TO ENHANCE TEACHING AND LEARNING OF WORK, ENERGY AND POWER IN GRADE 12 PHYSICAL SCIENCE CLASS",** in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 21 August 2017 to 09 July 2020.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Connie Kehologile at the contact numbers below
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Sabela High School

Dr. EV Nzama
Head of Department: Education
Date: 21 August 2017

...Championing Quality Education - Creating and Securing a Brighter Future

KWAZULU-NATAL DEPARTMENT OF EDUCATION
Postal Address: Private Bag X9137 • Pietermaritzburg • 3200 • Republic of South Africa
Physical Address: 247 Burger Street • Anton Lembede Building • Pietermaritzburg • 3201
Tel.: +27 33 392 1004/41 • **Fax.:** +27 033 392 1203• **Email:** Kehologile.Connie@kzndoe.gov.za/Phindile.Duma@kzndoe.gov.za •**Web:**www.kzneducation.gov.za
Facebook: KZNDOE....Twitter: @DBE_KZN....Instagram: kzn_education....Youtube:kzndoe

7.2 APPENDIX B: CONSENT TO PARTICIPATE IN STUDY

CONSENT TO PARTICIPATE IN THE STUDY

CONSENT TO PARTICIPATE IN THIS STUDY

I ………………… (participant name), confirm that a person asked my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read and understand the study as explained in the information sheet. I have had sufficient opportunity to ask questions and prepared to participate in the study. I understand that my participation is voluntary and that Iam free to withdraw at any time. Iam aware that findings of this study will be anonymously processed into a research report, and /or conference proceedings.

I agree to recording of the audio recording.

I have received s signed copy of the informed consent agreement.

Full Name of participant……………………………………………………………………………………………..

Signature of participant………………………………………………..Date…………………………………………

Full name of Researcher…………………………………………………   Date……………………………………

Signature of Researcher……………………………………………………Date…………………………………………

INSTITUTIONAL PERMISSION

PERMITION LETTER

Request for permission to conduct research at ……………………………………………………………………………………………

A strategy to enhance teaching and learning of work, energy and power in grade 12 physical science class

20/ o3/ 17

Name……

Building no ……

Department of education………

Telephone number………

Email address……

7.3 APPENDIX C: ETHICS CERTIFICATE

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

18-Sep-2019

Dear Mr Nyembe, Sipho S

Application Approved

Research Project Title:
A strategy to enhance teaching and learning of work, energy and power in a Grade 12 physical science class

Ethical Clearance number:
UFS-HSD2019/0331

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Digitally signed by Derek Litthauer
Date: 2019.09.18 16:25:55 +02'00'

Prof Derek Litthauer
Chairperson: General/Human Research Ethics Committee

205 Nelson Mandela Drive/Rylaan
Park West/Parkwes
Bloemfontein 9301
South Africa/Suid-Afrika

P.O. Box / Posbus 339
Bloemfontein 9300
South Africa / Suid-Afrika
T:+27(0)51 401 2116
F:+27(0)51 401 3752
WitthuhnRC@ufs.ac.za
www.ufs.ac.za

7.4 APPENDIX D: LANGUAGE LETTER

Member South African Translators' Institute
www.language-services.online

PO Box 3172
Lyttelton South
0176
31 July 2020

TO WHOM IT MAY CONCERN

The thesis titled "The strategy to enhance teaching and learning of work, energy and power concepts in grade 12 physical class" by Sipho Ian Nyembe has been proofread and edited for language by me.

I verify that it is ready for publication or public viewing in respect of language and style and it has been formatted as per the prescribed style of the relevant institution.

Please note that no view is expressed in respect of the subject-specific technical contents of the document or changes made after the date of this letter.

Kind regards

AMdeWet

Anna M de Wet

BA (Afrikaans, English, Classical Languages) (Cum Laude), University of Pretoria.
BA Hons ((Latin) (Cum Laude), University of Pretoria.
BA Hons (Psychology), University of Pretoria.

7.5 APPENDIX E: TURNITIN SUMMARY REPORT

3 August The strategy to enhance teaching and learning of work, energy and power concepts in grade 12 physical class

ORIGINALITY REPORT

%11	%8	%3	%8
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	scholar.ufs.ac.za:8080 Internet Source	%2
2	hdl.handle.net Internet Source	%1
3	Submitted to University of the Free State Student Paper	%1
4	Submitted to University of Witwatersrand Student Paper	<%1
5	scholar.ufs.ac.za Internet Source	<%1
6	Submitted to University of South Africa Student Paper	<%1
7	uir.unisa.ac.za Internet Source	<%1
8	Submitted to University of KwaZulu-Natal Student Paper	<%1
9	uzspace.uzulu.ac.za	