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The classroom practice diagnostic framework: A framework to diagnose teaching difficulties of a science topic

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The purpose of this paper is to present a conceptual framework for diagnosing teaching difficulties of a science topic in the science classroom. The development of the framework is presented as well as descriptions of the features of the framework. How the framework can be used is also elaborated? Furthermore, there is a detailed indication of an example in which the framework was used. It is also recommended that further studies can be done on the intersection between teacher knowledge and the kinds of discourse it promotes. That is the focus can be on the connection between teacher content knowledge and the classroom discourse. Hence, the researcher can use the framework to analyse the intersection of those from the perspective of teacher action.

Keywords: framework, science classroom, teacher practice, teaching difficulties

INTRODUCTION

Due to the nature of the science subject, difficulty in teaching can happen when teachers fail to make the means to achieve the end (Staver, 2007). In science teaching means to an end refers to achievement by students, meaningful learning, developing inquiry skills and problem solving skills in students (Abd-El-Khalick & Akerson, 2009). The means which in this paper refers to the classroom practices of the teacher was the focus of the research as the source of teaching difficulties as illustrated in Figure 1. In this study difficulty meant not being able to advance or do something with lost hopefulness. Teaching difficulty referred to the teacher's classroom practices which did not advance meaningful learning, misconception dissonance, development of inquiry and problem solving skills which influence student achievement.

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Therefore, the purpose of this paper was to present the CPDF as an alternative diagnostic tool for science classroom analysis and also show how it was used to diagnose teaching difficulties of the projectile motion topic. The framework may
assist with information to assist in professional training of in-service teachers. This is said because it should add into the resources of micro foundation for in-service support as there is impervious lack of micro foundation resources (Jita, 2004) for in-service training. This paper emancipated the possibilities of identifying teaching difficulties of a topic from the content knowledge and classroom practices with the aid of the classroom practice diagnostic framework (CPDF). This is necessitated by attempts by researchers and other stake holders in education to focus on the content knowledge as the source of teaching difficulties of a topic at the expense of classroom practices in general which integrates the very same content knowledge. Of course using the CPDF demands a focus on finer details in what the teacher and the learner does as it involves an integration of various aspects like discourse and interaction amongst others. Moreover, there have been many studies for example Louca, Zacharia and Tzialli (2012); Mortimer and Scott (2003); Scott, (1998) and Carlson (1990) that focused on student – teacher talk or teaching interactions in the science classroom. Yet, they did not integrate a focus on content knowledge as well as instructional strategies as sources of teaching difficulties. So this paper attempted to position the CPDF as an alternative to fill the gap as identified.

State of the literature

- Studies have focused on student – teacher talk or teaching interactions in the science classroom without a focus on content knowledge and classroom practices as sources of teaching difficulties.
- The possession of relevant content knowledge is only part of the teaching story; However, there appears to be limited research on what science teachers do in the science classroom
- There is a lack of support of the inside of the teacher's classroom practices, for example, the kinds of discourses that promote meaningful learning and the development of problem solving and inquiry skills.

Contribution of this paper to the literature

- This paper attempts to position the CPDF as an alternative to fill the gap wherein there is no intregetaion of the content knowledge with the clasroom pratices to identify teaching fifficulties.
- The CPDF is positioned as an addition to the resources for in-service training as there is as lack of micro foundation for inservice training
- Studies can be done on the intersection between teacher knowledge and the kinds of discourse it promotes. Hence, the researcher can use the CPDF to analyse the intersection of those from the perspective of teacher action.

HOW THE CPDF WAS DEVELOPED

Maxwell (2005:33) indicates that the conceptual framework is "the systems of concepts, assumptions, expectations, beliefs and theories that support and inform your research". Furthermore, it is something that one builds from pieces borrowed elsewhere and so it is not something that is readymade (Maxwell, 2005). These assumptions were taken into consideration when developing the CPDF. The CPDF was to be underpinned by the constructivism theory. Constructivism informs teacher

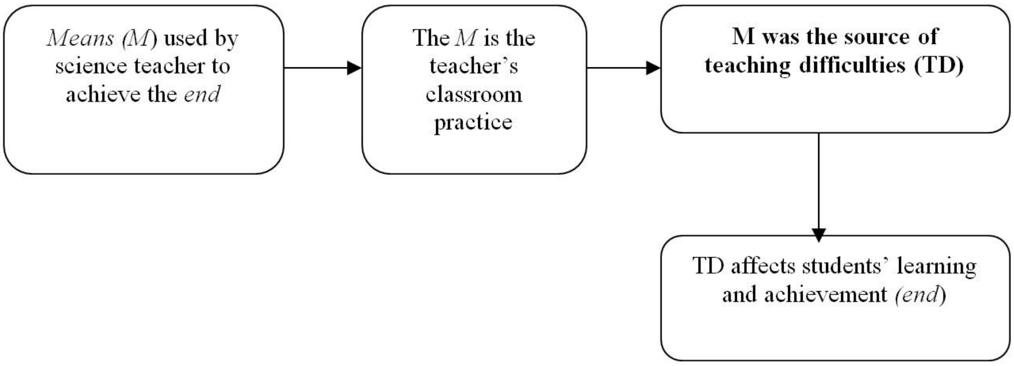

Figure 1. Source of teaching difficulty

practice (Hausfather, 2001); it is not a method of teaching but a theory of knowledge and learning, thus the emphasis is on the teaching context, student prior knowledge and interaction between the student and the content. Tobin and Fraser (1998) indicate that constructivism is to be used as a base for thoughts and actions by teachers. Consequently, Leach and Scott (2003: 102) typify the role of the teacher within constructivism as "to introduce and support the use of new knowledge on the social plane", whilst the role of the student is to "internalise the ideas for personal use". Furthermore, according to Hausfather (2001) the "amount" of teacher's content knowledge within constructivism theory is important for the development of understanding in students. He further indicates that the teacher supports the use of the new knowledge by creating situations wherein students interact with information, using it to solve problems, discussing interpretations and answering questions as it becomes their own. However, this requires the continuous restructuring of the subject matter knowledge by the teacher which Cochran, DeRuiter and King (1993) term pedagogical content knowing.

There are various forms of constructivist theories (Hausfather, 2001; Mathews, 1995 and Geelan, 1997), some of which are personal, radical, social, critical and contextual. According to Geelan (1997), these forms of constructivism can be organised into those that are social and those that are personal. They can further be classified as objectivist or relativist (Mathews, 1995), for example the social and critical constructivist theories. However, according to Leach and Scott (2003) these many forms of constructivism can be simply classified as two broad strands of the constructivist theories of teaching and learning which are based on individual views and on sociocultural learning. The individual view (Piagetian) focuses on the mental structure of the student (Leach & Scott, 2003; Nola, 1997 and Piaget, 1964). The sociocultural view integrates both the individual view and the social environment (Vygotskian). In this perspective learning takes place in a social milieu as well as in the mental structure of the individual (Kim, 2001; Lemke, 2001; Davydov, 1995 and Vygotsky, 1978). This point was also raised by Carr et al. (1994), who regarded science as a human and social construct and posited that learning is a personal construct which is influenced by the social context. Hausfather (2001:15) also indicates that social constructivism "proposes that knowledge emerges from human activity as people interact with each other and with the physical world using their minds and bodies as well as material and symbolic tools made available to them by their culture". So in this study social constructivism was used, taking into account the social context in which the study was conducted.

Within social constructivism the quality model, which is a generic theory of teaching (Biggs, 2001), was integrated to inform on the quality of teaching by teachers. This implies how teachers organised their teaching in their classrooms to support the learning of a science topic. Biggs (2001) posits three levels of teaching theory which are built on two concepts, which are teaching as transmitting knowledge, and teaching as facilitating learning. The three levels are fundamentally based on the causes of variation of students learning outcomes which the teacher is more or less responsible for. Table 1 shows the three levels of theories in order of complexity.

With the social constructivism theory as the overarching and underpinning theory for the framework, some pedagogical content knowledge (PCK) models were also adopted which enabled the researcher to focus on the specific classroom practice aspects of the teacher such as teacher knowledge as well as the kinds of instructional strategies he/she used in the classroom. PCK is the knowledge that includes "an understanding of what makes the learning of a specific topic easy or difficult" (Shulman, 1986:9). This is the knowledge that encompasses the understanding of preconceptions of students and common learning difficulties (van Driel, Verloop and

Table 1. The levels of a generic theory of teaching (Biggs, 2001)

Teaching as transmitting knowledge		Teaching as facilitating learning
Level 1. Focus: What the student is	**Level 2. Focus: What the teacher does**	**Level 3. Focus: What the student does**
Teachers operating at this level assume a teacher-centred, transmission model of teaching. The teacher is regarded as the guardian of knowledge whose responsibility is to know the content well and to explain it clearly. It is the responsibility of the student to listen, attend classes and take notes. Learning outcomes depend on the students' ability, their background and motivation. When teaching is not effective it is the students' fault. This level does not promote teacher reflection.	It is based on transmission. Learning outcomes depend on how skilful the teacher is in presenting to students. The emphasis is on what the teacher does, for example ability to use IT, forward planning, teaching competences and good management skills.	The focus is on teaching that leads to learning. It includes mastery of teaching techniques. To design effective teaching; desired outcomes have to be specified, teaching/learning activities must be arranged such that students are encouraged to do things that make it likely the desired outcomes will be achieved. The teacher supports students by aligning teaching methods, assessment tasks, and classroom climate to acquiring the kinds of skills and kinds of understanding that are required of students. Misalignment in the teaching results in students with inadequate learning.

Vos, 1998). Teachers then need knowledge of the strategies that will reorganise the understanding of students (Loughran et al., 2001). Sanders, Borko and Lockard (1993) indicate that PCK develops in a cyclical process. That is
where "teachers transform, instruct, evaluate, reflect, gain new comprehension, comprehend and transform again" (Sanders et al., 1993:725). PCK models were chosen because they make it possible to target certain aspects of teacher knowledge (Rollnick et al., 2008). The models that appealed to the aims of the CPDF are models by Rollnick et al. (2008) and Magnusson et al. (1999). In the latter model, more emphasis is on the knowledge and beliefs of the teacher, whilst in the model proposed by Rollnick et al. (2008) the emphasis is on the observations of the domains of the teacher knowledge from the teacher's practice. Other models for example by Loughran, Milroy, Berry, Gunstone and Mulhall (2001) was not ideal as it focused more on capturing teacher's PCK and portray it for others. In this framework the aim was to capture certain aspects of teacher knowledge which were best portrayed in the models chosen for this study. However, some of the questions that can be used to construct Pap-eRs were used during the interviews.

Within social constructivist theory, the interactions between the student and the teacher, the students themselves and the social milieu are the fundamental basis for knowledge construction by students (Leach & Scott, 2003). Furthermore, the discourse used to facilitate meaningful learning by the teacher is also fundamental within social constructivist theory (Leach & Scott, 2003). Consequently the analytical framework for analysing science teaching interactions by Mortimer and Scott (2003) was used in the framework to focus on the classroom interactions and discourse. The framework was called CPDF as it was used as the frame of reference from which teaching difficulties can be diagnosed.

THE CLASSROOM PRACTICE DIAGNOSTIC FRAMEWORK

In this section, what the CPDF entails is described as well as how it can be used.

Describing the framework

In the CPDF there are four main domains (A, B, C and D). Hierarchically, frame A occupies an important place for the understanding of the teacher's practice. That is, it is the source and it influences every action of the teacher as it contains the important knowledge in respect of teaching. Teacher knowledeege is made up of content, context and students' understanding knowledge. Frame B is informed by the teacher's knowledge. The teacher uses his or her knowledge to decide on instructional strategies. The instructional strategies are made up of epistemological perspectives, traditional teaching methods, explanatory frameworks and activities. His/her

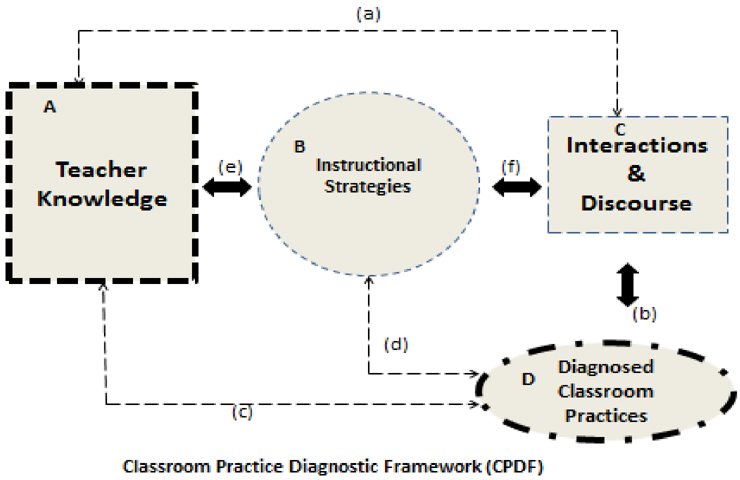

Figure 2. The Classroom Practice Diagnostic Framework (CPDF)

strategies lead to the interactions and discourse in the classroom. In the classroom interaction and discourse frame; the emphasis was on the types and patterns of discourse, communicative approach and teacher questioning. Types of discourses comprised the authoritative, dialogic and reflective discourses. Some of the actions or activities are spontaneous [this part is accommodated in the link (a) between A and C]. Frame C is the culmination of the interactions of frames A and B. The analysis or diagnosis focuses mainly on what happens in this frame or outcome. The outcomes of the analysis are however in all the frames, both in their interaction or individually. The frames can be related with links [(a), (b), (c), (d), (e) and (f)] to get to the bottom of the teacher's classroom practices (See Figure 2).

The application of the framework

The CPDF was used in diagnosing the classroom practices of the teacher, that is, the means (Staver, 2007) such as teacher knowledge, instructional strategies and interactions and discourse that were regarded as not helping the teacher to promote the end. The end was meaning making, misconception dissonance, the development of inquiry and problem solving skills, all of which influence the achievements of students (Abd-El-Khalick & Akerson, 2009).

The teacher is expected to know the common misconceptions and experiences of students and their prior knowledge so that s/he can introduce the new subject matter from those constructs for students to learn the new subject matter (Eryilmaz 2002; Galus, 2002 and Hausfather, 2001). Therefore, the framework was used as a frame of reference to establish whether the teacher was aware of the common misconceptions regarding the topic and, if so, how s/he used instructional strategies as well as the nature of the interactions and discourse to create misconception dissonance if they manifested during teaching. Moreover, the assertions that misconceptions may be created and/or introduced (Graham et al., 2012; Bayraktar, 2009; Prescott & Mitchelmore, 2005 and Prescott, 2004) during teaching by the teacher or students were also considered. So, it was not only about diagnosing the awareness but also finding out whether the teacher did have misconceptions which could be transferred to the students or if the teacher created or introduced misconceptions during teaching.

The framework was further used to diagnose how the teacher supported the meaning making process (Leach & Scott, 2003 and Mortimer & Scott, 2003). The focus was on the kind of the communicative approach and discourse the teacher used in the social plane wherein s/he introduced the new subject matter knowledge.

This was based on the notion that knowledge is constructed during social interaction (Carr et al., 2004; Lemke, 2001; Kim, 2001 and Davydov, 1995). Furthermore, the framework was used as a basis to diagnose how the teacher used instructional strategies and classroom interactions and discourse to facilitate internalisation of the subject matter knowledge by the students. This was so because according to Vygotsky (1978: 128) "the process of internalisation is where individuals appropriate and become able to use for themselves conceptual tools first encountered on the social plane". So it is the role of the students to internalise the new knowledge (Leach & Scott, 2003) and for teachers to support the process. How the teacher uses prior knowledge also influences internalisation of the subject matter because according to Hausfather (2001) learning involves continuous connection between the prior knowledge and the new subject matter.

The final phase in the process of meaning making is the application phase. So the framework was used as the reference point to diagnose the kinds of instructional strategies, interactions and discourse the teacher used to create opportunities for students to answer questions, solve problems and discuss the knowledge (Hausfather, 2001) to reinforce knowledge development. This was so because according to Nola (1997: 59) "only when they can go through the steps of reasoning by themselves and thereby make fully explicit to themselves the reasons for the answer will they have knowledge". The framework was also used to diagnose the kinds of instructional strategies and the interactions and discourse the teacher used to promote the development of inquiry and problem solving skills. For example, if the explanatory framework of the teacher is based on examples or the teaching methods entail largely question and answer and lecture, problem solving and inquiry skills may not be developed. This is so because those strategies do not promote reasoning and thinking ability (Nola, 1997), both of which are fundamental for the development of inquiry and problem solving skills (Abd-El-Khalick & Akerson, 2009).

METHODOLOGY OF IDENTIFYING TEACHING DIFFICULTIES USING THE CPDF

It was imperative for this study that close interaction with teachers was established as the teaching difficulties had to be understood from the teachers' viewpoints and classroom practices, as such a qualitative interpretative multiple case study was used. The research was also underpinned by the interpretive research paradigm which accepted that reality is a construct of the human mind (Cohen, Manion and Morrison 2007). The paradigm allowed the researcher to look at teachers as individuals, each with their own contextualised teaching difficulties. Teachers were studied in their natural world of work, namely the classroom. As a result, the phenomenon under inquiry was not detached from the researcher.

The sample of the study was from a cluster that had teachers who had a perception that projectile motion was difficult to teach. This was established during one of the cluster meetings in which the researcher was involved. Teachers were discussing the performance in the NSC Physical Science examination. They noted that projectile motion was always one of the topics identified wherein students did not perform well. Most teachers blamed the poor performance on the difficulty of projectile motion. It was for this reason that purposeful sampling was used to choose participants. The selection of the sample was based on the following criteria: they had to perceive projectile motion as difficult to teach; they also had to be teachers who had worked at their present school for more than three years. This was to ensure that teachers taught the cohort they had taught in the previous grade as it was the norm in the cluster. The practice was to ensure that students were familiar with the teacher's teaching style. The teachers in the sample also had to be qualified on paper to teach Physical Science at the Grade 12 level. That is, they needed to have studied Physical Science either in a diploma, degree or advanced certificate qualification. This was central to the study; according to Rogan and Grayson (2003), the level of training and qualifications can influence how the teacher teaches.

The schools in which the teachers in the sample were based had to have "good practices", a term which refers to the atmosphere in the school being conducive to teaching and learning. A school that was known to be dysfunctional in that it lacked discipline amongst students and with staff members who did not fully respect authority was not considered as it had "bad practices". So, teachers from such schools were not considered to eliminate the factor that the teacher's teaching practices were influenced by the "bad practices" in the school. This criterion was easy to apply because the cluster and the district were very familiar to the researcher and it was easy to eliminate teachers who came from schools that were dysfunctional. As there was more than one teacher to be considered, a multiple case study method was chosen. This was so because teachers work in different environments with different students. Furthermore, their knowledge is also different as well as experiences. Hence, each teacher was considered a case. With the teacher as a case his/her in-depth individual conceptions and teaching practices of the topic of projectile motion were analysed. The study was not about a comparison of the individual participants but focused on the descriptions of the phenomenon under inquiry and inferences from classroom practices; hence it was a descriptive multiple case study of three teachers teaching projectile motion.

Data was collected through interviews and classroom observations and the analysis was conducted through the development of themes and/or categories. As the data was analysed, patterns and categories that unexpectedly emerged were incorporated. Each case was analysed and interpreted as a unique case. Audio interviews were transcribed verbatim into a word document. Grammatical errors were not corrected so that the comment would not lose its original meaning. Where languages other than English were used, these were translated to English. Careful attention was paid to ensure that the original meaning of the comment was sustained. This was done by asking the respondent if the translation represented what he/she meant in his/her language. After the whole file was transcribed the document was perused whilst listening to the audio to ensure that what was in the word document was exactly what was in the audio. The interpretation of data for meaning was reached by two processes (Hitchcock & Hughes, 1995) namely: the first process was direct interpretations of the individual instances; in this process the instance referred to a theme as a whole or a part of the theme. It also referred to a statement a teacher made which could be interpreted on its own with no reference to other instances. However, this was limited in this study. This meant that an interpretation was reached without reference to other themes or based on a statement the teacher said. For example, an interpretation was made from the contents of the theme instructional strategies to derive the finding "instructional strategies that did not promote comprehension". The second process was Aggregation of instances: in this process an interpretation was reached after aggregating instances from various themes which resulted in a particular finding, for example, a linguistic challenge derived from the aggregation of instances from teacher knowledge and classroom interaction and discourse. But for the purposes of this paper, only one case is presented.

The researcher enhanced internal validity by ensuring that the findings were derived from the data collected for the study only (Maxwell, 1992). The researcher

Table 2. Teacher knowledge (Peter)

THEME	CATEGORY	CHARACTERISTICS
Teacher knowledge	**Content knowledge**	• **Researcher**: what did you teach? • **Peter**: vertical projectile, the downwards projectile (subject matter, main idea) • **Peter**: differentiate if an object is projected upwards and if an object is projected upwards (SMK, what was taught) • **Peter**: downwards projection-the velocity and acceleration are on the same direction – if upwards positive it means automatically downwards is negative or vice versa (SMK) • **Researcher**: The two components of a projectile that is vertical and horizontal, now what could make the learning of those components difficult? • **Peter**: If they are unable to identify the independent and the dependent variables it can make the chapter to be a little bit difficult in terms of graphs but if they are able to identify which one is the horizontal component and which one is the vertical component it becomes very simple. (SMK-no two dimension, difficulty)
	Context knowledge	• **Researcher:** What resources would you have used besides the ones you used to teach projectile motion today? • **Peter:** Like going outside the class and maybe let the learner climb on top of the roof and maybe I can say they can have a stone and then they can have a soft tennis ball… (resources) • **Peter**: learners (students) cannot afford to buy things that will make learning and teaching very easy [socio economic background] • **Peter**: you know the LTSM (learner teacher support material) we have got what we call… we are restricted (resources)
	Students' understanding	• **Peter**: We have learners (students) who have Physical Science and Mathematical literacy of which when I check they are coming to do this Physical Science knowing that they will fail and they will pass other learning areas (subjects) you know. It is like you are dealing with most learners (students) who are hopeless [difficulties-mathematical background as prior knowledge] • **Peter**: In fact I think it was coming from district level where maybe the district wanted to be competent with other districts that is my opinion or my point of view, this is what I have seen because initially the director came after we dropped our results and indicated to principal and the teachers that that what is the use of learners (students) doing physical science and pure Maths and then at the end they fail these 2 learning areas (subjects), we are destroying their future instead let them do Physical Science and mathematical literacy in such a way that even if they don't pass Physical Science they will pass Mathematical Literacy they will get that certificate of which maybe they will be employed somewhere and then they will do some other stuff rather than to pursue with their studies [difficulties- expectations- mathematical background as prior knowledge] • **Peter**: if learners (students) are unable to apply BODMAS it becomes very difficult for them to do their calculations correctly [difficulties- mathematical background as prior knowledge] • **Peter**: students struggle to answer questions because they do not have that kind of background-what is it that they need, when do they put negative and when do they put a positive (difficulty- background knowledge) • **Peter**: force of gravity-gravitational acceleration (prior knowledge required)

ensured that the research field was well prepared by communicating with the participants continuously about aspects pertaining to the research, such as confidentiality. The permission to gain entry was asked for many months in advance whilst the phenomenon, focus of the study as well as the unit of analysis were also well described. A reasonable rapport was established with teachers. Moreover, the researcher used triangulation technique. According to Cohen et al. (2007) triangulation is the use of two or more methods to collect data. Consequently, the researcher corroborated what the teacher said in the interviews with what was observed in the classroom which is methodological triangulation (Gall et al., 1996 and Hitchcock & Hughes, 1995). Accordingly, a teacher was interviewed before he was observed teaching the topic as well as after teaching the topic to attain the methodological triangulation. The researcher also allowed a teacher to listen to his/her interview after it was done for further clarifications, if any; to ensure that the researcher captured exactly what the teacher wanted to say. In addition, the researcher asked the participants for clarifications of instances which were deemed essential for analysing and interpreting the data during member checking, also known as informant feedback or respondent validation. An independent researcher also validated the coded transcripts before they were fully analysed.

Data presentation

Data is presented in tables using the themes and categories from the CPDF

Teacher knowledge

Table 2 captures some of the characteristics that exemplified the knowledge of Peter. The focus was on content, context and students' understanding knowledge.

Key of symbols and terms:

Symbol or term	*Description*
SMK:	Subject matter knowledge
ISMK:	Incorrect subject matter knowledge
M:	Misconceptions
Organisation of SMK:	Sequencing of concepts in the teaching of projectile motion
Difficulty:	Teacher's knowledge about difficulty in the topic
Prior knowledge: (PK)	Knowledge required or necessary or integrated in the learning of projectile motion at Grade 12
Resources:	Teaching and learning aids

Instructional strategies

Table 3 contains the characteristics of the theme instructional strategies for Peter. The focus was on activities, teaching methods, explanatory frameworks and epistemological perspectives.

Classroom interaction and discourse

Table 4 contains the characteristics of the theme classroom interaction and discourse. The focus was on the type and pattern of discourse demonstrated by the teacher, the purpose of his questions as well as the nature of his communicative approach.

DISCUSSION AND FINDINGS

Peter demonstrated adequate and organised subject matter knowledge albeit with a few misconceptions. The organisation of his subject matter was seen in how he introduced the topic and the sequencing thereafter (Kind, 2009). The extent and organisation of the subject matter is important because it influences the development of understanding in students (Hausfather, 2001). Peter indicated that his focus was on vertical projectile motion with attention on three types of problems [when the object is dropped, when an object is projected upwards and falls to the original position, and lastly when an object is thrown upwards and passes the original position when falling]. However, his three types of problems were not entirely correct as per the Physical Science framework. During teaching he infused concepts like acceleration, velocity and direction. When explaining direction his explanations were sometimes flawed or lacking in depth, for example not explaining why and when a direction is positive or negative as well as when to indicate direction or not.

His context and students' understanding knowledge which is frame A of the CPDF was also adequate, so it could have enabled him to teach the topic meaningfully. He had a laboratory which was fairly resourced and was observed teaching in there. However, he did not use any other teaching resource beside the chalk board and a

Table 3. Instructional strategies (Peter)

Theme	Category	Characteristics
Instructional Strategies	**Activities**	• **Peter:** Experimentally, demonstration, practical, those things are important-if learners (students) are learning something they can see or they can do it is difficult for them to forget [teaching method-demonstration, type of activity-experiments, reason] • **Peter**: I prefer experiments • **Peter**: learners (students) are able to see how to do those things and they learn skills (reason for experiment) • **Peter**: I usually do experiments at the beginning of the lesson or at the beginning of the chapter then more examples and exercises (how he teaches, empiricism) • **Peter**: he was observed anchoring lessons on problems as activities
	Teaching method	• **Peter**: I was lecturing and they were engaged in the lesson (lecture method) • **Peter**: the teacher solved the problem with the students watching how it is done [lecture method, demonstration, illustration] • **Peter**: you are not allowed to use x and y in the graph because you have s and t… (lecture method) • **Peter**: when we are doing presentations it allows you to demonstrate things for the learners (students) [demonstrations] • **Peter**: here is the chalk I am throwing it up look what happens…(demonstration)
	Explanatory frameworks	• **Peter**: *(the teacher writes an example on the board to show them how to solve a problem*) [example,illustration] • **Peter**: I prefer to use examples (examples)
	Epistemological perspectives	• **Peter**: more practice is needed and may be giving learners (students) different types of examples talking about one thing so that they get used to that [empiricism, explanatory framework-example] • **Peter**: they need to be given a lot of exercise based on the same work (drill, empiricism) • **Peter**: the teacher drew the table and showed students how to use the table method to inset values from the question (empiricism)

piece of chalk when demonstrating falling objects. He indicated, however, that he could have used different resources than the ones he used when teaching but did not explain why he had not used them at the time. He was aware of the challenges presented by the social background of his students. He indicated that he was forced to write on the chalkboard because students did not have some of the textbooks and could not afford to buy them. Peter was also aware of the prior knowledge students required to learn projectile motion in Grade 12. For example, he indicated that they needed knowledge of the force of gravity and gravitational acceleration. Prior knowledge is fundamental for learning to take place because according to Staver (2007); Eryilmaz (2002) and Hausfather (2001), learning involves the continuous connection between the prior knowledge and the new information.

Though the teacher indicated that he believed that Physical Science should be learnt through experiments and that he preferred experiments as activities, he did not conduct any during the teaching of projectile motion. There were opportunities to conduct one experiment, for example in the teaching of falling objects where he used a piece of chalk. He indicated that he usually does an experiment at the beginning of the topic or at the end of the topic yet during data collection the researcher was present when he introduced and concluded the teaching of projectile motion without conducting an experiment. During member checking he indicated that he usually conducts experiments as part of continuous assessment (CASS).

Peter preferred to use problems as teaching and learning activities. He introduced the lesson through two problems and explained his three types of vertical projectile motion using problems aligned to those situations. He did not teach problem solving skills but students were watching the teacher solving different types of problems. The disadvantage of this approach, according to Leach and Scott (2003), is that students have to internalise the ideas for personal use and with the teacher doing it for them that opportunity was not created. The teacher also largely used the lecture and

Table 4. Classroom interactions and discourse (Peter)

Theme	Category	Characteristics
Classroom Interactions and discourse	**Type and pattern of discourse**	• **Peter** when you start to engage learners (students) and say can you write the answer on the chalkboard it shows that now what they are doing they understand [dialogic] • (*student answered the first question, velocity and acceleration are always in the same direction*) • **First student**: it is true (response) • **Peter**: why is it false? (initiation, instructional question) • **First student**: because velocity and acceleration are not always in the same direction (response) • **Peter**: is it always the case? (initiation, instructional question) • **First student** (does not reply) [no feedback] • **Second student**: it is true and it can also be false…it depends… (response, incorrect) • **Peter**: it cannot be true (response, conveys information, Authoritative) • **Third student**: it is true because the object is coming down (response, incorrect)
	Teacher questioning	• **Peter**: which formula can we use? (lesson development, instructional question) • **Peter**: what is the value of a? (lesson development, instructional question) • **Peter**: what is the initial velocity? (lesson development) • **Student**: sir I solved the problem using a different formula which means there are other ways of solving the problem • **Peter**: show us what you did [evaluation] • **Student:** solved the problem using the formula ½ (vf-vi) t + v_it and got the same answer as the teacher's (incorrect formula) • **Peter**: where did you get the formula? (evaluation) • **Student**: there are many textbooks Sir (response) • **Peter:** in the exam they check the formula and if it is incorrect you will lose marks (conveys information) • **Student**: where will we get the formula?(initiation)
	Communicative approach	• (**Peter** solved the problem, interactive but authoritative) • **Peter**: the graph is positive because we are having a straight line [ISMK] • **Student:** is it always the case that if the object is moving downwards that direction is positive? (interaction) • **Peter**: what is the use of making the direction negative if they are in the same direction (acceleration and velocity) you cannot say the direction towards the ground is negative (Authoritative, dismissive)

question and answer method and sometimes demonstrations. He indicated that he preferred the lecture method because it allowed him to explain to students the concepts of projectile motion and that he used the question and answer method to find out if they had understood what he had taught them.

Peter was observed using illustrations and examples as his explanatory frameworks for the concepts in projectile motion. During teaching students largely sat watching and writing down what the teacher was writing on the chalkboard with infrequent questions. He also showed them how to use the table to solve problems using equations of motion. Moreover, by using the three types of problems [when the object is dropped, when an object is projected upwards and falls to the original position and lastly when an object is thrown upwards and passes the original position when falling] for the different situations with students observing how it is done the teacher was promoting learning by visual experience. He also indicated that students needed to be given more practice using different types of examples about the same aspect so that they could get used to it. Peter gave students tasks to do which were based on various problems which they had to solve by using equations of motion. Consequently, it was inferred that his epistemological perspective was empiricist in nature (Kuzniak and Rauscher, 2011).

In conclusion, Peter's instructional strategies which is frame B of the CPDF, did not create an atmosphere that maximally promoted meaningful learning and the development of inquiry and problem solving skills. According to Leach and Scott

(2003), within social constructivist theory the role of the teacher is to support the use of the new knowledge. Hausfather (2001) indicates that this support occurs when situations are created wherein students interact with information by using it to solve problems and by discussion. Peter did not create such opportunities through the instructional strategies he used. His instructional strategies were teacher centred (Biggs, 2001). Figure 3 illustrates the interrelationship of the instructional strategies Peter used.

The Venn diagram in Figure 3 shows the overlapping relationships of the instructional strategies used by Peter. At the top of the diagram the empirical epistemological perspective shapes all the other strategies (Kuzniak & Rauscher, 2011 and Kalman, 2009). This is followed by the problems as teaching activities which are executed through the lecture and question and answer methods and sometimes through demonstrations. During the lecture, question and answer methods and demonstrations, the teacher used illustrations and examples to teach the activities. At the bottom of the diagram, the explanatory framework used during lecture and question and answer and demonstration methods for the teacher activities shows the teacher's empirical epistemological perspective. Table 5 presents a summary of the instructional strategies of Peter.

Peter had begun his lessons by asking questions and students responded to these questions. However, the kind of feedback he provided was one dimensional in the sense that only that which was correct was emphasised and incorrect responses were not interrogated extensively. As such, the provider of the response could not notice why he /she was incorrect. This was necessary because according to Nola (1997) learning occurs through reasoning which enables construction of new meaning (Carr et al., 1994). So if the incorrect response is not engaged with, it creates dissonance in the mind of the student which may hinder the understanding of the new information.

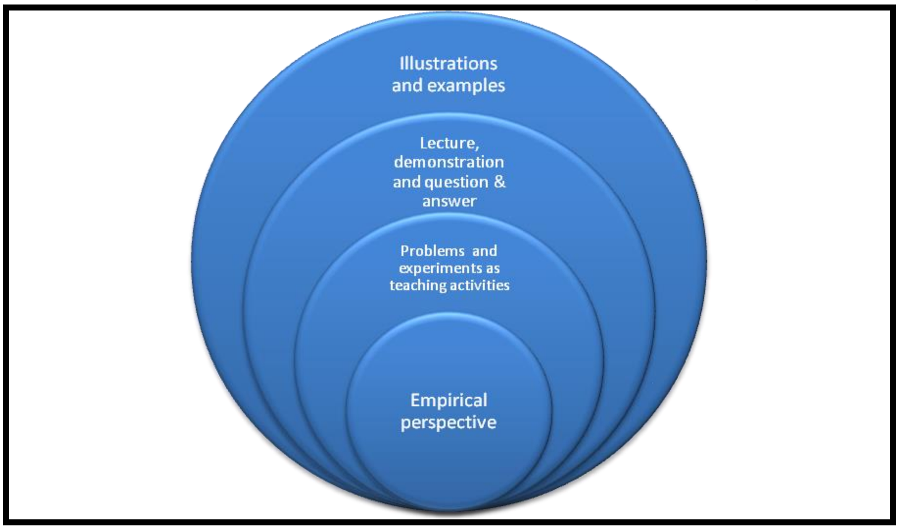

Figure 2. Venn diagram of Peter's instructional strategies

Table 5. Summary of Peter's instructional strategies

Instructional Strategies	
Epistemological perspective	Empiricism-Inductive teaching
Didactics	Demonstration Question and answer Lecture
Explanatory framework	Illustrations Examples
Activities	Problems

So for instance in one case a judgement was passed that the reason they responded incorrectly was because they did not read questions properly, for example a student that responded to the question that acceleration and velocity are always in the same direction. Even though the teacher interacted with the student about the incorrect response, the emphasis was not on assisting the student but on providing the correct answer as a fact. This was not an isolated incident: throughout the lessons the teacher did the same. The kinds of question he employed were instructional and with the intention to convey information, evaluate and develop the lesson. As a result the pattern and kind of discourse in Peter's classroom was IRF (Carlson, 1990) and authoritative (Chin, 2006). This kind and pattern of discourse does not promote the construction of meaning and debate which is necessary for understanding new concepts.

In another incident a student indicated that although he had used a different formula to solve a problem based on graphs – which the teacher solved using the area formula – he got the same answer as the teacher. The student indicated that he saw the equation from another textbook [½ (vf-vi) t + vit]. The formula was incorrect but the teacher did not thoroughly engage the student to explain why his formula was incorrect. Peter indicated that he would engage with the student after class if he still had problems. Other students then indicated that the formula which the teacher used was unfamiliar to them. Peter indicated that the students were supposed to know that formula as it was taught in the Mathematics class and that it was the area formula. If the teacher had assisted the student who used the incorrect formula in class it would have also assisted other students who questioned the same approach. The teacher then continued to the next problem without further discussion. It follows then that Peter's communicative approach was interactive but authoritative (Mortimer & Scott, 2003). Although Peter invited responses he discarded them if they were incorrect and focused only on the correct responses. Peter's classroom interactions and discourse which is frame C of the CPDF are summarised in Table 6.

Peter also indicated why the topic of projectile motion was difficult to teach. He argued that the top-down enforcement from the district office for students to take Mathematical literacy and not Mathematics created difficulties as students did not have the necessary mathematical skills. He mentioned that he had influenced most of the current cohort to take Mathematics instead of Mathematical Literacy. In addition, he felt that the topic becomes difficult to teach because it does not require only the teaching of equations of motion but also requires background knowledge such as the forces involved and explanations of velocity and acceleration. Peter pointed out that when teaching the topic students did not need theory only, but also needed to be provided with opportunities to understand and apply the new knowledge. Furthermore, he warned his students that the topic was challenging and that they needed to keep to the basics, by which he meant the rules, which he would teach them.

From the discussion of Peter's teacher knowledge, instructional strategies, and interactions and discourse which culminate into frame D of the CPDF, the following are what emerged as the teaching difficulties of the topic projectile motion.

Table 6. Summary of Peter's classroom interactions and discourse

Classroom interactions and discourse	
Type and pattern of discourse	IRF, Authoritative discourse
Teacher questioning	Lesson development Evaluation
Communicative approach	Interactive-Authoritative

Pollinating the creation of misconceptions

Peter demonstrated an attempt to infuse prior knowledge into his teaching. He indicated that prior knowledge was paramount to the teaching of projectile motion and created learning difficulties if it was ignored. This is a point also raised by Hausfather (2001) when he states that prior knowledge or the absence thereof can inhibit learning. Amongst other aspects which Peter used as background knowledge before focusing on the use of equations of motion was an explanation on direction. He indicated that when the object is moving upward the direction is negative and downwards is positive. However, there was no indication of why this was so.

The concept of direction and its use was not understood by students and this was noticed when one of them asked if it was always the case that when the object was falling the direction was positive. Their teacher simply indicated that "what is the use of making the direction negative if both acceleration and velocity are in the same direction?" This showed that to Peter the emphasis on direction was dependent on the motion of the object: when the object is thrown upwards and falls to the ground, then direction is paramount. Furthermore, in another incident Peter was asked by students if the answer was wrong if direction was not indicated and the teacher pointed out that they had to check the question and if it was not indicated he did not think they would be penalised. The teacher was not clear in his instructions to the students on what was expected of them in terms of direction.

Bayraktar (2009) comments that some misconceptions can be transferred by the teacher. This can happen when the teacher is teaching (Graham et al., 2012) and most teachers are not aware of their misconceptions (Prescott & Mitchelmore, 2005). This could be the case in this study because even during the interviews the teacher emphasised that "when we talk about direction we are talking about the positive and the negative". In another incident the teacher displayed misconceptions, for example, when he indicated that an object does not experience gravitational acceleration when it is going up but only when it is falling. This was not an isolated incident during his lessons. Consequently Peter was fertilising the creation of misconceptions or transferring his misconceptions to the students.

Teaching quality is of paramount importance in students' learning (Kaplan & Owings, 2001). This is so if one takes into consideration the assertion of Staver (2007) that science teaching is a means to an important end. Peter's students were exposed to a means which had the fertilisation of misconceptions. It follows then that Peter's students might learn incorrect concepts which could in turn affect how they learn and perform in assessments.

Curriculum demands not achieved

Peter's knowledge was suitable in terms of content, context and students' understanding to teach projectile motion meaningfully. According to Rollnick et al. (2008) most teachers from the previously disadvantaged colleges were under qualified in the sense that they were taught inferior subject matter which was no more than that of Physical Science content at Grade 12. However, what Peter displayed was acceptable. It could be due to the further qualifications he had acquired, for example the two ACE (Advanced Certificate in Education) qualifications in Mathematics and Physical Science and the Bachelor of Science (Honours) degree. Furthermore, if one considers Shulman's (1987) assertion that teaching begins with the teacher's understanding of what is to be taught and how it is to be taught, Peter displayed all those qualities. According to Kaplan and Owings (2001), what the teacher brought in terms of qualifications and professional preparation was adequate and therefore his quality as a teacher was not questionable.

However, in his lessons Peter did not teach well. He indicated that what students needed to be taught at Grade 12 were three types of vertical projectile motion and graphs. The structure of his lesson was not a true reflection of the Physical Science framework. He was focused on teaching for examinations as he indicated that they were pressurised by the district office to produce good results. His focus on examinations was also evident in his emphasis on examination requirements throughout the lessons. A focus on examinations cannot be totally incorrect if all aspects to be covered are dealt with adequately. Peter focused on solving problems on projectile motion using the equations of motion. Even the three types of vertical projectile motion he indicated were based on the types of problems he solved for the students. He did not teach amongst other aspects projectile motion in two dimensions. In conclusion, Peter did not put the curriculum demands (Tawana, 2009) into practice in the classroom.

Inadequate integration of background knowledge

The kind of background knowledge chosen by the teacher to anchor the new subject matter can also be the source of teaching difficulties as it shapes the meaningfulness of the subject matter for the students (Staver, 2007 and Hausfather, 2001). Galus (2002) indicates that it is important for students to have learnt forces prior to learning projectile motion. Furthermore, Eryilmaz (2002) also indicates that it is imperative for teachers to connect the new knowledge to the prior knowledge and experiences of students. However, in Peter's situation it was noted he neither integrated forces in the teaching of projectile motion nor diagnose the students' prior knowledge on forces, even though he had indicated that,

> In most cases I have seen that learners (students) are struggling to answer questions based on vertical projectile because they don't have that kind of background, so explaining that background it will make things easier for them to first understand the given statement before they apply or go to the questions that what is it that they need, when do they put a negative and when do they put a positive.

Peter conceded that students have difficulties with Mathematics and also indicated its importance in the learning of Physical Science and projectile motion in particular. However, when solving a question that required the knowledge of the formula for area which is taught in the Mathematics class the teacher assumed that students knew that particular formula. He did not ascertain whether they recalled the formula or not. Even after realising that they did not know it he just indicated that it was taught in the Mathematics class.

Peter knew that students' learning of projectile motion would be made easier when the background to the concepts was considered and taught. Yet the kind of background information he focused on was identifying direction in terms of velocity and acceleration in vertical projectile motion. Thereafter, he focused on solving problems by using equations of motion and there was no mention of any forces interacting with an object in projectile motion. In addition, when solving the question which required the description of the motion of the object, the motion was described in terms of direction. Peter indicated that when an object is falling the acceleration and velocity are in the same direction. He indicated that it is because the object is in free fall. There was no reference to the force that is causing the object to fall. This was not an oversight as he had spoken about the force of gravity as the prior knowledge and experience students bring to class. Even though the teacher was aware of the forces that are involved in projectile motion, he did not integrate them during the teaching of projectile motion.

In the light of the findings of Staver (2007), Eryilmaz (2002), Galus (2002) and Hausfather (2001) it can be inferred that due to the insignificant integration of prior knowledge Peter's students may be disadvantaged in that they may not make meaningful learning of projectile motion. Consequently, when students do not make meaningful learning, their performance may be poor (Chin, 2006).

Empirical epistemological perspective clouded good intentions

Peter had good intentions of using instructional strategies that would enable students to learn and comprehend the subject matter. For example, he indicated his preference of experiments as teaching activities because students do not only enhance their knowledge but also learn skills. When an experiment was not done after the first lesson, Peter indicated that he conducts them at the beginning or at the end of the chapter. During the period of data collection which began when he introduced projectile motion to when he was solving problems using equations of motion, no experiments were done. Furthermore, Peter knew his reasons for using lecture, question and answer and demonstration methods; he indicated that he used the lecture method for explanation, and the question and answer method to check if they understood what he said.

Yet, in practice it was noted that throughout the lessons his instructional strategies were entrenched in the empirical perspective (Boeree, 1999). This is so because the teacher was focused on his students gaining experience of how to solve projectile motion problems by using equations of motion as well as determining direction at the expense of giving them opportunities to think about all the aspects unfolding before them. He exposed them to gaining experience through examples he gave as well as problems which he solved while the students watched.

In conclusion, it is evident that the teacher's sound instructional strategies were clouded by his focus on students gaining experience on how to solve problems by using equations of motion rather than thinking opportunities. This is so because according to Childs and McNicholl (2007) and Hollon et al. (1991) explanatory frameworks and activities should engage students such that they are able to think and realise that their thinking is important. The assertions by Childs and McNicholl (2007) and Hollon et al. (1991) were not evident in Peter's observed lessons even though he gave students many examples and knew about the importance of experiments. In addition, the nature of the subject according to Abd-El-Khalick and Ackerson (2009) requires students to think (Nola, 1997) in order to develop problem solving and inquiry skills. Consequently, students may memorise the algorithmic way of using equations of motion without comprehending why it has to be so. Galus (2002) argues that this can be a challenge to Physical Science teachers.

The ultimate meaning making process compromised

When students make meaning from what they are learning it improves the possibilities of performance (Chin, 2006). The meaning making process occurs in three phases (Mortimer & Scott, 2003), that is, the social plane, internalisation and application process. Peter's students were largely exposed to the social plane where aspects like velocity, acceleration and using equations of motion were dealt with. The teacher also used the social language of school science which was appropriate and at the level of the students. However, the internalisation phase was compromised as there were limited opportunities for internalising the new knowledge. This is because Peter's lessons were epitomised by instructional questions intertwined with the lecture method. For example, when students asked where they would get formulas and gave the incorrect formula, they were told that they would find the formula in the formula sheet. When they further indicated that the formula did not appear on the formula sheet, the teacher replied that he meant those taught in the Mathematics class. Thereafter, he dismissed the incorrect input by the student without further engagement. This was an interacting-authoritative communicative approach (Chin, 2006). This approach is teacher centred and provides no opportunities for students to interact meaningfully with the subject matter (Chin, 2006 and Biggs, 2001).

Furthermore, Peter's lessons were dominated by the conveying of information to the students and this discourse, intertwined with the type of questions he asked to develop the lesson, was authoritative. For example, when he was solving problems using equations of motion he would intermittently ask students for input in terms of values for substitution in an equation. This kind of discourse does not foster student thinking (Chin, 2006) which is necessary for the development of problem solving and inquiry skills. Hence, the internalisation and application processes were seriously compromised. In conclusion, the communicative approach and discourse in Peter's classroom promoted rote learning, which was not surprising, considering that his epistemological approach was empirical. Taking into consideration that the DBE (2010, 2011a) asks questions to test for inquiry and problem solving skills, Peter's students were at a disadvantage. It will not be surprising if they do not perform well in the topic and the subject at large during examinations.

CONCLUSION

It was the purpose of this paper to expatiate on what the CPDF is, as well as illustrate how it was used to diagnose teaching difficulties. The researcher showed from the case that the CPDF can assist to diagnose teaching difficulties from an integration of aspects such as instructional strategies, interactions and discourse. It was also presented that the CPDF can assist in diagnosing a teaching difficulty from one aspect such as teacher knowledge of students' understanding and how it is used or not used during classroom practice. The other frameworks would not have assisted in achieving this. How the framework was applied to determine teaching difficulties should add into the debate on teacher practices in science teaching. It is also envisaged that the framework can be used as a fundamental resource for in-service training to identify the teacher's areas of development in their practices. The framework may also assist to derive a picture of how different facets of teacher practices can generate teaching difficulty which should make it possible to provide tailored intervention either be content knowledge, context knowledge, instructional strategies or nature of discourse if a deficiency was diagnosed. It is also conceded that the framework has not been tested at a large scale and other topics. So it is suggested that further research on a large scale and other topics perceived to be difficult to teach can be pursued.

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