

Using the Classroom Practice Diagnostic Framework (CPDF) to Investigate Teaching Difficulties of a Physics Topic

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Doi:10.5901/mjss.2013.v4n3p637

Abstract

Projectile motion can be a challenging topic because of misconceptions associated with it. Strategies have been identified and suggested to ensure that teachers teach the topic in a way that is accessible to students. So, it was not surprising that some teachers in one of the districts in the Gauteng Province (South Africa) indicated that the topic is difficult to teach. Moreover, according to the Department of Basic Education, students perform poorly on the topic. Even though teachers attended some in-service training to improve their content knowledge which was perceived to be the source, they still held the perception that projectile motion is difficult to teach. Therefore, it is the purpose of the paper to increase the tools for fundamental resources for in-service training for teachers who perceive certain science topics as difficult to teach. The paper also intends to add into the discourses on teacher practices in science teaching. The classroom practice diagnostic framework (CPDF) was developed to analyse the classroom practices and identify teaching difficulties. One of the grade 12 Physical Science teachers who perceived projectile motion to be difficult to teach was identified. The teacher was interviewed prior to the teaching of the topic and after. The teacher was also observed teaching the topic. Then the framework was used to analyse data and the findings showed that the framework assisted in identifying the teaching difficulties. I also suggest areas for further research.

Keywords: teacher practice, teacher knowledge, instructional strategies, discourse

1. Introduction

Many frameworks have been designed to analyse science teaching the IRF (initiation, response and feedback) framework (Carlson, 1991). The framework was improved to IRFRF which is part of the analysing science teaching interactions framework (initiation, response, feedback, response and feedback) by Mortimer and Scott (2003). It was further improved to II-ER (Identification, Interpretation-Evaluation, and Response) framework by Louca, Zacharia and Tzialli (2012). Even though each framework is different from its predecessor, we found the frameworks focusing more on teacher-students interactions. Some frameworks give more emphasis to the teacher who elicit and construct students' ideas. This is a weakness claimed by Louca (2012) as the reason for their new framework which gives more emphasis to the contributions by students as well as that of the teacher.

The classroom practice diagnostic framework (CPDF) builds on those frameworks. It is designed for the teacher who perceives certain science topics to be difficult to teach. The framework gives emphasis on the teacher with a view of finding ways to help the practicing teacher to teach better. This is so because the framework draws from not only the analysis of interactions but also taps into the instructional strategies the teacher uses, teacher knowledge and teacher accountability. I acknowledge that some may view the focus on the teacher as a weakness but I am of the understanding that it is important to also focus on what the teacher uses, does as well as his intention either short term or long term whilst teaching a particular cohort in order to have a positive impact on the classroom practices. I also accede to the fact that a focus on teachers who have teaching difficulties is not to be viewed as limiting because studies and experiences in science teaching have shown that teachers can perceive some topics of the science curriculum as difficult to teach (Gunstone, Mulhall and McKittrick, 2008 & Tao and Gunstone, 1999) and teaching difficulty is not something easy to articulate (Geelan, Wildy, Loudon and Wallace, 2004). Due to the nature of the subject, difficulty in teaching can happen when teachers fail to make their classroom practices assist them to achieve the end. In science teaching, the end refers to achievements, meaningful learning, developing inquiry skills and problem-solving skills by students (Abd-El-Khalick and Akerson, 2009 & Staver, 2006).

The framework should be of assistance to the practitioners in teaching, for example, school head of departments, deputy principals, subject advisors and other service providers who are expected to assist teachers in their classroom practices. I contend this because it should add into the resources of micro-foundation for in-service support by introducing the classroom practice diagnostic framework as one of the tools that can be used to investigate teaching difficulties in the teaching of science. This is so because there is impervious lack of micro-foundation resources (Jita, 2004) for in-service support with a focus on classroom practice, yet experiences and observations show that much focus on the in-service trainings has been on improving the teacher's subject matter knowledge in Physical Science. Furthermore, the framework has aspects of paramount importance which I am of the view that they are intertwined and needs to be developed independently and jointly to positively influence performance (Staver, 2007) through meaningful learning by students (Chin, 2006). Consequently, the following research questions were answered:

1. What is the nature of the CPDF?
2. What are the teaching difficulties of projectile motion topic?

Literature Review

This section explores projectile motion or force and motion and the classroom practice diagnostic framework.

1.1 A case of projectile motion

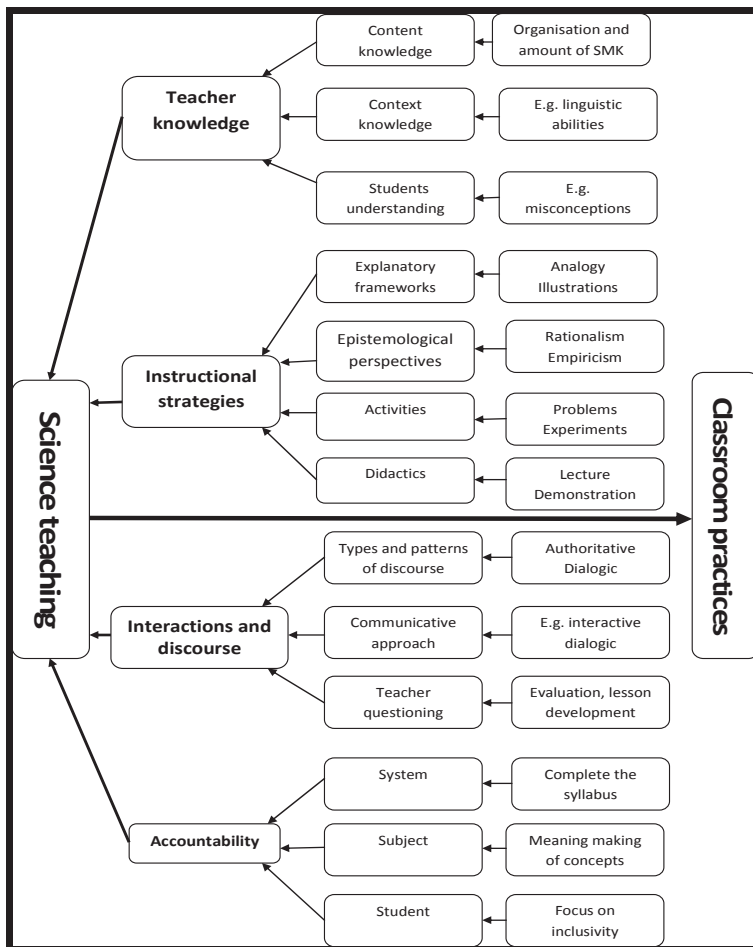
Much has been documented on projectile motion or force and motion for example (Graham, Berry and Rowlands, 2012; Bayraktar, 2009; Dilber, Karaman and Duzgun, 2009; Prescott and Mitchelmore, 2005; Tao and Gunstone, 1999 & Gilbert and Zylbersztajn, 1985). Some of these studies showed the development of the concept of force and motion, misconceptions associated with force and motion, conceptual change as a strategy to change the misconceptions and theories that misconceptions also develop during teaching. Previous studies considered them as ideas developed outside the science classroom. For example, other studies suggested strategies like computer modelling as an explanatory framework that will make the learning of projectile motion accessible to students. Yet, there are still teachers who have knowledge that there are misconceptions in projectile motion and have studied physics topics in their undergraduate and some in their postgraduate studies, who still perceive projectile motion as difficult to teach in one of the districts in the Gauteng Province in South Africa.

This is not surprising if one notes all the studies that have been done in projectile motion about ways of teaching it and illuminating misconceptions. These teachers attended in-service training to improve their subject matter knowledge because it was assumed that it is because they lack the subject matter knowledge. Rollnick, Bennett, Rhemtula, Dharsey, and Ndlovu (2008) highlighted that some teachers who were trained in the former colleges had subject matter knowledge which was not more than the last level of high school in physics. Amidst all the strategies to assist in-service teachers with topics they perceive difficult to teach, I am of the view that there is a need to focus on the teacher's classroom practice hence the development of the CPDF. Through the framework, it should be possible to identify at a minuscular level what the teacher does which makes him have a perception that projectile motion is difficult to teach.

1.2 The classroom practice diagnostic framework (CPDF)

In the CPDF, the following domains of the teacher's pedagogical content knowledge were focused on: teacher's content knowledge of projectile motion, knowledge of students' understanding of projectile motion and the knowledge of the context in which projectile motion is taught. These domains of teacher knowledge are intertwined with the teacher's interactions and discourse in the classroom and the instructional strategies he/she used in the teaching of projectile motion as well as his accountability focus. The CPDF is expatiated next.

Figure 1: The classroom practice diagnostic framework (CPDF)



The teacher's content knowledge meant the amount and organisation of subject matter knowledge in the teacher's mind with a focus on projectile motion. Knowledge of students' understanding referred to the teacher's knowledge of the prior knowledge the students need to learn projectile motion, linguistic abilities and interests of the students as well as misconceptions students might have of projectile motion. The knowledge of the context referred to all the contextual aspects that could influence the teaching of projectile motion. The contextual aspects included some of the following: resources in the classroom, socio-economic background, the curriculum, time available and class size.

The instructional strategies were made up of epistemological perspectives, didactics, explanatory frameworks and activities. Epistemological perspectives referred to how a teacher demonstrated through practice how knowledge was acquired. This was identified by focusing on the two approaches of epistemology namely rationalism and empiricism. Didactics referred to the traditional teaching methods like lecture as well as demonstration methods which the teacher used. Explanatory frameworks or representations were the analogies, models and/or illustrations the teacher used to make the learning of projectile motion accessible to students. Activities implied problems, demonstrations, simulations, investigations or experiments which the teacher used to help students comprehend the content.

In the classroom interaction and discourse, the emphasis was on the talk by the teacher to/and with the students. The focus was on types of science classroom discourses, patterns of discourse, communicative approach and teacher questioning. Types of discourses were the authoritative, dialogic and reflective discourses. During authoritative discourse, the teacher used traditional methods like the lecture method and focused only on science concepts without acknowledging alternative conceptions. Dialogic discourse referred to the discourse wherein the teacher used a variety of methods to help students comprehend the targeted concepts. The teacher also acknowledged alternative concepts and

prior-knowledge and involved students more in the lesson. In the reflective discourse, the teacher taught through negotiations than transmission of new knowledge. The teacher also acknowledged alternative concepts and prior-knowledge. The focus was on student's thinking.

Patterns of discourse engrossed on the initiations of the teacher as well as the feedback he/she provided, for example, the IRF (initiation, response and feedback) pattern. The communicative approach was attentive to the way the teacher communicated with students to make them comprehend the targeted ideas and concepts. Four classes of communicative approach namely interactive-authoritative, non-interactive-authoritative, interactive-dialogic and non-interactive-dialogic were focused on. Teacher questioning focused on the teacher's orientation when asking questions. That is, if he/she asked questions to evaluate, to construct understanding or to develop a lesson.

Accountability referred to the three accountability themes, namely, the accountability to the system, students and subject/discipline. In the accountability to the system, the teacher focused on the results by emphasising the completion of the syllabus within a short period of time and also emphasising the pass rate in the subject. Accountability to the subject had the focus on the instructional strategies the teacher used in engaging students to make meaning out of the content presented. Lastly, accountability to the students referred to the teacher's endeavour to focus on all his/her students by using their personal experiences outside the classroom in the teaching and learning process. The focus was also on the students' abilities and language issues so that all students participate in the science classroom.

Research Methodology

The participant *Mr Mulalo* (not his real name) was qualified to teach Physical Science and was the head of department for Physical Science and Mathematics at his school. He had more than 15 years experience in teaching Physical Science. He perceived projectile motion as difficult to teach. *Mr. Mulalo* was not alone as the same sentiment was also shared by other members of his cluster. The same notion was also evident during the grade 12 marking session wherein projectile motion was one of the topics wherein students did not perform well and the Department of Basic Education (2010) in the moderators report apportioned the blame on how teachers teach the topic. *Mr. Mulalo* was interviewed before the teaching of the topic and after the teaching of the topic. He was also observed teaching the topic to the grade 12 students. The purpose of the interviews and observations was to determine what makes the teaching of projectile motion difficult. The CPDF was used to analyse the classroom practices. What I did was to read the data with the framework in mind and identified relevant data which I organised using the table which had themes as indicated in the framework. How data were presented for interpretation is shown in table 1 which shows the data for theme teacher knowledge and category content knowledge.

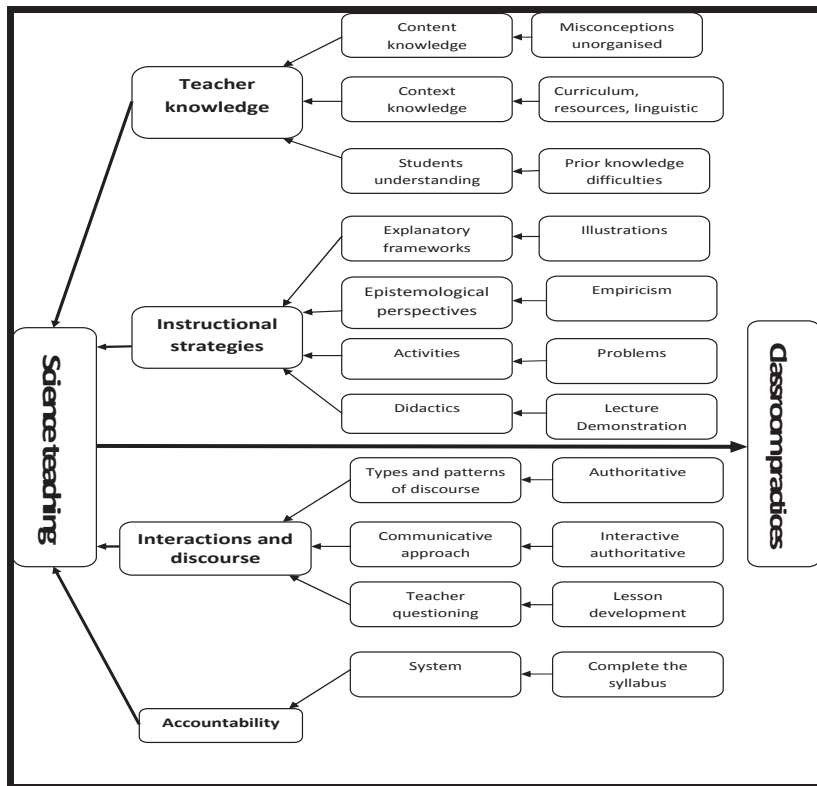
Table 1: Data presentation of content knowledge

Theme	Category	Characteristics
Teacher knowledge	Content knowledge	<ul style="list-style-type: none"> - (Researcher) Give the order in which you will teach the following and motivate. A. ball is thrown straight upwards and it rises and then drops, B. a ball rolls horizontally on a friction surface, C. a ball is thrown horizontally from the table edge, D. a ball is dropped and E. a ball is thrown at an angle. - (Teacher) No I will start with c and then we will go to b because with c the table is smooth and I can make it a bit rough, ayi sorry its b to c the difference of frictionless and then in c you bring a bit of friction some object will hinder the friction of the ball. (Incorrect order ~deficiency in the SMK) - (R) How will you answer a student that says...a ball which is rising is accelerating upwards? (T)I will always tell the learner (student) that he must understand it is not accelerating upwards the ball moving upwards it always experience the downwards acceleration (incorrect response, ISMK, M) - (from the picture and thereafter this is what the teacher said) Everything that is thrown upwards come down because mother earth has what is called weight. [incorrect subject matter knowledge (ISMK), misconceptions (M)] - the weight of each object is controlled by the weight of mother earth which has a special name (ISMK, M) - (T) What is the special name of force? (S) It is mass. - Mass is one of the difficult names in Physical Science and it is one of the products of weight (ISMK, M)

	<ul style="list-style-type: none"> - Mass is a body and it can go anywhere (subject matter knowledge (ISMK, M)) - There is a relationship between mass and weight but weight cannot be taken as mass because weight has Newton which mass does not have (ISMK, M) - Which physical quantity has the same unit as Newton? (S) Force. (T) Correct. (ISMK, M) - (students asked to jump) - (T)When you jump your height is not the same. What makes it not the same? (S) It is air resistance. Yes it is. (ISMK, M) - [T] What is free fall? [(group 1) when an object fall and there is no air resistance, (group 2) when object experience gravitational force from the earth and there is no air resistance, (group3) when an object comes down due to gravity. (T) The words which are common are air resistance but you must not say there is no air resistance but that air resistance is ignored because the object comes down due to force of gravity. (ISMK, M)
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Prior to the interpretation of data, I completed the blocks in the framework with what I identified from the data presented. The completed framework assisted in interpreting what could be the teaching difficulties which the teacher could not identify. I then interpreted what the data was showing through the framework and gave the findings of what could be the teaching difficulties using the framework.

Figure 2: The CPDF after data analysis



Findings using the framework

1.3 Teacher knowledge

The teacher's content knowledge was loaded with misconceptions and not organised as shown in table 1. It was also noted that the teacher demonstrated adequate context knowledge because he was aware of what the curriculum entailed

in the teaching of projectile motion from Grade 10 to 12 as well as the resources available to him at his school. For example, the laboratory was available even though he did not have enough chairs but was fairly equipped. Furthermore, he acknowledged the challenges offered by the linguistic abilities of his students in the learning of Physical Science. The teacher was also conversant with the prior knowledge students needed to learn projectile motion. Eryilmaz (2002) showed that students' learning capabilities depend largely on their prior knowledge and experiences.

The teacher's knowledge which comprised content, context and students' prior knowledge revealed that it had deficiencies either in the knowledge itself or in the use of the knowledge during teaching. It is interesting to note that in terms of the description of Kaplan and Owings (2001) of teacher quality, Mr. Mulalo is a quality teacher because he is qualified and brought evidence of a preparation in the classroom. So, it cannot be surprising that Mr. Mulalo considered himself as such and expected the performance of students to be reciprocal and this was due to his perception that the topic was difficult to teach.

1.4 The nature of the language used and meaning making

Though Mr. Mulalo was aware of the linguistic challenges his students had, he did not do much in the classroom to alleviate or stop the challenge. His language was also loaded with words which showed that the teacher himself also had challenges with the language of teaching. He was observed saying that,

...the weight of each object is controlled by the weight of the mother earth which has a special name and... mass... is one of the difficult names in Physical Science and it is one of the products of weight...

The discussion between the teacher and the students is very important as it facilitates learning and is central to meaning making. Furthermore, Mortimer and Scott (2003) indicate that meaning making takes place in three phases which are the social plane wherein the teacher provide new content and internalisation wherein the teacher help students make sense of the new knowledge and lastly, the application of the new knowledge. It was so in Mr. Mulalo's case because of the language the atmosphere of new knowledge and internalisation phase was not conducive. The words which the teacher used did not help students comprehend the content as they did not respond correctly to some of his questions, for example, questions pertaining to weight as well as problem solving.

So, some teaching difficulty resulted from the failure to create a situation for the internalisation process to take place because of the language used or words which did not facilitate meaning making by students. In general, it can be concluded that the failure of the teacher to use the language that can help students to make meaning or even being careful with his words can result in the perception that projectile motion is difficult to teach as the students will fail to make meaning (Mortimer and Scott, 2003) and consequently perform poorly.

1.5 Prior-knowledge

The teacher knew the prior knowledge students needed to learn projectile motion at grade 12 but its use in the classroom was undesirable. Prior knowledge is important in the learning capabilities of students (Staver, 2007 and Eryilmaz, 2002). Moreover, Staver (2007) also indicated that when planning for lessons teachers must take into cognisance the complex interaction between the students' prior knowledge, their experiences and the new knowledge. Staver (2007) and Eryilmaz (2002) assertions were not evident in Mr. Mulalo's teaching. He did not adequately infuse the students prior knowledge and experiences in his teaching.

However, the teacher had acknowledged that students have a problem of not bringing over what they have learnt in the previous grades which hampered the comprehension of the new content. This was evident during the interview when he indicated that:

"What I see is that learners tend to have learned horizontal motion in grade 10 & 11 and they did not want to link because the only change is the acceleration, they think that the acceleration is due to gravity is a bit different to the horizontal motion whereby they need to know that it is only the acceleration that is constant in the free fall than in the horizontal one".

Furthermore, Galus (2002) indicated that before teaching projectile motion, it is important that students are taught motion for example forces. Mr. Mulalo demonstrated that because in the introduction of the lesson he focused on the force. However his explanations were full of misconceptions. This was not surprising as shown before that he had challenges with comprehending forces.

Therefore, even though the teacher knew what prior knowledge is required, he did not integrate it such that students make meaningful learning out of it. On the other hand, even though he began his lesson with forces, the explanations were loaded with misconceptions which can be transferred to students (Bayraktar, 2009 and Prescott & Mitchelmore, 2005). It can be concluded that some teaching difficulties are as a result of lack of integrating students' prior knowledge and experiences during the teaching process because it is necessary for the comprehension of the new knowledge (Eryilmaz, 2002) and to avoid memorisation (Galus, 2002).

1.6 Lack of use of resources

In the introduction of the lesson, the teacher took out a plastic ball and told students that he always tells them that he does a simple demonstration before teaching. He did a demonstration using an empty packet of chips, a plastic bottle and a piece of chalk. He told students that they must observe what is going to happen to the objects. He held them high and released the bottle first followed by the piece of chalk and asked students what happened to the objects. The second part of the demonstration involved the teacher throwing the plastic bottle and the empty packet of chips upward. However, the explanations which came from the demonstration did not help students comprehend what the teacher intended to do. This was evident from the lack of responses from students as well as the time taken on discussion on weight.

So the knowledge of the available resources did not help him to conduct a proper demonstration as well as allowing students to conduct the experiment. He claimed that he cannot use the laboratory because there are no chairs. It did not make sense as students had chairs in the classroom which they could have used in the laboratory. This called into question the seriousness of using the laboratory at all. This is the case because when asked why he was teaching students in a room without tables he indicated that, there are no tables because they had to split with the other group which is doing a different subject and the laboratory is not in good condition so they use the classroom for Physical Science lesson and thereafter students report back to their normal classroom where they are stationed. So, the reason for not using the laboratory was not entirely the issue of lack of chairs or its dirtiness. The teacher deliberately avoided using the laboratory.

Therefore, it was not the lack of resources that the teacher opted to use the apparatus he used to introduce the lesson but it was a matter of choice. It can also be concluded that some teaching difficulties resulted from the ignorance of using available resources to enhance the comprehension of the subject matter.

1.7 Authoritative discourse and the development of inquiry and problem solving skills

The nature of communication between the teacher and the students was largely interactive but authoritative. This means that the teacher did invite responses from the students but if they were incorrect he discarded them; as a result, there was a minimal interaction with the students' responses. For example, he asked students to discuss in their groups what free fall is. After some time all the groups had indicated that the object was in free fall because there was no air resistance. The teacher told them they should not say that there is no air resistance rather they must say that air resistance is ignored because the object comes down due to force of gravity. He then said that the group that did the correct thing is the one that said gravity but did not say anything about air resistance. *Mr. Mulalo* then moved to the second question about equations of motion.

According to Staver (2007), learning is an internalised mental process. So, the teacher had to provide an atmosphere that will enable the student to internalise new meaning by showing the student where the mistake was made, but the teacher did not do that. Even the kind of questions the teacher asked was to develop the lesson rather than to evaluate where they still lack. Hence, it was not surprising that the nature of the discourse was authoritative with a teacher having a fixed intent of rushing to teach equations of motion. Moreover, according to Chin (2006), authoritative discourse is made of factual statements and instructional questions which do not leave room for students to think about what the teacher was presenting, which was evident in *Mr. Mulalo's* interaction with the students in the classroom.

The non-provision of opportunities for students to think cannot help students develop inquiry and problem-solving skills (Akarsu, 2010; Akerson & Donnelly, 2010 and Abd-El-Khalick & Akerson, 2009). The DoE (2007) and DBE (2010) also indicated that they examine students on inquiry and problem-solving skill in projectile motion. So, it is not surprising that students do not perform well. This is so because they are not exposed to the development of those skills in the classroom. As a result, the teacher perceive projectile motion as difficult to teach because after teaching them, students

do not perform as he did not teach them to develop the inquiry and problem-solving skills. So, some teaching difficulties may result from the nature of classroom interactions and discourse.

1.8 Empiricism and the comprehension of abstract concepts

The teacher used illustrations as his explanatory framework and problems as activities to develop the lesson. According to Magnusson *et al.* (1999), explanatory frameworks and activities should be used by the teacher to help students to comprehend the subject matter knowledge. However, the teacher was focused on providing students with examples so that they learn through experiences without reasoning. Yet the nature of the subject matter is such that it is loaded with abstract concepts (Gunstone *et al.*, 2008 and Schwartz and Lederman, 2008) for example forces, and it demands appropriate explanatory frameworks for students to comprehend such concepts.

It was also noted during interviews that the teacher had indicated the intention to also use experiments in his teaching, of which he indicated that:

"If something that involves like in the mechanics part then learners (students) must be taken out of that environment of the class and get outside and investigate some of the things and come back and see if it makes sense".

But in practice, the teacher used traditional methods of teaching, for example, demonstrations, lecture and questions and answer methods. According to Schwartz and Lederman (2008), traditional methods of transmitting information which *Mr. Mulalo* used do not help students comprehend such abstract concepts. Even Hollon *et al.*, (1991) indicated that instructional strategies should engage students such that they are able to think, which in turn develop problem-solving and inquiry skills. Yet, the instructional strategies used were so constrained such that they did not offer opportunities to develop problem-solving and inquiry skills which are a teaching difficulty.

Childs and McNicholl (2007) indicate that the teacher who lacks content knowledge resorts to constrained pedagogy and this was the case for *Mr. Mulalo*. Therefore, it can be concluded that the instructional strategies the teacher used did not promote comprehension of the abstract concepts which is a teaching difficulty because, according to Kaplan and Owings (2001), instructional strategies are also an important factor in student achievement.

It can also be inferred that the choice of the instructional strategies was influenced by the epistemological perspective (Kuzniak and Rauscher, 2011 and Kalman, 2009) of the teacher which was empiricism. This is so because from the empirical perspective, the focus is on learning from experiences (Boeree, 1999) and this was evident in *Mr. Mulalo's* instructional strategies. Therefore, some teaching difficulties result from the teacher's epistemological perspective.

1.9 Accountability to the system

During the interviews, the teacher indicated that:

"I see myself as a Physics teacher who has a passion for each and every learner (student) to understand what has transpired in the lesson...when we want to progress the rate we always look at the understanding of the concept because they are going to be questioned by somebody they don't even know because I have been given a syllabus. One must ensure that at least what we have done if not 100% at least a learner must get 80% of what we have done then the learner can pass at the end of the year because we cannot get 100% all the time but if you get 80 or 70% of what we have learned you have done justice for that and then we complete the syllabus."

So the teacher had intentions to help students understand the content as well as complete the syllabus, but in practice, the focus was more on completing the syllabus. The teacher rushed through the lesson and even though he had planned an experiment to be done prior to the teaching of the equations of motion, it was not done. He did not infuse their prior knowledge as well as using their own languages in the explanations of some concepts, for example, the weight. If that was done, it would help with the internalisation phase (Mortimer and Scott, 2003) and improve meaning making which in turn influence performance.

The past results of the school and the external pressure from the district and provincial office could have left the teacher rushing through the content without taking into cognisance if students comprehended the content or not. Even though extra time was taken by the teacher to complete the syllabus the focus was not on giving students more time to comprehend the content but to finish the syllabus. Therefore, the teacher was accounting to the system (Jita, 2004). So, even though the teacher had indicated that he accounts to all stakeholders, it was not evident in his practice. Therefore, it

can be concluded that some teaching difficulties are as a result of the accountability focus of the teacher in the classroom.

Conclusion

It was the purpose of this study show that the CPDF can be used to analyse the classroom practices of a teacher and to determine the teaching difficulties. I am of the view that this article showed that the framework can be used for that purpose. The way the framework was used and how it assisted to determine teaching difficulties should add into the debate on teacher practices in science teaching on what are the areas to focus on and how that can be done. I also envisage that the hands-on practicing members of the teaching community which are the science teachers, head of departments, deputy principals and subject advisors and other service providers can use the CPDF as a fundamental resource to identify the teacher's areas of development in his/her practices. I also envisage that researchers can use the framework as it was done in this study to derive a picture of how different aspects generate the teaching difficulty. The study also showed that it can be possible to provide tailored intervention either be content knowledge, context knowledge, instructional strategies or nature of discourse as the deficiency will have been outlined in the CPDF. We also concede that this has not been tested at a large scale and it will be an interesting area for further research.

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