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Transforming content knowledge : learning to teach about chemical change

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2009-05-20T12:33:58Z
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CHAPTER 1

INTRODUCTION TO THE STUDY

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1.1 Introduction

Many learners in secondary schools end their academic career path with regard to science at the grade 9 level. This may be due to the level of difficulty and rather abstract nature of the subject matter knowledge, together with the negative stigma attached to it by their predecessors. Possible suggestions may be that the laboratory level of chemistry (macroscopic interpretation) and the microscopic level (atomic or molecular interpretation) are not easily distinguishable, a major concern for teachers of chemistry. The ability to bridge the gap between these levels is an invaluable asset to the chemistry teacher and will enable learners to develop security and confidence in their subject matter knowledge. However, if the distinction between macroscopic and microscopic levels remains fuzzy, the difficulty that teachers encounter with regards to marketing their subject to learners will continue to increase, and ultimately result in far reaching implications for fostering a skilled workforce. The purpose of this study is aimed at uncovering how teachers of science can discourage the perception of chemistry as purely abstract, through their pedagogic practice, thereby dispelling the stigma attached to it. The manner in which the latter may be accomplished is dependent on how teachers present and transform their subject matter knowledge, so as to make it comprehensible and less intimidating for learners.

1.2 Rationale for the study

Research on teachers' pedagogical practice is common. Many attempts have been made to examine teachers' practice with respect to the types of knowledge that a teacher must possess in order to function at the optimum level in the classroom. Mere transmission of content knowledge is not sufficient anymore; a teacher must proceed beyond this point to the stage where he or she is thinking of how to transform subject matter knowledge, if they wish to engage with learners in an effective learning environment. However, given the notion that human beings are complex in nature, it is reasonable to assume that the manner in which teachers transform their knowledge is rather intricate and tacit in most cases.

In 1986, Lee Shulman suggested that the "cognitive psychology of learning" has focused on questions regarding teacher practice solely from a learners' perspective. He maintains that the pedagogue's practice must take priority and deserves further

exploration in order to understand the issues surrounding the way in which they choose what to teach, how to represent their instruction, how to deal with learners' misconceptions, and to find the origin of their explanations. In a quest for a more coherent framework of teacher content knowledge, he introduces three categories, namely: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge.

While all three types of knowledge are essential to a teacher, the academic construct that has attracted perhaps the most commentary and subsequent research is pedagogical content knowledge. Shulman (1987) describes pedagogical content knowledge (PCK) as the "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding". In addition, PCK includes knowledge of learners, of educational contexts and educational purposes as outlined by Shulman (1987).

Other proponents of PCK have expanded on Shulman's ideas with the purpose of suggesting alternative frameworks (Geddis & Wood, 1997). Furthermore, in an effort to make explicit the tacit nature of teacher practice, the use of tools to capture and document PCK have been explored by Loughran, Mulhall & Berry (2004).

As a practising teacher, this study allows for the examination of PCK within the confines of chemistry, more specifically chemical change. Using a case study approach, I investigate the manner in which two teachers, each from different backgrounds, relate to the topic and deliver it to their respective grade 10 learners. While one teacher has extensive chemistry teaching experience, the other teacher has general pedagogic experience but is a novice to this section of work. His expertises lie in the biological sciences. Other studies (cited in Gess-Newsome & Lederman, 1999a) have inspected similar scenarios, especially with regard to the PCK of pre-service teachers and in-service teachers, however fewer studies have examined differences in chemistry and non-chemistry specialists in the school context. Furthermore, this study highlights the practice of teachers who are in a system which advocates skills based approach, coupled with time constraints which will invariably impact the actions of the teacher.

The section of chemical change as described in the National curriculum statement (Department of education, 2003) is broad. This study focuses on the meaning of chemical change and characteristics that define this chemical event. While the concept of physical change is delineated, the purpose of this is merely to draw essential comparisons and contrasts. Thus, the study does not allow time and space for physical change and other sections included in chemical change, for example, stoichiometric calculations.

1.3 Aim of study

The aim of the study is to investigate how two teachers transform their content knowledge when teaching the section of chemical change, in particular chemical reactions, in order to make the subject matter understandable for their learners.

1.4 Research questions

The present study captures and documents the PCK of two teachers teaching chemical change in an effort to answer the research questions mapped out below.

1.4.1 What are the distinct features of PCK of an experienced physical science teacher and a non-specialist chemistry teacher when teaching chemical change?
1.4.2 What impact does subject matter knowledge have on PCK?
1.4.3 How does each teacher transform their subject matter knowledge into accessible forms?

1.5 Statement of the problem

Mathematics and Science are key areas of competence for the social and economic development of South Africa, especially in the context of competing as global players. However, most performance indicators (TIMSS and other tests in Taylor, Muller & Vinjevold, 2003) suggest that South African learners experience the greatest challenges with Mathematics and Science. In addition, the quality of school leavers' scientific knowledge and understanding has been considerably criticized due to the poor performance of learners in Mathematics and Science (Centre of Development and Enterprise, CDE, 2004). While many participants in the educational arena share the

view that learners generally perform poorly due to the abstract nature of the Mathematics and Science, the NRF suggests that the focus has recently been shifted from poor learner achievement to teacher capacity and supply. Essentially, the capacity of teachers to meet academic expectations and foster meaningful learning is paramount if learners are to raise the level of their performance. Therefore, the manner in which teachers package and communicate their specific content knowledge remains a key component of their pedagogy, and ultimately affects general improvement of learner performance. With regard to the poor supply of teachers, the CDE (2004) reports that 1998 statistics show only 39, 7% of physical science teachers in South Africa have a degree in any discipline including science. More recently, CDE (2007) reports that only 550 potential maths and/or science trainee teachers graduated from South African universities. There were no Postgraduate Certificate of Education students registered as taking physical science as a major subject in 2007 at the University of the Witwatersrand (Rollnick, 2007). Consequently, the shortage of qualified science teachers brings with it other factors that contribute to the poor learner performance and thus, the study also serves to explore one of these factors which is the use of non-specialist chemistry teachers who may be involved in teaching science.

Research in science education unique to this study will serve to inform textbook writers, policy makers and teacher education institutions. It is anticipated that the findings will have the potential to influence future classroom practice, thus making learning more meaningful and purposeful. Finally, the study may serve to motivate school teachers and teacher training facilities to make a concerted effort to raise the level of learner performance in science education looking through the lens of PCK.

1.6 Sequence of the research report

Chapter one begins with the introduction, describes the rationale for the study, states the research questions, explores the statement of the problem and summarises the aim of the study.

The second chapter reviews relevant literature on the theoretical frameworks with respect to PCK and expresses the characteristics of learning about chemical change and

teaching chemical change. Furthermore, teacher subject matter knowledge is expanded upon and directions from the literature are given.

Chapter 3 describes the research design and methodology. It gives an overview of the research instruments used, the data collection process, and endeavours to address matters of validity and reliability, and triangulation in the study. In addition, the sample, institution and contexts within which the study was conducted are explained, culminating with a critique of data collection methods.

The fourth chapter is concerned with capturing and documenting PCK with the use of Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs). The construction of the CoRes is explained and the corresponding PaP-eRs are elucidated, giving a narrative account of each teacher's practice.

Chapter five deals with distinctive features of PCK and serves to answer research question 1.4.1 and 1.4.3. The chapter discusses how each teacher pronounces each element of PCK in their own classroom practice in an effort to make it explicit, according to the Geddis & Wood (1997) framework. Furthermore, it uncovers how each teacher transforms their subject matter knowledge in order to make it accessible for learners to understand.

Chapter six attempts to expose the teachers' subject matter knowledge for teaching and the relevance it has to PCK with a view to answer research question 1.4.2. It incorporates the diagnostic test analysis and looks at similarities and differences between learner performance and teacher performance.

Finally, chapter 7 reports the overview of the study and discusses the findings of the research project. Limitations of the study are elaborated upon and recommendations are proposed. In addition to this, directions for future complementary research are suggested which closes the chapter.

CHAPTER 2

LITERATURE REVIEW

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2.1 Introduction

This chapter deals with the different views from literature on the study of pedagogical content knowledge and the concept of chemical change.

The first part of the chapter is concerned with how pedagogical content knowledge is perceived. The common ideas that filter through each discussion are highlighted in order to give the reader a richer understanding of this academic construct.

Central to this study is the concept of chemical change and how it is delivered by two teachers. Therefore, the discussion elaborates on the meaning of chemical change and the difficulties that are encountered when one is teaching it.

Finally, the discussion culminates in relevant issues that can be extracted from the research to relate to this study.

2.2 Theoretical framework

2.2.1 Pedagogical Content Knowledge

The concept of pedagogical content knowledge (PCK) was introduced by Shulman when he suggested that research on teaching and teacher education has neglected the content or subject matter of lessons taught (Shulman, 1986). In addition to the teacher's subject matter knowledge and their general knowledge pertaining to instructional methods, Shulman (1986) embraced the construct of pedagogical content knowledge as a vital component in order for effective teaching to take place. He suggested that due to the tacit, complex nature of teacher understanding and communication of content, there was a dire need for a coherent theoretical framework which would help categorize and explain characteristics of professional practice.

PCK is a type of knowledge that is unique to teachers and is largely based on the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge. Therefore, it may be explained as an integration of what teachers know

about teaching with their knowledge of the subject matter. According to Shulman (1986), PCK for a specific domain includes

> …the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations, - in a word, the ways of representing and formulating the subject that makes it comprehensible to others.

Furthermore, the knowledge of learner conceptions, misconceptions and preconceptions, also feature strongly in the PCK of a teacher and could be demarcated for particular topics of instruction as intimated by Shulman (1986). It is thus imperative for a teacher to understand and ascertain the prior knowledge with which learners begin and how to represent alternative forms of subject matter that allow for effective learning to occur. This skill is most easily sharpened by the teacher's experience in the field, however, for the novice or non-science teacher, it is undeveloped.

Shulman's conception of PCK is expanded by Geddis, Onslow, Beynon, & Oesch (1993) as well as Geddis & Wood (1997) as the transformation of subject matter into forms that are accessible for learners. Geddis & Wood (1997) propose that the value of focussing on transformation of subject matter is that it draws attention to subject matter, learners, as well as educational goals. Geddis et al. (1993) make the following claim relating to the issue of conversion that teachers must address as they transform subject matter knowledge for teaching:

> "To make subject matter knowledge accessible to particular students, it needs to be transformed. But, subject matter also has to be represented in as authentic manner as possible".

Therefore, teachers must be able to modify their subject matter knowledge, and still retain its authencity, in order to make it comprehensible for learners. Effective learning of subject matter knowledge may be achieved once this conversion is successful.

The different kinds of knowledge employed when transforming subject matter may be portrayed as the teacher's PCK. Geddis et al. (1993) and Geddis & Wood (1997) prototype of knowledge transformation is adapted from Shulman (1986, 1987) and

includes the following which fall under the umbrella of PCK, and facilitate transformation of subject matter:

a) learner's prior concepts
b) subject matter representations
c) instructional strategies
d) curriculum materials
e) curricular saliency

Within the area of transformation of subject matter knowledge, Geddis et al. (1993) use Shulman's (1986, 1987) concept of PCK to articulate the manner in which two student teachers and an experienced teacher teach chemical isotopes. The study served to codify aspects of PCK important for teaching chemical isotopes, and highlights the importance of curricular saliency as an essential component of PCK. Furthermore, the study is useful for adding to the knowledge base of both experienced and novice teachers. Geddis et al. (1993) contend that other topics in chemistry need to be explored in the same way in order to articulate and capture the manner in which teachers' package and transform their knowledge. They framed PCK into four categories which are enumerated above, with the exception of curriculum materials which was included in the framework of Geddis & Wood (1997). The diagram below serves to describe each of the categories briefly and will be discussed in more detail below.

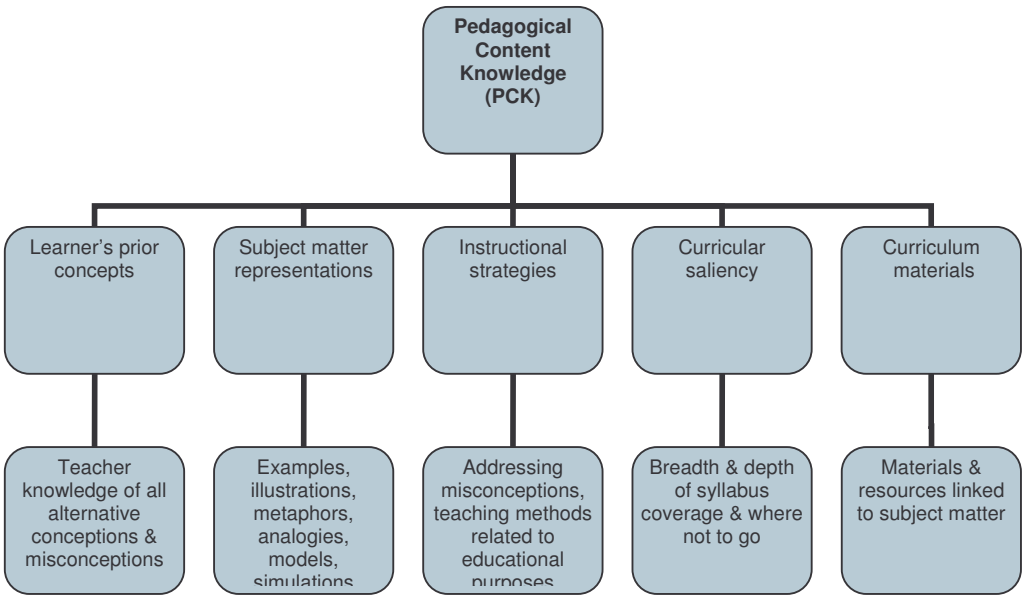


Figure 2.1: Types of teacher knowledge that facilitate transformation of subject matter (as perceived by Geddis & Wood, 1997).

a) Learner's prior concepts

According to Geddis et al. (1993), learner's prior concepts are inherent in all teacher-learner interactions. They maintain that learners bring "already formed ideas" about important concepts, even in unfamiliar topics which may be different from acceptable views. Gabel (1999) suggests that learning chemistry concepts consists of "making intricate networks in long-term memory more consistent with accepted scientific thought" and she maintains that effective learning results when new information is connected to information that is already stored in the learners' memory. Therefore, if teachers possess knowledge of alternative conceptions that learners already have, they can make decisions about how to reorganise content knowledge for teaching. Coupled with alternative conceptions, misconceptions may also emerge during the initial and latter stages of the instruction. Once again, the knowledge of these conceptions is invaluable to the teacher and will shape subsequent lessons.

b) Subject matter representations

The use of subject matter representations and the extent to which it is employed is unique to each teacher. However, Geddis et al. (1993) contend that chemistry teachers are likely to use a variety of representations of their subject matter. These may include molecular formulae, chemical symbols, Lewis dot structures, physical models and other related tools. In their study, they focused on the use of examples as a primary source for the representation of subject matter. Gabel (1999) considers that representation of subject matter to be a vital component with respect to fostering sound understanding of chemical concepts. She advocates the threefold representation of matter model (Johnstone, 1991, cited in Gabel, 1999) which links the macro, sub-micro and symbolic level of matter. She suggests that relating all three levels may help the learner improve their conceptual understanding of the subject matter. This model is discussed later in the chapter under the heading of 'Instructional barriers'.

c) Instructional strategies

Instructional strategies are necessary approaches that focus on the purpose for teaching a particular topic and may simultaneously address misconceptions or alternate conceptions that teachers find apparent in their learners' prior knowledge according to Geddis & Wood (1997). Therefore, the learners' prior concept category requires the teacher to identify alternate conceptions and misconceptions, while the present category expects the teacher to actively tackle those conceptions. The study conducted by Geddis et al. (1993) described the problem-based approach used by an experienced teacher to contextualise the topic of isotopes rather than focusing on an algorithmic approach of calculating relative atomic masses of isotopes. Furthermore, the intention of developing conceptual knowledge rather than the procedural knowledge was more desirable to the experienced teacher. Of all the components illustrated in figure 2.1 above, perhaps this category is the most central to PCK. All other categories seem to fuel and influence the instructional strategy of the teacher. Therefore, the teachers' decision to adopt a specific approach may be dependent on the their knowledge of learner's prior knowledge, the manner in which the teacher plans to portray the subject matter, the curriculum materials that are acquired and the curricular saliency issues that the teacher is aware of.

d) Curriculum materials

Geddis & Wood (1997) suggest the use of appropriate resources which effectively link to subject matter and support teaching strategies. Therefore, the stronger the link between materials and subject matter, the easier it becomes to transform subject matter knowledge and will invariably guide teaching strategies. These may include a variety of materials such as worksheets, transparencies, chemicals, laboratory apparatus, and books among other materials. While curriculum materials may aid learning, the use of unfamiliar materials, especially in chemistry instruction, could also hinder the learning process according to Gabel (1999). She also contends that resources that teachers use should be related to learners' everyday life. This factor is explained later in the chapter as an instructional barrier to learning.

e) Curricular saliency

The manifestation of curricular saliency is visible in the teacher's ability to discern the relevance of various topics in a broad and extensive curriculum according to Geddis et al. (1993). They maintain that curricular saliency is sharpened by experience in the field; however, even experienced teachers find difficulty in this regard, especially with new topics in the curriculum. The property of curricular saliency may also be described as the teachers' knowledge of the breadth and depth of the curriculum (Geddis & Wood, 1997) and how a specific topic impacts the learners' understanding of the balance of the curriculum (Geddis et al., 1993). In their study, the novice teacher was overcome by the pressure of completing the content and resorted to adopting a transmission mode of instruction. The experienced teacher was able to effectively deal with the tension between "covering the curriculum" and "teaching for understanding", thus he made deliberate decisions to focus on relevant portions of the topic and skim over or exclude other parts. Furthermore, the experienced teacher was also aware of potentially confusing concepts contained in the topic, thus his decision to avoid such content while still accomplishing his objectives. This concludes the five types of knowledge that Geddis & Wood (1997) and Geddis et al. (1993) have described as important features of PCK.

With respect to PCK, Geddis & Wood (1997) suggest that Shulman (1986, 1987) gives no clear indication of how all of the above components interact. Their framework illustrated above provides a means of analysing the teaching process and depicts how subject matter may be transformed from the teacher's own individual understanding of subject matter into forms that are accessible to their learners. Furthermore, they acknowledge that this typology is not a linear process due to the intuitive and messy practice of teachers; rather it serves to provide useful categories that frame PCK.

Both Geddis & Wood (1997) and Geddis et al. (1993) maintain that the issue of transforming subject matter knowledge is critical with respect to development of PCK, however, the temptation to focus one's attention purely on content knowledge and simultaneously the learner, is a difficult process to negotiate successfully. Furthermore, in many instances, teachers may revert to the traditional method of transmitting content knowledge, instead of taking cognisance of learner prior conceptions, alternative

representations, as well as curricular saliency. Therefore one must realize that good PCK considers all of the above-mentioned aspects of teaching and provides a richer context in which effective learning may occur.

Shulman's (1986, 1987) construct of PCK is not congruent with Cochran, de Ruiter & King (1993); instead they chose to modify the concept based on constructivist views of teaching and learning. In their view, the term knowledge refers to a static phenomenon whereas constructivism is mainly concerned with the active process of knowing and understanding. Therefore, they refer to PCK as pedagogical content knowing (PCKg) and explain it as follows:

> "a teacher's integrated understanding of four components of pedagogy, subject matter knowledge, student characteristics, and the environmental context of learning".

The teacher's understanding of students and the environmental contexts of learning is regarded as the focus of PCKg. While these factors are mentioned by Shulman (1986, 1987) whose area of interest was transformation of subject matter knowledge, Cochran et al. (1993) embark on a more holistic incorporation of student understanding and environmental contexts of the student. These include ages and developmental levels, attitudes, motivations, as well as prior conceptions. Furthermore, teacher understanding of social, political, cultural and physical environmental contexts that mould the teaching and learning process is considered to be the second focal point.

van Driel, Verloop & de Vos (1998), like Cochran et al. (1993), move away from the framework of transformation of subject matter knowledge, rather they consider adequate subject matter knowledge to be a requirement for PCK. In addition, they perceive PCK to be a specific form of what is referred to by Grimmett & MacKinnon (1992) as craft knowledge (cited in van Driel et al. 1998). They define craft knowledge as a type of knowledge that attempts to guide the teacher's behaviour and delivery of subject matter in the classroom, the teacher's "accumulated wisdom with respect to their teaching practice". It follows that PCK viewed in the light of craft knowledge, mainly refers to integration between what teachers know about teaching and their knowledge of subject matter, together with curriculum matters and student conceptions.

It was Shulman's (1986) ideas of types of teacher knowledge which sparked new interest in the world of educational research. He maintained that among the knowledge base of teachers, subject matter knowledge was a crucial component .In recent years, this thought has become congruent with national reform movements which suggest that teachers must have a "deep and highly structured content knowledge that can be accessed flexibly and efficiently for the purpose of instruction" (Sternberg & Horvath, 1995; Talbert, McLaughlin & Rowan, 1993) cited in Gess-Newsome & Lederman (1999b).

In their study, Gess-Newsome and Lederman (1999b) chose to research five broad categories of secondary teachers' knowledge, namely: conceptual knowledge, subject matter structure, and nature of the discipline, content-specific orientations, and contextual influences on curricular implementation. The first category, which is conceptual knowledge, is aligned to my study. The operational definition of conceptual knowledge according to their study included the "facts, concepts, principles, and procedures" that are commonly taught in secondary schools and are vital for PCK.

Several studies which compared novice teachers and experienced teachers were cited by Gess-Newsome & Lederman (1999b) which gave insight into my study since one of the teachers in my sample is a novice to the topic of chemical change in the science classroom context. Teacher subject matter knowledge and the influence it has on their classroom practice is central to the discussion that follows. Clermont, Borko & Krajick, (1994, in Gess-Newsome & Lederman, 1999b) concluded that novice teachers' knowledge was inadequate and inaccurate in their instruction of chemistry, while experienced chemistry teachers were accurate in their explanations concerning suitable demonstrations, and were more confident in their chemistry knowledge applied to respective demonstrations. They concluded that experienced teachers held a "more developed repertoire of content representations".

Lantz & Kass (1987, in Gess-Newsome & Lederman, 1999b) suggest the following about secondary chemistry teachers they surveyed who were not chemistry majors: they "relied heavily on textbooks than chemistry majors of similar teaching experience". They maintained that as teachers became more confident with their content knowledge and teaching experience, they depended less on "officially approved materials".

Another study (Hashweh, 1987, in Gess-Newsome & Lederman, 1999b) examining the differences in instructional practice between teachers who taught in and outside of their area of qualification made the following observations: teachers within their area of certification had detailed knowledge, extensive knowledge of related concepts, and methods of linking the "target concept to other concepts". In contrast, teachers outside their area of expertise displayed more conceptual inaccuracies and made fewer links to related topics. In essence, their curricular saliency knowledge was weak in comparison.

To sum up, Gess-Newsome & Lederman (1999b), compared the differences between teachers with strong conceptual knowledge and extensive experience with those of poor conceptual knowledge and little experience in the following manner:

Experienced teachers with strong conceptual knowledge	**Inexperienced teachers with poor conceptual knowledge**
More detailed knowledge of topic.	Less detailed knowledge of topic
More connections & relationships to other topics.	Fewer links & relationships to other topics.
Lesson plan begins with knowledge of learners.	Knowledge of learners not a priority. Less likely to use learner understanding as scaffold.
Draws upon previous activities & content representation that worked & modified these along the way.	Activities suggested by the text were used.
Textbooks & official materials are used infrequently.	Textbooks & official materials are used frequently.
Well organised activities & lectures – synthesis of information emphasised.	Activities & content are limited to textbook suggestions and were covered in sequential, isolated fashion.
High level questioning results, moving beyond text & allowing learners to explore topics.	Rely on recall questions & control learner exploration within limits of teacher knowledge and textbook.
Detect learner misconceptions & use them to enhance content understanding.	Unsure of how to deal with learner comments & incorporate it into lesson.

Table 2.1: Differences between experienced and inexperienced teachers

van Driel, De Jong & Verloop (2002) focused on the design of science teacher courses in The Netherlands. More specifically, factors that directly influence the development of PCK were explored using a sample of twelve pre-service chemistry teachers during the first semester of their one-year post-graduate teacher education programme at two universities. Their research also reported the principal factor which contributed to the growth of PCK was the classroom teacher experiences, which allowed the pre-service teachers the opportunity to appreciate student's specific misconceptions and learning difficulties. This was followed by the university-based workshop session that made teachers more aware specific teaching strategies and developed their subject matter knowledge. Finally, about 50 % of teachers identified the meetings with their mentors as key to the development of their PCK. Beside the 3 factors mentioned above, the study also indicates that the subject matter knowledge of teachers is an important platform for the development of PCK.

For most proponents of PCK, including Cochran et al. (1993); van Driel et al. (2002) & van Driel et al. (1998), teacher experience is considered to be the main factor regarding the acquisition of PCK, thus craft knowledge. However, Geddis et al. (1993), contend that if novice teachers acquire PCK, perhaps through prior research into various science topics of instruction, it may aid them in moving past the anxiety of instructional competence to effective, productive transformations of subject matter knowledge. In this instance, the access to documented PCK is invaluable to novice teachers in particular, but also non-specialist chemistry teachers, who may be required to teach science in secondary schools, due to teacher shortages.

Much of the prior discussion has been concerned with the characteristics of PCK and many attempts have been made by researchers to frame teacher knowledge in the light of Shulman's initial ideas (1986, 1987). However, few have been able to adequately document and capture practitioner's knowledge and teachers rarely draw from a shared knowledge base to improve their practice (Hiebert, Gallimore & Stigler, 2002). Brodkey, cited in Shulman (1987), suggests the following:

> There is a good deal of transient experiential learning among teachers, characterized by the "aha" of a moment that is never consolidated and made part of a new understanding or reconstituted repertoire.

In addition, Bucat (2004) asserts that the chemical education enterprise is desperately seeking research that probes and documents topic-specific PCK of respected teachers. From the latter discussion, it follows that PCK for domain-specific content will indeed be a resource that all science teachers could draw from, and the appropriate tools for which to document this resource are demonstrated and utilized by Loughran et al. (2004).

2.2.2 Capturing and documenting PCK - PaP-eRs and CoRes

Loughran et al. (2004) were motivated by the idea that a teacher's professional knowledge is rather difficult to communicate and is mostly tacit. Furthermore, unlike van Driel et al. (2002), Loughran et al. (2002) used in-service teachers that were relatively experienced in their specific PCK to inform their study and an attempt to document their science content representations and instructional strategies were explored.

With the use of individual interviews, observation of classroom lessons and reflections on these lessons, the authors examined ways of articulating professional practice, however, these methods were not conclusive and the tools of Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eRs) were employed to uncover and portray science teachers' PCK. The CoRe serves to "codify teacher's knowledge in common ways" and thus identify relevant features of the content (referred to as 'Big ideas'), whereas the PaP-eRs (developed by researchers and teachers together) involves the actual practice and pedagogy of the teacher with the particular CoRe to navigate through the lessons planned.

Loughran et al. (2004) found that the use of a CoRe was invaluable in extracting content knowledge from experienced teachers. The CoRe was a tool that incorporated all the main ideas in the specific domain of the Particle model and identified misconceptions that learners would have concerning terminology and theoretical views about matter. In addition, the CoRe (essentially their PCK) was developed, refined and validated by a significant body of science teachers unlike the experiences of individual pre-service teachers that was recorded in van Driel et al. (2002). The CoRe had a direct bearing on PaP-eRs which were constructed with the classroom teaching situation and student

responses, together with the teacher's thought about each 'big idea' in mind. The researchers also discovered that the use of different CoRes for a particular domain enhanced the understanding of learners and teacher PCK. PCK cannot be confined to one conceptualization; instead it is integrated between teaching, content and learning.

PaP-eRs and CoRes certainly provide an effective frame for the development of PCK. However, one may be tempted to follow expert pedagogue PCK religiously (almost like a recipe) and neglect one's unique interpretation of the content which may bring to light fresh ideas and methods of practice. Therefore, these tools should not be used in isolation, rather other factors that contribute to effective PCK, as mentioned in van Driel et al. (2002), can also be exploited.

2.3. Chemical change

2.3.1 Learning about chemical change

It is widely accepted that chemistry teaching occurs at the macro level and the symbolic level; however, many student misconceptions arise from the inability of students to make the mental shift from macro (laboratory level) to the micro (molecular) level. Many teachers often expect students to relate interpretations on the microscopic level (Gabel, 1999) and are unaware of the difficulty they experience in this regard. Tsaparlis (2003) suggests that a more in-depth understanding of chemical change can only occur once the concept of molecules and atoms has been introduced.

A study conducted by Tsaparlis (2003) examined whether 197 tenth-grade students and 77 first-year university chemistry students were able to make a distinct connection between chemical reactions and chemical change. Chemical change or chemical phenomena were defined as processes in which one or more new substances are produced (Gensler, 1970, cited in Tsaparlis, 2003). He included examples of burning; rusting of iron; action of an acid on a material.

Using 19 physical and chemical phenomena, students were asked to distinguish between the two and provide cases where one or more chemical reactions occur. A number of students (both university and high school) intuitively view chemical change as processes that are fairly simple, thus may be symbolically expressed by means of

chemical equations. Some also believed that chemical reactions are elementary processes expressed by means of chemical equations. Still many students failed to identify chemical phenomena with reactions due to supposed differentiation of chemical change into natural and man-caused processes.

Chiu (2005) was instrumental in conducting a six-year nationwide survey in Taiwan that essentially examined student conceptions of their understanding of chemical concepts. The student categories varied between elementary, junior, and senior phase candidates. Their results were of a similar nature to those experienced in the Western world. In addition to exploring the issue of conceptions, the researchers probed into the source of these misconceptions in an attempt to address the cause in a methodical manner.

Pertinent to this study, their findings indicated that oxidation and reduction was a difficult concept for students to assimilate. They believed that mass was not conserved during the rusting process (iron had lost mass because they believed it rusted). Senior students (40%) perceived reduction as a process where a material is reduced from a compound to the elemental state.

Possible causes of these misconceptions that the team suggested after their research included poor language skills due to the difficult chemistry language students had to contend with. Furthermore, poor background knowledge of chemistry seemed to compound the problem and contribute to their poor conceptions. Finally, students had varied backgrounds and thus varied understanding of scientific concepts.

The understanding of chemical change takes into account that the concept of "chemical reaction" is a prerequisite item of knowledge for chemical change. Tsaparlis (2003) argues that this concept must be understood at the macroscopic, experimental level and essentially forms a basis for chemistry, more specifically, chemical change. Kind (2004) asserts that learners experience difficulty in recognising when chemical reactions take place, in addition, she suggests that the discrimination between chemical change and physical change is problematic for many learners. She defines chemical change as the process whereby atoms or ions in reactants are rearranged to form new substances,

furthermore, changes in physical appearance, production of a gas, light and energy characterise such a chemical event.

Ahtee & Varjola, 1998, (cited in Kind, 2004) explained that 20% of learners between the ages of 13-18 years old represented dissolving and the change of state as chemical reactions, whereas only 14% of university students could successfully explain the mechanism of a chemical reaction. Other studies also report similar confusion which involves the distinction between change of state and chemical change cited in Kind, 2004 (Schollum, 1981 & Briggs & Holding, 1986). Voelker (1975), conducting a study with grade 6 learners suggests that children, prior to the age of 12, do not have the ability to think abstractly, thus the movement between macro and micro levels is impossible. He further comments that their classification regarding physical and chemical change is poorly developed, while their ability to group may be more pronounced at this stage.

Gensler, 1970, (cited in Kind, 2004) disagrees with this generalisation and asserts that the meaning of chemical and physical change is confusing to learners. He maintains that there is conflict between sensory information with what is being taught, therefore, learners cannot be expected to believe that recrystallised sugar, for example, is the same substance that dissolved, hence a chemical change must have occurred. Since scientific concepts are learned most effectively through experimentation, Gensler's (1970) argument regarding sensory evidence and the assimilation thereof becomes credible. Kind (2004) suggests that learners rely heavily on this type of learning, thus the difficulty in distinguishing between physical and chemical change.

As a result of the above discussion, the need to redefine chemical change arises and is outlined by Strong (1970) cited in Kind (2004) as follows:

a) Identity of product determined by identity of materials
b) Mixing of initial materials is essential when more than one reagent is involved
c) Discontinuity between properties of initial materials and final product
d) Invariance of product properties when temperature, pressure and composition are varied.

This definition allows one to associate relevant criteria with the chemical event that has occurred and ensures that the possibility of error is minimised.

Ahtee & Varjola (1998), (cited in Kind, 2004) agree with Tsaparlis (2003) that the difference between chemical and physical change may only become explicit once the learner has been introduced to the microscopic representation of matter, namely, the atom. Tasker & Dalton (2006) support the notion that many learner difficulties and misconceptions are due to inaccurate mental models at the molecular level. They maintain that in the past, most representations of chemical change were restricted to the laboratory level, while teachers assumed that the learner's model of the molecular level would develop naturally. Consequently, they propose the use of animations and simulations that involve visualisation of the molecular level as a means of assisting learners to consolidate sensory evidence, thus linking the laboratory level to the symbolic level.

Hesse and Anderson (1992) concluded that high school students experience difficulty at three levels after having completed a six week unit on chemical change. These levels included: chemical knowledge, conservation reasoning and explanatory ideals which involved an understanding of acceptable explanations regarding chemistry concepts. Only one learner, out of 100, was reported to have demonstrated mastery on all three levels. They maintain that chemical change is more complex than teachers imagine, furthermore, learners' naïve concepts persist even after a significant period of chemistry instruction. They propose that traditional teaching methods will not suffice if learners are to assimilate the concept of chemical change. Rote learning will result in a simple recall of the meanings of physical and chemical change, however, conceptual change techniques must be employed by teachers.

2.3.2 Teaching chemical change

2.3.2.1 Instructional barriers

Much of the discussion above has depicted the concept of chemical change as one which is abstract and obscure. The nature of the content requires learners to think on the atomic or molecular level, as maintained by many of the researchers above. Gabel (1999) supports this notion and suggests that molecular models are necessary in

understanding the differences between chemical and physical change, as is the case when making the distinction between elements and compounds. She identifies barriers to learning chemistry and highlights important characteristics that teachers must be aware of in order to make their instruction meaningful and comprehensible.

The first barrier according to Gabel (1999) is that chemistry instruction occurs primarily on the most abstract level, that is, the symbolic level. She affirms that while teachers understand the three levels of chemistry, consisting of macro, sub-micro and symbolic level (Johnstone, 1991, cited in Gabel, 1999), they predominantly focus on the latter feature, as is the case in many textbooks. Just as learners need to associate particles with the models and analogies, models must be associated with symbols, thus the isolated use of the symbolic level is not productive. However, the integration of three levels suggested by Johnstone's (1991) model will serve to improve the conceptual understanding of chemical phenomena.

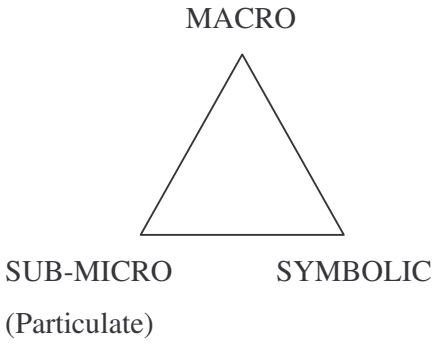


Figure 2.2: Three levels of chemistry (Johnstone, 1991)

The second barrier is the lack of practical work in the laboratory and ineffective linkage to instruction. Gabel (1999) suggests that learners value this approach and it could enhance learning. However, teachers expect observations made on the macroscopic level to be interpreted on the microscopic level. Furthermore, the ability to strategically link practical work to the content of the lesson allows for increased understanding. If practical work is not successfully integrated, then it may lose its impact and may become a barrier rather than a support to conceptual understanding.

An additional barrier is the use of unfamiliar materials that may be prevalent in the chemistry discipline. Gabel (1999) states that the use of unfamiliar chemicals serves to hinder conceptual understanding since learners do not recognise the substance on a

macroscopic level. Teachers and textbook writers ignore this factor; however, learners cannot be expected to imagine the physical properties of chemicals they have never encountered before, much less understand their chemical behaviour on a microscopic scale.

The careless use of language in the chemistry discipline is also problematic. It is common for learners to experience confusion between symbols of ions, atoms and molecules of the same element (Bucat, 2004) and, the language demands on learners compounds the situation. Bucat (2004) agrees with Gabel (1999) that there are many instances where the mismatch between everyday and scientific meanings of words is challenging. For example, the use of weak and dilute, concentrated and strong, melt and dissolve may create unnecessary confusion, even more so for the second language learner. Bucat (2004) suggests that strong PCK will alleviate this problem to a large degree.

Finally, Gabel (1999) alludes to the structure of the chemistry discipline as an additional barrier. The sequence of theoretical concepts discussed is important since learners need to make the right connections at the appropriate time with regard to the level of understanding. While some concepts are necessary throughout the study of chemistry (moles, solutions, molecules, etc), other concepts only serve to complicate matters. The demands of the curriculum may impose on the best route (Gabel, 1999) that fosters learning, thus careful consideration is required in the planning stages.

2.3.2.2 PCK - Transformation of subject matter

Bond – Robinson (2005) poses the argument that effective chemistry teaching is likely to follow if the teacher has the ability to transform subject matter knowledge. This is based on Shulman's (1986) construct of PCK which focuses on the ability of the teacher to successfully transform subject matter knowledge in order to make it comprehensible for learners. She sees value in linking a chemist's ideas of concepts to the macroscopic level of the learners, which constitutes a transforming explanation. She defines transforming explanation in the following manner:

> …as a discipline-specific illustration of how people in that discipline think about a disciplinary process, which is linked by the explanation to students' thinking about the same disciplinary-related process.

Chemists explain their observations in relation to the invisible level of atoms, ions and molecules. She proposes that the chemical explanation of chemists must be transformed to the level of the learner, using a mental model.

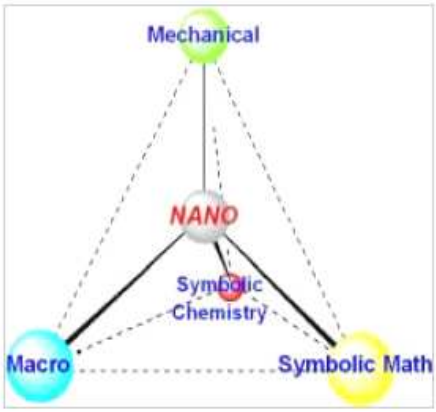


Figure 2.3: Five modes of representational reasoning in chemical work (Bond-Robinson, 2005)

The tetrahedral model is an adaptation of Johnstone's (1991, cited in Bond-Robinson, 2005) model and illustrates the reasoning of chemists in order to improve conceptual understanding in learners. The five modes of representational reasoning include mechanical, macroscopic, symbolic math, nanoscopic and symbolic chemistry levels. Using this model leads to a systematic method of transforming explanations each time a new topic is taught, furthermore, it may be implemented by novice teachers as well. However, she intimates that this model must be frequently used in order for learners to acquire the pattern and the habit.

2.3.2.3 A constructivist approach

According to Bond – Robinson (2005), learners' experiences predominantly exist on the macroscopic level, thus effective transforming explanations must repeatedly return to the macro level of the chemical process concerned. In other words, teachers must start from what learners already know and investigate ways to connect them to new chemical

processes required. This approach is congruent with the constructivist theories of learning. Hewson & Hewson (1984) also verifies the notion that learners' existing knowledge influences the acquisition of their scientific knowledge through the concept of density in floating and sinking. Her approach is essentially one of constructivism, where she makes a direct comparison between explicit and implicit techniques of teaching and addresses the misconceptions inherent in the section of density. Finally, the nail rusting experiment in Scott, Asoko, Driver & Emberton (1994) confirmed that learners were able to accurately apply their knowledge on chemical changes six weeks later. The fact that learners were actively engaged in linking new ideas to old ones, on a personal and social capacity, made the learning process more meaningful. Therefore, frequent modelling of constructivist teaching practices are necessary in order to promote transforming explanations.

All three research studies portrayed constructivist theories in a positive light. Studies mentioned earlier in the chapter (Shulman, 1986 and Geddis & Wood, 1997) also recognise the credibility of prior learning and suggest that teachers must include this in their repertoire of knowledge. Therefore, a constructivist approach is effective for establishing a solid foundation of learning.

2.4 Conclusions

The literature has elucidated pedagogical content knowledge as a construct that is central to teaching. It suggested an amalgamation between the general pedagogic practice of a teacher and the subject matter knowledge for teaching. Much attention was given to the transformation of subject matter knowledge, which includes knowledge of the context, the learners' background knowledge, and curricular saliency as vital components of PCK. Furthermore, since teacher practice is inherently tacit in nature, the notion of capturing and documenting PCK was useful for both experienced teachers and especially novice teachers.

The topic of chemical change was initially perceived by me to be a simple concept; however, research has shown that learners struggle with the macro and micro interrelationships. In addition, knowledge of atoms and molecules were requisite in order to effectively teach this unit of work. Therefore, a migration from the macroscopic

world (laboratory level) using constructivist approaches is necessary for assimilation to occur, as suggested by the research.

2.5 Directions from the literature review

The literature helped to give the study direction and more defined boundaries. The Geddis et al. (1993) and Geddis & Wood (1997) framework served to focus my attention on how the transformation of subject matter knowledge within a specific topic of instruction may manifest itself. Five types of teacher knowledge are elaborated, and each category may be used to give an account of how the teacher uses their subject matter knowledge in the transformation process. Therefore, this framework assisted me to track the process of transformation and allowed me to examine teacher practice in a structured manner. Table 2.2 below illustrates crucial indicators of PCK, as delineated by Geddis et al. (1993) and Geddis & Wood (1997), furthermore, it includes features that I have considered as essential for strong PCK. The five types of knowledge and their respective indicators will be used to analyse the PCK of the respondents in chapter 5.

Types of teacher knowledge	Learner's prior concepts	Subject matter representations	Instructional strategies	Curriculum materials	Curricular saliency
Indicators	▪ Recalling & linking previously taught concepts ▪ Showing awareness of learner misconceptions	▪ Key terminology describing topic ▪ Chemical symbols, formulae ▪ Examples & illustrations ▪ Physical models	▪ Contextualising the subject matter ▪ Practical investigation ▪ Lecture method ▪ Addressing learner misconception	▪ Resources that enhance or impede understanding of subject matter ▪ Materials that complement instructional strategy	▪ Knowledge of the curriculum and links to other sections. ▪ Salient aspects of the topic for teaching ▪ Excluding areas of ambiguity or confusion

Table 2.2: Indicators of PCK within different types of teacher knowledge

The use of CoRes and PaP-eRs to capture and document PCK was invaluable to me. This tool assisted me to grasp the thoughts of respective teachers within the topic and permitted me to portray their everyday classroom practice. Furthermore, the tool

informed the nature of teacher subject matter knowledge and ultimately aided the response to the research questions.

The practice of other teachers, both novice and experienced, are highlighted in the literature. The characteristics of their strengths and weaknesses indicated various similarities in my study, which helped to bring life to this study.

The macro and micro theme emerges strongly from the literature. This allowed me to look through the lens of the microscopic world and focus on how the teachers introduced the concept and fostered learner understanding while teaching chemical change. Finally, the literature also enabled me to analyse the learner response to the diagnostic test. Common trends were identified and as a result, corresponding conclusions were drawn.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

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3.1 Introduction

The previous chapter focused on the review of relevant literature with respect to PCK and chemical change.

This chapter outlines the research design and the methods that were employed during the study. The research sample is examined and, thereafter, the learning institution and access to both the former and latter is discussed.
I describe the instruments used to collect data and critically comment on the effective use of such instruments which concludes the chapter.

3.2 Research design

The proposed study was informed mainly by a qualitative case study using semi-structured interviews and observation. According to Opie (2004), a case study may be viewed as an "in-depth study of interactions in a single instance in an enclosed system". Hitchcock and Hughes (1989, cited in Opie, 2004) further state that case studies involve a tight focus on a particular instance with the intention of uncovering ways in which events converge to create certain outcomes. Cohen, Manion & Morrison (2000) suggest that case studies provide an idiosyncratic example of "real people in real situations" and thus serves to enable readers to understand ideas more clearly especially when presenting them with abstract principles. Therefore, I considered this design due the contextual reality it will bring to the study. Although it is generally regarded by many researchers as difficult to organize and analyze, it is based upon a real happening and is strongly related to my own experiences as a teacher.

My research questions relate to the nature of the teachers' pedagogical content knowledge, distinct features that influence how they navigate through the content and deliver the lesson in a unique manner. Therefore the choice of a case study design is significant for my study since it allows me to focus sharply on a number of interactions between the teacher, the learner and the subject matter, thus constructing a mental picture of how the teachers transform their subject matter knowledge.

To gather data for a case study, the best methods are observations and interviews. Cohen et al. (2000) claim that observation studies are preferred when collecting data on non-verbal behaviour and investigators are able to make key notes concerning the behaviour as it unfolds. Furthermore, case study observations serve to allow the investigator to develop an ongoing informal relationship with the respondents due to the extended period of time within which it occurs.

The use of a case study approach was suitable since it was my goal to investigate the manner in which two teachers package the same subject matter knowledge and communicate it to their learners.

Often case studies have been criticized for their inability to allow one to generalize from findings that emerge. While they are extremely informative and rich in content, this weakness will always be inherent in such a research design. However, Wellington (2000) suggests that people reading case studies can often relate to them, even though they cannot always generalize from them.

3.3 Instruments

3.3.1 Semi-structured interview

Opie (2004) agrees that interviews are flexible and provide opportunities to probe and expand the interviewee's response. As stated above, the tacit nature of a teacher's knowledge requires this type of approach in order to gain a more accurate indication of the construct of PCK. Furthermore, due to the fact that I was well known to both respondents, a semi-structured interview would contribute to an informal, comfortable environment, a non-threatening surrounding that is suitable (Fraenkel & Wallen, 1990).

However, the danger of conducting a semi-structured interview with respondents who are familiar with me may result in a casual response from them, which may contain little substance. Thus a tight focus must be continually maintained and questions must be carefully positioned so as to elicit suitable responses. Another weakness of a semi-structured interview is the possibility of researcher bias, however, this must be recognized and controlled (Cohen et al., 2000 & Opie, 2004). Conclusions drawn from the questions may not be synonymous with what the respondent states or implies. In

order to overcome this problem, the entire interview was audio-taped and then transcribed (appendix 11). Hitchcock and Hughes (1989) comments that tape recording the interview session enables one to produce the most complete record of what was said, thus accuracy is not comprised in any way. In addition to the pre-interview, a post interview which involves the joint discussion of the lesson will follow.

Finally, Cohen et al. (2000) comment that interviews allow for a greater depth through probing. When one considers that tacit nature of PCK mentioned earlier, it follows that personal feelings, attitudes, conviction of responses, facial expressions, and the like can only be captured in a face-to-face encounter.

3.3.2. Lesson Observation

3.3.2.1 Video-recording

The purpose of the observations was to answer research question 1: **What are the distinct features of the PCK of an 'experienced' physical science teacher and a non-specialist chemistry teacher when teaching chemical change?**

Lesson observation was included in the data collection process due to the nature of the data required to conduct a case study of this kind. It was anticipated that observations would reveal characteristics of the subjects, and the teaching and learning process that would have been impossible to discover by other means. Cohen and Manion (1994) maintain that observation allows one to probe deeply and analyse intensively the diverse phenomena that constitute the lifestyle of an individual unit. Opie (2004) supports this and agrees that observational research provides information about the environment as well as human behaviour.

There are two principal different types of observation, namely: participant observation and non-participant observation. In the former, observers engage in the activities they are observing and in the latter, observers distance themselves from group activities and teacher-learner interaction (Cohen & Manion, 1994). I maintained a non-participant observer status because it allows the researcher to be an objective observer and maintain the distance between the learner and the group activity. As Bell (1993) comments, it is

easy to adopt the objective observer stance especially if all the members of the group being observed are not acquainted with you.

3.3.2.2 Field notes (appendix 10)

Opie (2004) states that field notes may include records of conversations, discussions, interviews, as well as observed behaviour of the respondent. I was able to take notes while the video recording of the lesson continued. Adding notes while observing the lesson is extremely valuable because one is able to record the non-verbal communication of the teacher and the atmosphere of the learning environment. The interviewer cannot give sufficient attention to what is being said if he or she is too busy trying to write every detail according to Hitchcock and Hughes (1989). Cohen and Manion (1994), who support Hitchcock and Hughes (1989), state that until one records observations and impressions from one classroom visit, there is no point in returning to the classroom.

3.3.3 Diagnostic test (appendix 6)

A diagnostic test is a useful instrument that may be used to determine the extent to which both the teacher and the learner understand the subject matter. The diagnostic test was a post-test that was given to both teachers and their learners two weeks after instruction on the topic was concluded. Thereafter, the next module of chemical change was covered by both teachers, a unit which does not relate to this study. Therefore, it could not be used to track an increase in understanding, but only to document the status of conceptual understanding at that point in time. With respect to the teacher, their responses to the content knowledge being assessed not only indicates, but centrally affects their pedagogical content knowledge. The test was completed at the teacher's leisure; thus, additional research could have been used to answer the test. Therefore, teacher responses may have not been a true reflection of their content knowledge at present.

The learners were given a diagnostic test that was mainly employed to gauge their understanding of the concept of chemical change and ultimately indicate whether the differences in PCK could be traced to learner performance. In addition to assessing their

understanding, misconceptions inherent in the learner's understanding begin to surface. This factor may indicate whether the teacher addressed misconceptions adequately during the instruction period.

Learner responses to the test can also serve to mislead the researcher. Learners may present an inaccurate account of their knowledge due to many external factors, namely: delayed time period between the instruction and the test being administered, inadequate preparation for the test, assurance that the test would not impact their internal school based summative assessment. However, a time delay may ensure that learners only write what they truly recall and understand. Further comment on this factor will be discussed under limitations of the study in Chapter 7.

3.4 Validity and Reliability

According to Opie (2004) reliability refers to the quality of "goodness" of the research. Wellington (2000) provides a more concise definition: "The extent to which a test or technique functions consistently and accurately by yielding the same results at different times or when used by different researchers". The instruments used in my study may not provide similar results due to the nature of social educational research. Some conditions in the classroom may be beyond the researcher's control therefore Opie (2004) makes reference to the data-gathering process and refers to the reliability of the process instead. He further states that one should judge the process and not the product.

In order to ensure that the data-gathering process was reliable during observation, I took field notes during the lesson observation and then further supplemented and refined the notes with the reviewing of the video-recorded lesson. The use of a researcher aid enabled me to write more accurate notes which would have been difficult to do if my attention was diverted.

During the semi-structured interview, I made brief notes (using appendix 9) and audio-taped the discussion. This ensured that the discussion was transcribed verbatim. The process of transcription and noting the non-verbal behaviour of the teacher added to the richness of the context and the reliability of the instrument.

The diagnostic test was piloted before administering it. Furthermore, test items had been previously used by Taber (2002), thus the possibility of any ambiguity was reduced. As a result, the manner in which learners interpreted the test questions is expected to be consistent under the same conditions. However, the test was piloted with teachers and not learners. Learner perceptions may have attracted a different response as compared to teachers of Science.

Validity is essential in educational research since it draws a relationship between the instrument or method used and the claim that is made (Opie, 2004). Wellington (2000) suggests that it refers to the degree to which a research tool measures what it sets out to measure. Again, I agree with Opie's (2004) account where he describes the concept of validity as the accuracy of the relationship between the data-gathering process and the claim which the researcher is making.

The semi-structured interview schedule was adapted from the CoRe prompts used by Loughran et al. (2004). In his study, he used the prompts to investigate the salient features of a topic for instruction that was gleaned from a number of experienced in-service teachers. While the prompts in the Loughran et al. (2004) study were used for a different purpose, it was suitable for structuring questions in my semi-structured interview and assisted me to gain some insight into the respondents' practice. Furthermore, I mentioned earlier that only experienced in-service teachers were used in the Loughran study. In my study, one respondent had relevant experience as a Science teacher while the other was a Biology specialist. Therefore, some of the questions that were posed to the Biology specialist did not attract a complete, informed response due to the lack of his experience in teaching chemical change and inadequate content knowledge. Wellington (2000) comments that no instrument can be said to be totally valid.

The diagnostic test was extracted from questions used in Taber (2002). He deals with common learner misconceptions in Chemical reactions. The test was designed to determine the level of understanding or misconceptions that learners had after being taught the concept of chemical change. However, the delayed time between the instruction period and administering of the test could have a negative impact on learner performance due to a change in their perception of physical and chemical change.

3.5 Data collection

3.5.1 Access to the learning institution

Bell (1993) states that researchers cannot demand access to an institution and the respondents who agree to participate are in fact doing them a favour. She further comments that the respondents must be informed of the expectations regarding their time commitment, number of tasks required, and the use of resulting information that will be extracted from the study. All of the above were given due consideration.

I had to consult the Gauteng Department of Education (GDE), which is the governing body for state schools, to request permission before the study began. This process involved stating the purpose of the research and the value it would bring to the education community of practice. In addition, the request form also detailed the conditions under which one may conduct research, and requested information such as: time constraints, learner and teacher commitment, and research methods and processes to be employed.

Thereafter, the principal of the learning institution was approached for his approval. A letter detailing the aim of the study and ethical considerations was given to him (see appendix 4). This particular institution was chosen because I had worked for approximately four years in this school, prior to the study, and had a good rapport with both the management and the teaching staff. Wellington (2000) states that the need to establish rapport is vital, furthermore, it is dependent on the ease of interaction between the parties involved. Thus, the complete support of the principal made the task much simpler to negotiate.

3.5.2 Access to teachers and learners

Once permission from the learning institution was confirmed, both respondents were approached. An informal discussion ensued where I described the aims, objectives and methods of the study and the extent of their participation that would be required. Their permission was requested and their anonymity guaranteed in the form of a consent letter (see appendix 3). The participation of the subjects was easily negotiated due to the existent rapport and previous interactions between the respondents and me. Hitchcock

and Hughes (1989) support the view that rapport between researchers and subjects foster feelings of trust and confidence.

The learners were not acquainted with me, thus the issue of gaining learner consent and canvassing their support was not as easy as the above-mentioned participants. However, I requested part of a lesson from each teacher in order to inform learners of the objectives of my study and explain its significance in the educational arena, particularly Science. I assured them of their anonymity being maintained at all times and that pseudonyms would be used if necessary. They were also given the choice to exclude themselves from the research, if so desired. Letters of consent was given to parents and requests their permission due to the minor status of their children in Grade 10 (see appendix 2). Learners' also received letters of consent to ensure that their participation in the study was forthcoming (see appendix 1).

3.5.3 The interview schedule

The interview schedule consisted of Section A (biographical data) and Section B (the Content of Representation – CoRe). This is detailed in appendix 8.

Section B of the interview was adapted from the CoRe prompts used by Loughran et al. (2004). This schedule served as a prompt that allowed me to gain understanding of the teacher content knowledge regarding the concept of chemical change; in addition, it described essential features of pedagogical content knowledge.

A copy of the interview schedule was made available to both respondents prior to the interview. This was necessary in order to allow for the respondents to acquaint themselves with the type and depth of response the questions would require.

3.5.4 The Interview

The interview was held in the respondent's classroom, during their non-teaching period, as this was easily available and undue interruptions were limited. I decided to begin the interview with questions that would require simple, straightforward answers (Section A of appendix 8) in order to allow the respondents to become comfortable with the

process and method of capturing the data. The entire interview was audio-taped and scant notes were made using appendix 9 that correlated with Section B of appendix 8. Both interviews were approximately 30 minutes each, after which, the respondents resumed their teaching responsibilities.

During the interview with the second respondent, roof contractors were busy working on the classroom and this hindered the process of capturing the data as was the case in the first interview. As a result, the transcription of the recorded material was difficult to decipher. In order to fill in the missing information, I relied on my hand-written notes that I had taken whilst recording the interview; however, these were partial summaries of the information. Therefore, the time period between the interview and the transcription was kept to a minimum in order to allow for the most accurate account to be recalled and recorded.

3.5.5 Observation of lessons

I observed six chemistry lessons, three taught by each teacher. Each lesson was approximately 35 minutes in duration and occurred on consecutive days according to the school timetable.

During the observations I was a non-participant observer. During each lesson, I preferred to sit at the back of the laboratory in order to prevent any unnecessary distractions and to allow learners the opportunity to be fully engaged with the teacher's presentation. I was assisted in video recording the lesson by a researcher aid who was former student of mine. Because he was a novice at this task, we had decided to position the tripod in a fixed place so that the teacher would not be distracted by any movement. Furthermore, the aid's assistance allowed me the advantage of making more comprehensive field notes.

In order to cater for my lack of experience in note-taking, the lesson was replayed and the notes were refined. Therefore, the video-taping of lessons not only aided me to reflect upon the field notes, but also ensured that no event went unnoticed.

Acquiring a video camera which was easy to use was troublesome. The researcher aid brought his own apparatus along. This was beneficial since he was well acquainted with how to manipulate the recording device. After the lessons were recorded, the data was transferred onto a digital video disk (DVD).

3.5.6 Joint discussion of the lesson (post interview)

After each teacher had taught their first lesson, I allocated a non-teaching period to discuss the strategies and methods that they employed in the lesson during a post interview. This occurred on the same day. This discussion was audio recorded and only specific portions of the lesson that prompted a response from the teacher or me were discussed. At this point, the tape was paused and a question or explanation followed.

3.5.7 Diagnostic test

The diagnostic test was developed using Taber (2002) worksheets. These worksheets dealt mainly with misconceptions about chemical reactions and chemical change. Four questions were included (appendix 6). Question 1 tested whether the learners understood the meaning of chemical change and Physical change. Question 2 and 3 assessed Physical change and chemical change respectively; while question 4 was left open to interpretation, that is, it could be classified as both a Chemical or Physical change, depending on the learner's motivation for the corresponding response.

No marks were reflected on the diagnostic assessment so that learners did not write under test conditions; in addition, they were informed that the result of the task would not impact their normal school based assessment whatsoever. Answers would be written on the question paper in order to limit detailed responses given, and to make the analysis process simpler.

3.5.8 Piloting the test

The diagnostic test was piloted using two experienced Science teachers, not involved in the study. The purpose was twofold: to suggest ways in which one could reframe the questions to eliminate any ambiguity or confusion (Wellington, 2000), and to determine

whether the time allocation was sufficient. These instructions were made clear to the teachers through an informal discussion and a letter attached to the diagnostic test (see appendix 5), however, the responses expected were not forthcoming. Both teachers answered the test completely but made no suggestions on how it could be improved. Through informal talk, they both stated that the questions were relevant and engaging and that they needed to refresh their knowledge of chemical change before answering some questions. Furthermore, they commented that the time allocation given to them was sufficient. The confirmation of correct timing allowed me to gauge what length of time learners would need in order to complete the test.

I expected a more informative critique of the test and the content. A possible reason for the lack of comment could be attributed to the source of the test. Since it was extracted from the Taber worksheets, one could deduce that these examples were piloted and used many times before the author published it. Consequently, no changes were made to the initial test other than the removal of the marks reflected for each question.

3.5.9 Administering the diagnostic test

The test was given to both respondents and answered by their learners, in my absence, during a science lesson in the classroom. No discussion or group response was permitted between learners in order to ensure that individual accounts of the learner knowledge and understanding were reflected. Approximately 25 minutes was allocated for the completion of the test, after which the respective teacher collected their learners' responses and returned these to me. Both teachers also answered the diagnostic test in my absence. Once they had finished their tests, these were collected together with the learner responses.

3.6 Triangulation on data collection

Hitchcock and Hughes (1989) define triangulation as the use of more than one method of data collection within a single study. They imply that this process increases the validity of the data and consequently makes the analysis of the data more reflective of the actual study. Cohen and Manion (1994) agree with Hitchcock and Hughes (1989),

furthermore, they state that triangulation eliminates the danger of the researcher having a distorted view of a particular event being investigated.

Methodological triangulation which involves using different methods on the same object of study (Cohen and Manion, 1994) was employed. I used lesson observation and interviews to collect data that would assist in assessing the teacher's PCK.

Beside the researcher bias that may result from using a single method to collect data, it is common practice for a teacher to propose particular teaching strategies in the interview and deviate from these during the delivery of the lesson. Therefore, the process of triangulation is necessary to ensure and cement the researcher's confidence in the data collected.

3.7 Research sample

The sample that I had chosen comprised of two teachers in a high school. Both teachers were qualified, one as physical science teacher (Mr Johnson) and the other as a biology teacher (Mr Moodley). Both names are pseudonyms. The physical science teacher had many years of experience and taught at university level as well, whereas the biology teacher had been involved only in schools teaching biology, until now. There were two grade 10 science classes and the school had requested that the biology teacher teach science instead of employing another teacher for just one additional class.

Doherty, Goodwin & Benson (2000) argue that there is an increasing proportion of secondary science teaching by colleagues who are formally qualified in biological sciences. They attribute this occurrence to the increasing shortfall of teachers with a background of physical sciences, apparent in many other countries, beside South Africa. They also state that many such biologist-science teachers teach chemistry and physics really well, thus science qualified teachers may not be the only educators that demonstrate good PCK. However, the reverse may also be true. Therefore, the presence of two teachers, both with different qualifications, teaching the same content in the same school, offers an opportunity to study the differences in their pedagogic practice and thus a richer context of PCK is to be expected.

3.8 Context of study

The South African education department has recently adopted a new approach to the curriculum entitled the National Curriculum Statement (NCS) for the Physical Sciences Grade 10 which serves as an introductory course in Physics and Chemistry. The NCS is based on extending learner's prior knowledge, in addition, the content and contexts are a means of achieving learning outcomes. This outcome strives to make science education more relevant in terms of understanding its impact on the environment and thereby assists in solving practical problems.

The section of chemical change is primarily concerned with representing chemical change through writing chemical reactions and equations. Macroscopic changes in everyday contexts are considered and explained through the understanding of atoms and molecules, which is regarded by the NCS as the fundamental skill for understanding chemistry (Department of education, 2003).

3.9 Institution

The learning institution was a previously advantaged school that is located in the North of Johannesburg. The school had an enrolment of approximately 750 learners between Grade 8 and Grade 12. Class sizes, on average, consisted of 25 learners in both the junior and senior grades. Furthermore, classes in grade 10 were not ability grouped, thus they had learners with different competency levels in each class. Regarding the demographics of this school, the institution was a former White school, however, the number of non-white learners rapidly increased. At the time of this study, there was a minority of White learners. Majority of the Black learners attending the instituting were residing in nearby informal settlements and it is reasonable to assume that they belonged to the working class sector.

3.10 Ethical Considerations

Ethical concerns encountered in educational research can be extremely intricate and may place the researcher in moral dilemmas according to Cohen and Manion (1994). They further state that it is difficult to strike a balance between the researcher’s pursuit

for truth and their subject's rights. However, informed consent is necessary if the researcher wishes to obtain the assistance of the subject and the organisation concerned.

Two teachers together with their corresponding classes who consist of grade 10 learners were included in the study. A letter was written to each learner, as well as each teacher, regarding information about the aims of the research study in such a manner that it is unambiguous and simple to comprehend. The letter advised learners that their participation would be completely voluntary, furthermore, the lack of participation would not result in any of them being penalised in any way. In addition, learners were advised that if they accept the invitation to participate, any verbal or written communication would be treated in a strictly confidential manner and if any information is to be used, it would be anonymously reported so as to protect their identity. Furthermore, learners were informed that information gathered from them would only be used for research purposes and invariably improve the quality of education that other learners receive. A letter of consent accompanied the above-mentioned letter (appendix 1), in which the learners were requested to add their signature.

The Gauteng Department of Education (GDE) and the school principal also received a letter that detailed the aims of the study and requested permission for me to conduct an investigation during lessons with the assurance that the learning process would not be hindered and that the identity of the institution would remain anonymous. A formal application was made to the GDE in addition to the above letter to the principal of the learning institution (appendix 4).

Due to the age-group of the learners and their minor status, the parents also received a letter (appendix 2) to inform them of the aims of the study and requested their permission to use their children in the study.

Application to the Human Research Ethics Committee of the University of the Witwatersrand had to be completed as well. This involved a number of documents for submission, namely: the research proposal, interview schedule, letters of consent to the all concerned, and permission from the educational authority.

3.11 Critique of data collection methods

The decision to video-record the lessons were to provide me with a means of reviewing essential material and so enhance the quality of the field notes taken. However, due to the nature of such observational techniques, and the presence of two investigators (researcher and researcher aid) in the classroom, the teacher may, consciously or unconsciously, change their behaviour when being observed according to Opie (2004). This phenomenon is rather difficult to control and may only be minimized, possibly through regular interaction with the research subjects and the ability to maintain a non-judgmental role.

Wellington (2000) states that interviews are vital because they allow the researcher to investigate and prompt things that cannot be observed. However, the skills of an experienced interviewer are polished and effective in eliciting valuable and sometimes implied information. I did not possess this degree of skill. This study was conducted after the completion of a research methods course held at the University of the Witwatersrand, in which I interviewed a colleague before embarking on the study. Expert skills cannot be mastered in one interview session.

Piloting of the diagnostic test was carried out with two Science teachers. While I intended the sample to answer the test, learners were also requested to complete the assessment as a means of establishing their understanding of the concept of chemical change and thus gauge whether their teacher's subject matter representations (PCK) were effective or not. The test should have been made available to both teachers and learners not involved in this study, for piloting to obtain a true interpretation of the level of difficulty associated with it.

An advantage regarding the diagnostic assessment was the time frame that elapsed between the instruction on chemical change and the administering of the test. Due to the nature of school terms and the holidays in between, I was only able to administer the test after three weeks. This delay could have ensured a more accurate account of the learner understanding of the subject matter. The learner would have only recalled what was properly assimilated and reflected their responses accordingly.

The following chapter discusses the tools, namely the CoRe and PaP-eR that were used to capture and document each teacher's PCK. In addition, the construction of the tools ensues as well as a detailed account of each teacher's CoRe and PaP-eR.

CHAPTER 4

CAPTURING AND DOCUMENTING PEDAGOGICAL CONTENT KNOWLEDGE

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4.1 Introduction

This chapter presents a portrayal of Pedagogical Content Knowledge (PCK) for the topic chemical change for the two teachers. The approach used below is based on what Loughran et al. (2004) have termed a CoRe (Content Representation) and PaP-eR (Pedagogical and Professional-experience Repertoire). As mentioned in chapter 3, the CoRe codifies the teacher's knowledge about the content. Loughran, Mulhall & Berry (2006) maintain that it outlines aspects of PCK that are most attached to the content, however, they suggest that while it is necessary, it is not the only representation. With respect to the PaP-eR, they comment that it allows the reader to examine the teaching/learning situation in which the content moulds the pedagogy. Therefore, the PaP-eR is necessary to give readers an idea of the actual teaching practice of the specialist's knowledge, skills, and ability; in addition, it makes the teacher's tacit knowledge more explicit.

4.2 Construction of the CoRe

The CoRe represented below focuses on one 'big idea' that was extracted from the teacher interviews, video recorded lesson observations, field notes and post-interviews while observing the recording of at least one lesson.

The inclusion of another big idea was explored; however the brief mention and scarce practice of one of the teachers regarding that idea did not provide sufficient information to complete the CoRe. Therefore, evidence of the second big idea was only visible in Mr Johnson's practice. Perhaps, the extension of the second big idea would have manifested in subsequent lessons.

The manner in which I used and constructed the CoRe differs from Loughran et al. (2004). In their study, a number of experienced science teachers were used to explore the main ideas surrounding individual topics. From this interaction, many big ideas were extracted. However, my study focuses on my interaction with two teachers, namely, Mr Johnson who was experienced and Mr Moodley who was a not a chemistry specialist.

The CoRe was formulated using a variety of data sources, thus it did not emerge solely from the pre-interview. The pre-interview was used as a starting point and strong connections were made to each prompt in the CoRe. Thereafter, lesson observations were carefully scanned to identify teacher actions and decisions that fitted into each prompt. In addition, field notes of the lesson observations were reviewed in order to extract pieces of information that were not apparent in the lesson observations. This information was also added to the CoRe. Finally, post interviews with each teacher while viewing one of their respective lessons served to make their instructional strategies explicit, thus it was valuable to the construction of the CoRe. Therefore, the CoRe consisted of information that was derived from all of the above data sources and ensured a richer context of PCK for each teacher.

For example, consider question 7 regarding teaching procedures that would be used and the response allocated to it. In the pre-interview both teachers considered using investigative approaches, however, their practice during the lessons allowed me to enrich the response to this question. Mr Moodley adopted an unguided discovery approach (practical investigation); in addition, he used an experimental design approach to conclude the section of chemical change. Mr Johnson relied heavily on teacher demonstration to communicate his objectives which was visible throughout his lessons. This led him to adopt a teacher-centred approach during most of the initial instruction where he entertained almost no interaction between learners and himself. The above was not apparent from the interview alone. Therefore, the CoRe consisted of information that was derived from all of the above data sources and ensured a richer context of PCK for each teacher.

I decided to arrange the responses in the CoRe alongside each other so as to enable the reader to draw a comparison between the two teachers more easily. The complete CoRe for the two teachers is shown below in table 4.1.

4.3 CoRe for Mr Moodley and Mr Johnson on chemical change

Big idea	**Chemical change involves substances reacting to form new products.**	
Questions	Mr Moodley	Mr Johnson
1 What do you intend the students to learn about this idea?	▪ Difference between CC and PC. ▪ Criteria required to differentiate between the two. ▪ Law of Conservation of Matter	▪ Difference between CC and PC. ▪ Examples of CC in everyday situations.
2. Why do you think it is important for students to know this?	▪ Cannot understand CC if uncertain about characteristics of it.	▪ CC relates to chemical reactions; chemical word equations; balancing equations ▪ To understand stoichiometric calculations
3. What else do you know about this idea that you would not share with the students yet?	▪ Rearrangement of atoms & phase change may be categorized as both PC and CC e.g. NaCl dissolving in water.	▪ Factors affecting reaction rates. e.g. Temperature, pressure, concentration, the use of a catalyst.
4. What are the difficulties associated with teaching this idea?	▪ Mass does not change when phase change occurs. ▪ Understanding macro and micro concepts- he was not specific about what this implies. ▪ Macro level is not always visible	▪ Poor chemistry background of learners -names, symbols, formulae, writing chemical reactions ▪ Visualization of micro changes when considering macroscopic views of everyday items e.g. Velcro.
5. What knowledge can you share about student's thinking that influences your teaching of this idea?	▪ They struggle with basic chemistry concepts, i.e. writing chemical formulae, symbols and chemical equations ▪ They are unreliable with apparatus→ safety factor.	▪ They have convergent thinking regarding chemistry ▪ Learners lack of connection between science and everyday experiences ▪ Learners' poor macro/micro concept knowledge.
6. Are there any other factors that would influence your teaching of this idea?	▪ Biological sciences knowledge – use of examples from this context to explain CC & PC ▪ Difficult terminology contained in the section of CC.	▪ Difficult terminology involved in section of CC ▪ Language barrier for most 2nd language speakers.
7. What teaching procedures would you employ?	▪ Unguided investigative approach ▪ Practical work ▪ Experimental design ▪ Tools: Blackboard & worksheets	▪ Guided investigative approach ▪ Tools: Overhead transparencies; blackboard. ▪ Methods: Lecture method; Group work & collaboration ▪ Teacher demonstrations using relevant examples.
8. Why would you use these procedures?	▪ Learners are eager to engage in hands-on practical work.	▪ Good understanding and memory is achieved by "doing" and "seeing".
9. What strategies could you use to ascertain learners' conceptions/misconceptions of this idea?	▪ Ask questions at the end of the lesson in order to gauge learner understanding.	▪ Include a worksheet/task with structured, diagnostic questions. ▪ Review of previous lessons - recall and recap.

Table 4.1: CoRe for Mr Moodley and Mr Johnson

(PC – physical change & CC- chemical change)

4.4 Discussion of the CoRe

The CoRe indicated similarities between Mr Moodley and Mr Johnson with regard to chemical change. Both teachers highlighted the main objective as the need for learners to be able to differentiate accurately between physical and chemical change, furthermore, they were concerned with the learner's grasp of changes at the macroscopic and microscopic level. A point of concern common to both teachers was the learner's prior knowledge with respect to basic chemistry. Their inability to write correct chemical formulae, name chemical compounds and write chemical equations was central to the teachers' anxiety. Finally, both teachers used an investigative approach in order to accomplish their lesson objectives, even though this strategy was employed with some variation during the subsequent lessons. They maintained that learners were eager to engage in practical work; furthermore, this method encouraged prolonged memory and strong understanding of chemical concepts.

Some important differences also emerge from the CoRe. Mr Moodley focused strongly on the criteria to determine the difference between chemical change and physical change, while Mr Johnson gave it adequate attention, but indicated that his intention was to pave the way for discussing subsequent topics which learners would have encountered later in that year. The topics included chemical reactions, balancing equations and stoichiometric calculations. Mr Johnson indicated that language was a barrier to learning since most learners were second language speakers. Difficult terminology that was included in the topic would present a problem; however, Mr Moodley did not seem to think it was an issue. He said that most learners understood English adequately. Another essential difference is the manner in which each teacher communicated their approach to ascertaining understanding. Mr Moodley suggested that simply asking learners questions relating to the subject matter would expose misconceptions. However, Mr Johnson stated that he would recap after each lesson and ascertain the learners' understanding from the discussion; furthermore, he also planned to give them structured, diagnostic questions that would demand varied cognitive levels of thinking. This would indicate to him their apparent misconceptions.

4.5 Construction of the PaP-eRs

The PaP-eR represented a narrative account of each teacher's practice that was observed and recorded by means of a video recorder, in addition, the interview and field notes were used to give a richer version of the PaP-eR. A brief synopsis was written at the beginning of each PaP-eR in order to give the reader a brief overview of lessons as they unfolded. After repeatedly watching each lesson, I began scanning the contents of the lesson for salient features of pedagogical content knowledge that emerged. Whether it had been communicated explicitly or implicitly by the teacher, I recorded it as PCK that was inherent in each teacher's style of instruction which served to make the PaP-eR that much richer in context.

Prior to the practical investigation, learners in each class were allocated into groups of four to six people. During the investigation the teacher walked around the laboratory giving some guidance where it was required and ensuring that necessary precautions were observed. Some of the interactions between the learners are included in the PaP-eRs, once again focusing on the portions that are relevant in the context of the study. In addition, teacher-learner interactions are mentioned that occur during a teacher demonstration or the review after an exercise.

4.6 PaP-eR for Mr Moodley on chemical change

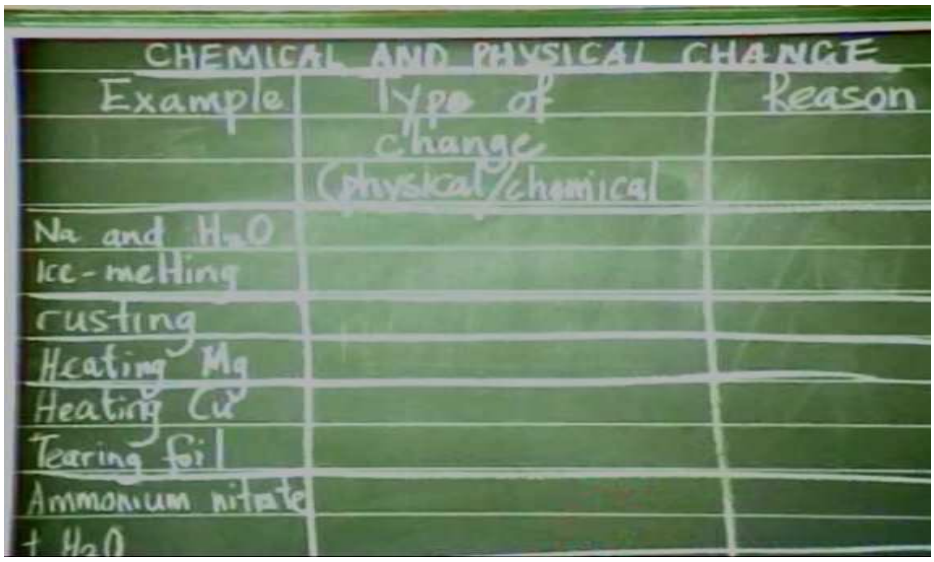
Mr Moodley allows his grade 10 learners to conduct a series of practical investigations that would allow them to uncover a set of characteristics to determine whether a physical or chemical change occurred. Thereafter, he discusses the observations that learners made and asks them to substantiate their choice with relevant reasons. After a brief period of practice using a worksheet exercise, Mr Moodley focuses on experimental design. In this activity, he requests that learners write a scientific report on how they would distinguish between physical and chemical change using prescribed apparatus and chemicals. Parts 1 – 3 are lesson objectives and are not arranged as separate teaching sessions. Thus they may have continued across classroom lessons.

Part 1: Investigating reactions involving physical and chemical change

Mr Moodley began his lesson with the intention of employing an investigative approach that would help learners see a pattern which would allow them to differentiate between physical and chemical change. The big idea that he saw as vital to this section of work was deducing the criteria involved in successfully determining what chemical change was, or that chemical change was not a physical change. He maintained that if learners

do not grasp this concept of difference, then they would not be in a position to understand chemical change.

As the learners settled to give Mr Moodley their attention, he commented "...you are going to be the scientists for today". At this point, the learners became visibly excited due to the fact that they were rarely given the opportunity to conduct experiments, in fact, Mr Moodley admitted to not having used this approach before in the current year. He briefly informed them that their goal was to determine criteria for what constitutes a physical or chemical change, without actually telling them what these concepts mean or indicating any kind of definition that would guide learners in their task. Learners copied the following table from the chalkboard as instructed by Mr Moodley:



The last row is not visible on the snapshot

Example	*Type of change – physical/ chemical*	*Reason*
Na and H_2O		
Ice melting		
Rusting		
Heating Mg		
Heating Cu		
Tearing foil		
Ammonium nitrate + H_2O		
Sparklers		

While learners were copying the above table (a one-line method was indicated on the adjacent board for each item listed above), he divided the learners into groups of six. Mr Moodley did the first example involving sodium and water as a demonstration because he was nervous about allowing learners to work with this metal due to its reactive nature. He cut a small piece of sodium and dropped it into a trough of water. The following discussion ensued:

Mr Moodley: "Right, you have sodium in water there, what gas is going to be released?"
The learners collectively mumble a variety of suggestions: "Sodium oxide, paraffin."
Mr Moodley: "Sodium plus water is going to give you sodium hydroxide and what gas?"
Thabiso: "Oxygen" (other learners chuckle)
Mr Moodley: "What's the explosive gas, what makes a pop sound when you test for it?"
John: "Paraffin" (learner screams out answer).
Mr Moodley: "Hydrogen!" Ok, so that's just a small piece of sodium. If you put a large piece you will get an explosion because the heat will cause the gas to explode…" (inaudible).
Sipho: "I said hydrogen sir!"

Mr Moodley referred to the table that learners had copied and indicated the manner in which it should be completed. Even though he had demonstrated the first experiment as indicated above, he was careful not to commit to filling in any explanation regarding whether it was a physical or chemical change. He stated the following:

"You are going to come up with the criteria, you are not going to be assessed on the correctness of your explanations, but we are going to pool the ideas together in your next lesson and come up with a set of criteria to decide whether something is a chemical change or a physical change."

Learners proceeded to their respective workstations (as directed by Mr Moodley) that had all the apparatus laid out, except those needed for the 'rusting' practical. Before the learners actually engaged with the practicals, Mr Moodley referred to an excerpt that he had given to each group leader and read it out aloud. The excerpt that Mr Moodley dictated is given below:

> Physical and chemical change occurs all around us and even inside us everyday. Cooking or tearing a piece of paper involves some type of change. You are going to be conducting and observing several experiments that have been set up and decide whether physical or chemical change occurs and explain why you think so. Your conclusions will not be

> assessed on accuracy, but on the criteria that you have chosen to decide what type of change has taken place. (classroom lesson)

The excerpt commented on a chemical and physical change in a general manner and indicated that it was an everyday part of life. It further discussed the purpose of the practicals and reiterated that the accuracy of the conclusions drawn were not as important as determining a set of criteria to differentiate between physical and chemical change.

Mr Moodley attempted to contextualize physical and chemical change as part of one's everyday experience. Initially, he did not give learners a definition of either term; however, he implied that their ability to recognize some sort of defining criteria would be the ultimate goal of their experimental investigation. He changed the order of the experiments as laid out in the table (in order to save time) and briefly cautioned learners regarding the burning process, especially when using magnesium. Learners proceeded with experiments and classified each observation as physical or chemical change, simultaneously attempting to provide reasons for their choice. Some learners used their textbooks to aid their decision, while most others simply relied on their knowledge. Learners were visibly enthusiastic about conducting practical investigations and seemed to enjoy the freedom of handling apparatus and continuing the investigation independent of teacher intervention.

The rusting process indicated in the table above was simply described by Mr Moodley because learners could not conduct this investigation in the allocated time.

He made the following comment:

> "Ok guys, with regard to rusting, rusting is when you notice any rust on any metal, right, some of your tongs might be rusting…you'll see some rust on them." (classroom lesson)

The adjacent chalkboard reflected the balanced chemical equation of the rusting process:

$4Fe$	+	$3O_2$	→	$2\ Fe_2O_3$

This reaction may have aided learners in deciding on whether the change was physical or chemical. New products accompany a chemical change, as was repeatedly stated by Mr Moodley at a later stage.

The learners completed the final experiment and Mr Moodley reminded them to complete their explanations after having cleaned their respective workstations. He directed their attention to the sparklers used. He stated:

"With regard to the sparklers, uses of, you'll find that these are basically applications of chemicals, using chemicals, right. What chemicals do you think are in these sparklers? You burned the magnesium, you saw the bright white light, so you can use things like magnesium dust, even iron or steel dust to give off white light, if you burn copper, the other fireworks that you get, you get bluish or green light." (classroom lesson)

The mention of the word "chemicals" may have been used by Mr Moodley to direct the learners to some kind of a 'chemical' change; however, this was not a conclusive method of differentiation. Furthermore, the mention of substances involved in the make-up of sparklers drew learner attention to the change that magnesium underwent when burned. This allowed learners to deduce the same response given for burning the sparklers; however, it was not certain whether this was Mr Moodley's intention or whether the learners made that deduction.

Part 2: Classification of reactions with explanations

Mr Moodley began by informing learners that they would review the table that was given to them in the previous lesson. He directed his questions to specific groups and waited for a response to the sodium-water reaction with respect to whether it was a physical or chemical change.

Mr Moodley: "Group 1, what did you classify sodium and water as?"
Farida: "It is a chemical change."
Mr Moodley: "What was your reason?"
Farida: "Sodium dissolves and releases a gas."
Mr Moodley: "Right, we said that hydrogen gas was released, but you can dissolve something and it won't be a chemical change, for example, if you dissolve sugar in water. Do you think that is a chemical change?"

Farida: "No."

Mr Moodley: "Not every time you dissolve something are you going to get a chemical change. That will be a physical change because the sugar molecules are basically in the water molecules. We are not changing any molecules."

Mr Moodley attempted to make explicit the difference between chemical change and physical change using the terminology used by the learner – "dissolve." He recognised the need, at the very beginning of the review, to clarify that not all processes where "dissolving" takes place involved a chemical change. He highlighted the fact that a gas may be released in a chemical change (indicating that a new product is formed), whereas in a physical change, reactant molecules are not changing.

Mr Moodley emphasised that there are some 'grey areas' when one talks about physical and chemical change, according to readings that he had done. He used the example of sodium chloride when dissolved. He maintained that after evaporation, one is still left with crystals of salt; however, there was a rearrangement of atoms in the process.

As Mr Moodley proceeded to the next example (ice melting), he wrote the learner's response on the board and indicated the phrase "same product" under the third column to serve as an explanation. He paused for a moment and informed learners that this observation was important as it differentiated between physical and chemical change. He commented that a physical change was characterised by obtaining the same product and a change in state; however, the properties remained the same. The product molecule was still identical, in this case, H_2O. Mr Moodley reviewed each of the other examples that learners had been given.

After the review, Mr Moodley displayed a table of differences between physical and chemical change on transparency:

Physical change	*Chemical change*
No new substances formed.	*New substances formed.*
Molecules rearranged but not changed.	*New molecules formed by chemical bonds.*
Easily reversible eg. Ice to water, water to ice.	*Not easily reversible*

The learners were given two exercises on worksheets. The first one required each of them to indicate what their understanding of physical and chemical change was. After a brief discussion of the learners' answers, he allowed them to attempt the other exercise which consisted of a number of examples, with illustration, that required both classification and explanation. This activity concluded the lesson.

Part 3: Using experimental design to differentiate between physical and chemical change.

During the review of the previous exercise, Mr Moodley discussed the reaction of nitrogen gas reacting with oxygen gas to form nitric oxide. He informed learners that if the word "react" is used, it provided a clue that the reaction was a chemical change. Another example he highlighted was indicated by the phrase: "bicarbonate of soda in water used in baking". He stated that this represented a physical change only if it excludes the part "used in baking" since its composition would change. Therefore, learners were asked to delete the latter part of the statement in order to prevent confusion at a later stage.

After review of the exercise, Mr Moodley gave learners an additional task. He required them to design an experiment (individually or in pairs) using sugar crystals to show the difference between physical and chemical change. He provided a list of apparatus and chemicals that were at their disposal. These included the following: sugar crystals, 2 beakers, 2 stirring rods, sulfuric acid and water. Mr Moodley stressed that the final product of the task must be presented in the format of a scientific report, using the scientific method. Toward the end of the lesson, Mr Moodley realised that learners were hesitant and offered more guidance, this time he was more explicit about what they needed to do.

4.7 Discussion of Mr Moodley's PaP-eR

Mr Moodley's approach to the topic demanded a mature response from the learners. He stated that they would be responsible for determining the criteria for chemical change, an approach he had never used before in that year. While this method of learning appealed to the learners, Mr Moodley had to monitor the classroom activity carefully

and guide the process without actually divulging the characteristics of chemical change, which he did. However, his approach directed the learner's attention to merely obtaining a set of criteria that would distinguish between physical and chemical change without really understanding the justification for their response. He stated prior to the investigation that the "correctness" of their substantiation was immaterial.
In a subsequent lesson, he alerted learners to key words that may be used to describe a chemical change, namely, the word 'react'. This practice unconsciously encouraged learning without authentic understanding, an approach that may be equivalent to rote learning. Furthermore, he merely mentioned rusting without emphasising the process and formation of the metal oxide. Thus learners knew that it was a chemical change, but were not confident about why or how it occurred, which was evident in their diagnostic tests (See chapter 6).

While doing the experiment, learners were uncertain of their understanding, and perhaps the direction in which they should proceed, hence they resorted to using their textbooks to explore possible classifications. However, prior to the investigation, Mr Moodley did contextualise the topic, quoting two everyday examples that may have advanced learner understanding.

When learners spoke of the 'dissolving' of sodium in water and its related chemical change, Mr Moodley intuitively recognised a possibility for learners to misinterpret this phenomenon. He swiftly corrected their perceptions with other examples where substances had dissolved but a physical change had resulted. However, during his explanation of the dissolution of sodium chloride, he maintained that two possibilities could co-exist, namely chemical change and physical change. He gave justification of his thinking; however, it may have been insufficient to make it plausible to learners. This view indicated that Mr Moodley realised that scientific concepts are not always definitive and without variation. He was willing to show that he was uncertain regarding his content knowledge and openly communicated this view to his learners.

Finally, his use of the experimental design strategy seemed to be beyond the learner's ability, unless further guidance was given. Learners were uncertain of the expectations; in addition, they had to work within prescribed conditions. Mr Moodley became aware of the situation and offered further guidance. His decision to be more explicit was

necessary in order to obtain experimental results from the learners. At this point, it was unclear to me whether learners knew what occurs when sulfuric acid reacts with sugar. Furthermore, the acid needed to be concentrated to have the desired dehydrating effect on the sugar crystals. This was not indicated in Mr Moodley's list of chemicals, perhaps he was not aware of the type of acid that could be utilized. From previous discussion regarding sugar dissolving, it seemed obvious that they would add water to sugar, allowing it to dissolve, and classify it as a physical change. However, I am uncertain as to whether the expected outcome was achieved because the duration of time afforded to me by the respondents had ended.

4.8 PaP-eR for Mr Johnson

Mr Johnson demonstrates a number of examples highlighting the differences between physical and chemical change, while explaining the theme of macroscopic and microscopic changes that occur. He allows learners to engage in practical investigations in order to apply their knowledge of the content discussed. Finally he offers remedial instruction where misconceptions arise. Parts 1 – 4 are lesson objectives and are not arranged as separate teaching sessions. Thus they may have continued across classroom lessons.

Part 1: Establishing the difference between physical and chemical change through visual representation and teacher demonstrations

Mr. Johnson began his lesson by reminding the learners about what content was covered in previous lessons. He referred specifically to the periodic table and pointed to the metals and non-metals; in addition, he clarified their association with each other to form "substances". He mentioned the exercise of writing chemical formulae and informed the class that their focus would be aimed at the interaction between these substances in the sections of physical and chemical change. Mr Johnson strategically called on the learner's prior knowledge of elements in the periodic table to allow them to contextualize the substances that they dealt with. He also made reference to their poor ability to write chemical formulae in the pre-interview and saw this as a major obstacle to understanding the section in its entirety.

He showed the learners a colour-coded transparency depicting written information regarding both physical and chemical change. It contained the following information:

Physical & Chemical change

- **Substances may change in two ways:**

-Physically

-Chemically

- **These changes may be viewed in two ways:**

-Microscopically

-Macroscopically

Physical change

- **Change in the physical state or form of the substance.**
- **The identifying properties of the substances remain unchanged.**
- **These changes usually accompanied by change in: temperature; pressure; phase; form; size; shape…**
- **Use descriptive words like: dissolving, boiling; subliming; melting; condensing …**

Chemical change

- **Substance changes into different substance or substances.**
- **Each with its own distinct properties.**
- **It's a result of a combination of elements/compounds to form new compounds.**
- **It involves the breaking and making of bonds – covalent/ionic.**
- **Atoms/molecules/ions rearrange themselves differently.**

Before proceeding to complete the notes on the transparency, Mr. Johnson paused at the second bullet point to emphasize the meaning of the macro/micro concept. He acknowledged that the National Curriculum document (Department of education, 2003) included this important concept as a theme that is common to the module of chemical change, thus his eagerness to concentrate on its meaning.

His first example was a compact disk. He maintained that learners can see the disk, a macroscopic view ("viewing it normally") of it, however, with the right equipment, a microscopic view would be possible. He then showed them an exploded view of a disk from a book. His second example included a number of different types of glues, as well as "Velcro" tape. Once again, he used the same book to show the "microscopic enlargements of the macroscopic situation". Finally, he referred to a laser printed page of information, showing learners the number of beads needed to imprint one letter of the alphabet – a microscopic view. Mr Johnson attempted to make learners realize that science is not confined to the classroom; rather it is evident all around them. He stated:

> "Quite often your students think very narrowly, they sort of have tunnel vision, and they sort of come in the science lab and think chemicals and things like that, where they don't really see the application of it in everyday life, in their homes, and where they encounter these types of things." (pre-interview)

The examples used above were encountered by learners in their everyday activities, indicating that relevance was of paramount importance when engaging with an audience of this age.

Physical change

Mr Johnson moved his focus to discussing the concept of physical change. He made the following statement before proceeding:

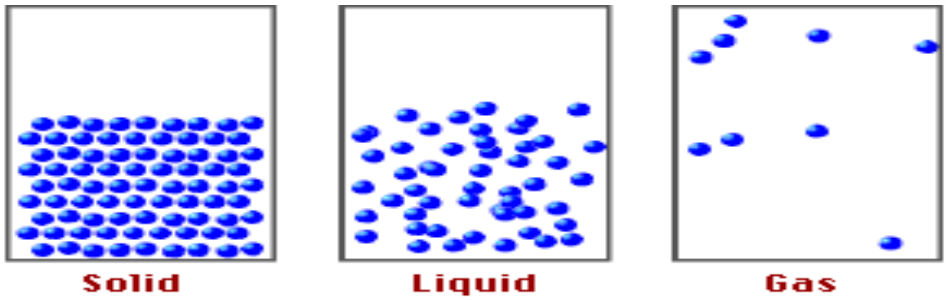
> "As we go along, I'm going to make a note of the substances in symbol form because we are to going to start working in symbol form more often that in word form and eventually we'll be using them later in chemical reactions" (classroom lesson)

This action made explicit his intention to remind learners of the symbols of elements used and prepared them to write chemical reactions that indicated physical or chemical change, as chemist would do. Chemical reactions were fundamental in their understanding of stoichiometric calculations, a section that would be dealt with later. Furthermore, he was concerned about their poor chemistry background:

> "I think a lot of kids hear about various chemicals and how they undergo chemical change, a lot of them get lost with the names of the chemicals, and so they don't really know what you're talking about half the time, except some of the brighter kids. So, the chemical names and of course the various reactions we go through will probably be confusing for some of them in the beginning, until they get used those chemical reactions and of course the symbols involved. If they don't know the name, symbol, there could be problems there." (pre-interview)

On his table, he displayed a number of substances that helped learners understand the points illustrated on the transparency. These included different shapes and forms of iron (nails, filings, dust), sulfur (rolled, powder) and carbon (charcoal, powder). He

reminded learners of other allotropes of carbon that were discussed earlier, namely, graphite and diamond. Other substances displayed include ice, water and boiled water (to indicate water vapour). He referred to phase change which is generally accompanied by a temperature change and revisited the theme of macro/micro concept in this regard using a beaker with polystyrene balls to represent molecules of H_2O, also depicted on another overhead transparency. He was also careful to explain the shape of the water molecule as not being simply spherical as depicted in his transparency below.



Mr Johnson's next demonstration involved the dissolving of sodium chloride as a physical change. He stated:

> "What happens here is that we are looking at a physical change and not a chemical change, although this can be a bit of a grey area as well".

He did not follow this train of thought and explain what he meant by 'grey area', however, he displayed another overhead which illustrated the NaCl crystal lattice and how the respective ions bonded to the water molecule, making reference to ionic bonds and ion-dipole forces. He did indicate that because solid NaCl would remain after evaporation, it represented the same substance, hence a physical change.

His final demonstration of physical change included heating a piece of nichrome wire, quoting applications of an electric stove, geyser element, filament in a bulb and an electric heater.

Chemical change

Mr Johnson explained chemical change by demonstrating the following: a matchstick burning, a cigarette lighter, a gas burner and paraffin lamp, indicating that the main product formed in each case is carbon dioxide. He continued to show learners two other

spontaneous reactions and wrote the chemical reactions on the board to indicate the new substances that were formed. These were:

Na	+	H_2O	→	NaOH	+	H_2

Zn	+	HCl	→	$ZnCl_2$	+	H_2

As the lesson approached an end, Mr Johnson recapped the characteristics of physical change and chemical change, allowing learners to respond to questions.

Part 2: More exciting chemical change demonstrations

Mr Johnson continued from previous lesson with more demonstrations involving chemical change. He began with the non-spontaneous reaction of zinc powder and iodine mixture, adding water as a catalyst. Again, he was careful to write the chemical reaction on the board for learners to see the new product formed.

Zn	+	I_2	→	ZnI_2

Thereafter he used potassium iodide and mercury chloride to show a chemical change. He reminded learners of the dissolution of NaCl and the physical change that it represented, similarly, the dissolving of potassium iodide and mercury chloride, in individual beakers that created colourless solutions. Mr Johnson did not label the beakers, so learners did not have any clue to the chemical contents of each beaker. An extremely thick orange precipitate resulted when the solutions were mixed, indicating a chemical change that had occurred. The formation of the bright orange precipitate impacted many learners, cementing the explicit difference between chemical and physical change. In this instance, Mr Johnson did not complete the reaction on the board; instead, he told them what products were formed. Furthermore, he demonstrated that this reaction could also be reversed in the aqueous phase.

The final demonstration that he did was the reaction between hydrogen peroxide and manganese dioxide with dishwashing liquid. The nature of the exothermic reaction

made it very apparent that a chemical change had occurred, once again, learners were excited by the spontaneous result. As the end of lesson approached, Mr Johnson informed learners that they would do six practical activities in which they would be tasked with classifying physical and chemical changes, with relevant substantiation for each.

As mentioned above, the number of demonstrations did allow the learner to become more confident in their understanding of chemical change. This is what Mr Johnson said concerning the value of this approach:

> "The meaning is definitely more enhanced. They tend to remember the practicals or demonstrations and the explanations to what is actually happening during those demos and practicals. They remember it longer and understand it better when they look at examples".

Part 3: Learner investigation on physical and chemical change.

Six practical activities were set up by Mr Johnson that would enable learners to apply what they had learned in the previous lessons. They were required to state their observations, classify each reaction as physical or chemical change and provide a relevant reason for their choice. He proceeded to explain how they should conduct the practicals, safety measures to be observed, and the manner in which they should write down their observations. Instead of completing all 6 activities at once, he advised learners to group around the adjacent desk to discuss observations and then record their results after each activity. While time management could be problematic with this approach, the type of discussion that learners would engage in could prove to be more valuable.

Mr Johnson quickly demonstrated two explosions: a balloon bursting when in contact with a flame, and a firecracker. He asked learners to discuss these and fill in their responses on the worksheet in the space provided. In the interim, he moved around the classroom to listen to learner discussion. Here are some interesting responses:

The balloon explosion

Group 1: "Physical change- because balloon material has not really changed – smaller pieces result due to explosion.
Group 2: "Physical change - because no chemicals are involved."

Firecracker explosion

Group 1: "Chemical change – because powder reacts with flame"
Group 2: "Chemical change – fumes are given off after explosion – powder reacts."

Thereafter, learners engaged in the other practical activities which included the following:

- Copper sulphate dissolving in water

Group 1: (Learners not sure whether it is a chemical or physical change, even though their observations are accurate – they refer to notes given).
Group 2: (Chemical change – but cannot explain why).
Group 3: "Physical change – colour of water is blue."
Group 4: "Physical change – just dissolves – no new substance is formed."

- Magnesium ribbon ignited in air

Group 1: "Physical change – ash has formed – change in shape – solid to ash."
Group 2: "Physical change – Mg broke into smaller pieces – metal becomes soft."

From the above responses that were randomly recorded, it seemed that learners were not confident about their understanding of the topic. Furthermore, their reasons for a particular classification were incorrect at times, superficial and lacked depth. Mr Johnson was aware of their difficulty and decided to stop learners from proceeding with the other investigations until he had addressed the problem.

Part 4: Clarifying the classification of physical and chemical change

In order to remind learners, Mr Johnson reviewed the transparency which showed the essential characteristics of physical and chemical change. He comments:

> "Don't change your answers now; all we want to look at is how you came about those answers and why you came about those answers".

With regard to the balloon explosion, the majority of learners had indicated a physical change due to the change in form and shape of the balloon. One learner spoke of pressure which Mr Johnson explained was the crucial factor that contributed to the explosion, due to the rapid expansion of the gas. He likened this phenomenon to the sound of thunder that occurs after lightening bolt is seen. Most learners seemed to understand that the copper sulphate dissolving was in fact a physical change since no new product was formed and the word 'dissolve' was used.

Finally, some learners were confused with magnesium burning in air, indicating that it was a physical change since it changed from a metal to being a 'soft ash.' Mr Johnson focused their attention on the fact that an entirely new product with new properties were formed, thus it underwent a chemical change. However, it seemed as though some misconceptions crept in due to the learner's attention given to key words used to denote the relevant change, for example: form, shape, size, etc. In other instances, they did not notice temperature and pressure differences which generally indicate physical changes according to Mr Johnson's notes.

4.9 Discussion of Mr Johnson's PaP-eR

Mr Johnson's introduction of the topic was based on a constructivist approach. He used the learners' prior knowledge to support his delivery of the subject matter. Furthermore, his intentional choice of examples involving macroscopic and microscopic illustrations was relevant to learners, thus making the concept more plausible. This strategy links strongly to the view that science includes one's everyday experience, whether simple or complicated in nature.

A common thread visible in Mr Johnson's approach was his awareness of topics (e.g. chemical reactions & balancing equations) that would follow the teaching of chemical change. He consistently ensured that chemical symbols and reactions were reflected on the chalkboard whenever he had completed a demonstration. This practice enabled learners to become comfortable with seeing and writing chemical reactions in symbolic form since word equations were used prior to this. His decision to avoid explaining the controversy regarding the dissolution of sodium chloride could be attributed to the premature understanding that learners had at that stage of the lesson. A sharp awareness of the topic and his intentional omission of 'grey areas' may be categorized as curricular saliency as envisaged by Geddis et al. (1993), a feature of PCK which was discussed earlier in chapter 2.

The number of physical change demonstrations conducted indicated that Mr Johnson was aware that visual representation and repetition were vital ingredients for effective learning. He wanted to ensure that a concrete understanding of the concept was achieved before progressing to the main topic for discussion, namely, chemical change. If learners are aware of the difference, then classification became that much simpler. The learners were intrigued by the spontaneous results, and no learner disruptions were evident during this period due to the fact that Mr Johnson ensured that preparations were complete before the start of the lesson.

Mr Johnson also recapped at the end of each lesson in order to consolidate information that was communicated earlier. This practice was especially useful when learners were engaging in practical investigation. He used it as a means to address learner misconceptions that he noticed in their responses reflected on the practical worksheets. As an experienced teacher, he was more interested in establishing the root cause of their misconception, rather than merely addressing whether their answers were correct or incorrect. He wanted to delve into the learner's thought process and rectify misconceptions that may be common among them.

4.10 Conclusions

Mr Moodley and Mr Johnson's strategies were different. They both used a practical approach to teach the topic of chemical change, however, it was pitched in a dissimilar

manner to learners. While Mr Johnson seemed to relish the idea of practical demonstrations and learner investigation, Mr Moodley alluded to not having done learner practical investigations prior to this point as mentioned earlier in this chapter. The question that emerges is whether he would have adopted this approach if he had not been involved in the study. The traditional transmission of knowledge approach may have been adopted in order to satisfy the demands of the lengthy syllabus. This approach may be a common occurrence in many secondary schools.

Each teacher's classroom environment was particularly distinct. Mr Johnson's learners were more attentive and exhibited higher levels of concentration with little opportunity for classroom interaction while Mr Moodley's learners were rowdy and more open to teacher-learner interaction. Learners in both classes were not ability grouped. Thus their was a lack of discipline may be due to Mr Moodley's looser approach during his classroom practice.

In the light of the above discussions, both teachers were surrounded by learners who displayed similar degrees of misconception and misunderstanding. Mr Johnson's summary of notes on physical and chemical change was much more detailed and explicit than Mr Moodley, however, his learners still found difficulty in classification of each chemical event. It was expected that Mr Johnson's class would be more confident in their understanding since Mr Moodley was a novice to this section of work while Mr Johnson was well acquainted with it and portrayed a deeper PCK of the topic. However, this was not the case. Perhaps, poor learner performance was due to Mr Johnson's focus on the use of key phrases used in his explanation of chemical change and physical change which may have led to rote learned definitions.

Mr Johnson placed more emphasis on the macro and micro concepts in comparison to Mr Moodley. He prepared transparencies, researched books that illustrated exploded views of microscopic pictures and related these in a manner that engaged learners' interests. Furthermore, his notes reflected a much deeper acknowledgement of macro and micro views while Mr Moodley's notes indicated a shallow interpretation. Mr Johnson's strategy assisted the transformation of new knowledge that learners had to digest and understand.

The CoRes were instrumental in allowing me to understand the nature of each teacher's knowledge base with respect to the subject matter, learners, learning contexts, and curriculum matters. It provided a clear comparison between Mr Moodley and Mr Johnson's intentions, which were confirmed in their respective practices. The PaP-eRs were essential in order to delineate their classroom practices and helped to give insight into their teaching strategies. It also enabled me to contextualise the learning environment and understand the typical atmosphere in a chemistry classroom. It gave more insight into teacher thinking, implicit and explicit actions, in essence, it served to make tacit knowledge clear to me.

CHAPTER 5

SALIENT ELEMENTS OF PEDAGOGICAL CONTENT KNOWLEDGE

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5.1 Introduction

Shulman (1986) embodied pedagogical content knowledge (PCK) as a particular form of subject matter knowledge that is essential for teaching. He included a range of types of knowledge as components of PCK that teachers must possess and transform into teaching.

Geddis & Wood (1997) examined Shulman's (1986, 1987) conception of PCK and expressed dissatisfaction with it. They maintained that stating the components of PCK, but not examining their interaction in relation to one another, did not capture the actual transformation process. They propose that the value of focusing on transformation of subject matter is that it draws attention to subject matter, learners, as well as educational goals, as mentioned earlier.

Geddis & Wood's (1997) prototype of knowledge transformation is adapted to the following categories:

- learner's prior concepts
- subject matter representations
- instructional strategies
- curricular saliency
- curriculum materials

Geddis & Wood (1997) suggest that a variety of different kinds of knowledge are instrumental in shaping the teacher's ability to transform the subject matter knowledge. They characterize the elements in the following manner as illustrated earlier in chapter 2:

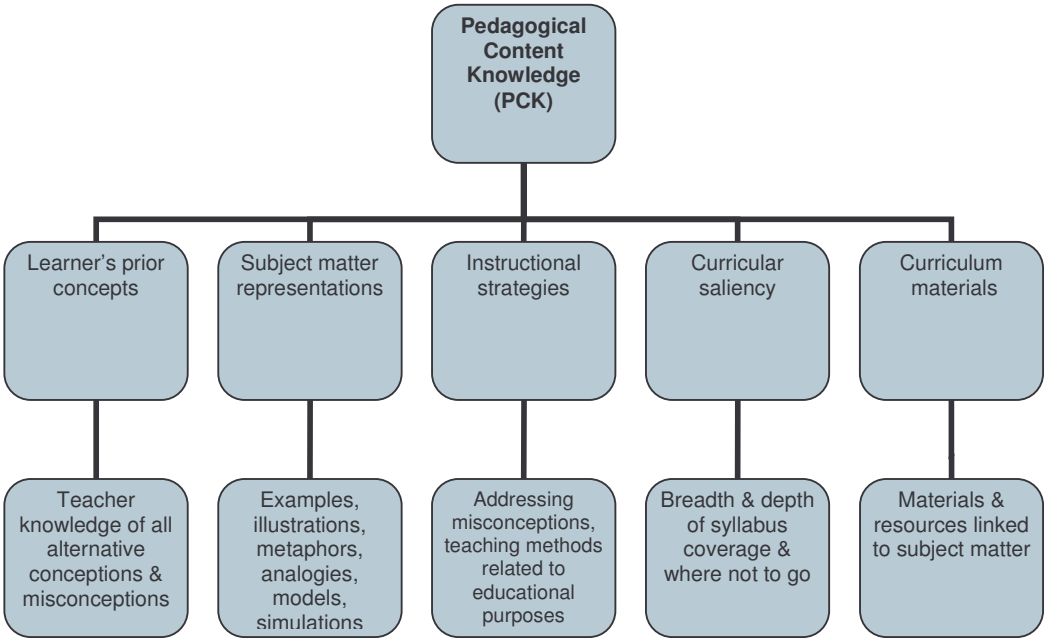


Figure 5.1: Types of teacher knowledge that facilitate transformation of subject matter (as perceived by Geddis & Wood, 1997).

The Geddis & Wood (1997) framework is appealing to me because it attempts to unpack how teachers can transform their content knowledge into forms accessible for learners. Moreover, the framework provides a tight fit to my data and the connections between the data and categories illustrated above are apparent to me. This study focuses on how each teacher aims to transform their subject matter knowledge and may be used to inform other teachers (both novice and experienced teachers) of how to approach this particular area, namely chemical change. Furthermore, Geddis & Wood (1997) acknowledge that the process illustrated by their framework is not linear in nature. Teacher practice is tentative, messy and continually modified, which is congruent with my philosophy of science, however, the categories are useful to frame PCK.

The data that I collected comprised mainly of pre-interviews, lesson observations, field notes and post-interviews, which included the use of a video recorded lesson to glean more information from the respective teacher. Each of these was carefully reviewed in order to ascertain whether they related to various types of knowledge which a teacher with adequate PCK would possess, according to Geddis & Wood (1997).

While teacher practice closely resembled the above framework, deeper inspection was necessary to examine whether teachers actually gave attention to learners' prior concepts, curricular saliency and the degree to which they used representations and resources to make the subject matter accessible to learners. The lesson observations were repeatedly viewed to ascertain whether information regarding the above categories could be justifiably allocated, in addition, their instructional strategy became apparent after viewing all their lessons in succession.

The Content Representations (CoRe) for each teacher proved to be extremely useful in extracting relevant information. However, statements that teachers made during the interview process did not regularly materialise in the classroom environment, as is common in many teacher-learner interactions. Nevertheless, teacher awareness of curricular saliency, misconceptions, and instructional strategies are vital components of PCK.

The transformation of subject matter is discussed below under the categories outlined by Geddis & Wood (1997).

5.2 Salient elements of PCK

5.2.1 Learner's prior concepts

According to Geddis and Wood (1997), learners' prior concepts include typical preconceptions; misconceptions; and alternate conceptions. Teachers' awareness and knowledge of this factor is a critical constituent of PCK and must be ascertained by the teacher in order to support effective learning. The knowledge of notions that learners have of the topic is an important factor for the teacher. Whether these ideas are correct or incorrect, teachers may use it as a starting point of their instruction and it allows them to make necessary adjustments to the format of the lesson or their strategy. If learners' prior conceptions are ignored, it could result in further distortion of the subject matter which may be more difficult to correct at a later stage.

Learners' knowledge of the Periodic Table and Chemical bonding (done prior to present section of work) was of paramount importance to Mr Johnson who used this as a platform for his introduction into the section of physical change and chemical change. The video evidence of his lessons showed that he commented on their knowledge of combining substances to form new compounds and made reference to writing chemical formulae to indicate this new compound. Furthermore, he referred to metals and non-metals that had been discussed and their association in the form of covalent and ionic bonds. Mr Johnson planned to pave the way for his introduction of macro and micro concepts that was to follow. Therefore, he started his lesson with microscopic views of chemistry as he was more aware of learner misconceptions in this area. This awareness became obvious in his repeated efforts to show learners the illustrations of microscopic views and testified to Mr Johnson's superior PCK.

Mr Moodley made no reference to any prior learning and delved straight into the new section. In pre-interviews, both teachers acknowledged that learners' chemistry background was extremely poor. They referred to the learner's inability to write chemical formulae, their ignorance with regard to names of chemical compounds, and their difficulty to communicate on the symbolic level. In addition, Mr Moodley suggested that they had misconceptions concerning the Law of Conservation of Matter in a physical or chemical change. With respect to the former, he maintained that learners thought that weight changed during a change of phase. He planned to address this misconception during lessons that were to follow.

During the review of the practical experiments, Mr Moodley addressed the concept of dissolving when a learner made the following comment:

Learner: "Sodium dissolves and releases a gas."

Mr Moodley made explicit that the process of dissolving was not necessarily indicative of a chemical change, as was the case of sodium metal reacting with water. He maintained that if reactant molecules were unchanged during the dissolving process, then a physical change had occurred. Mr Moodley saw the need to bring more clarity at that stage of the discussion to avoid the occurrence of any misconceptions that may arise later. However, Mr Johnson preferred to handle misconceptions at a later stage,

that is, after the learner practical investigation. He did not expect that learners' misconceptions would remain after the initial instruction. He states:

> "…once you start teaching and showing examples and doing practicals, and discussing things further, you find that a lot of those misconceptions are not apparent". (Mr Johnson-Interview)

His plan was to arrange prescribed questions for learners, that would help expose any misconception he was unaware of.

> "My whole strategy is to give them worksheets and move around to each child and check on them. Worksheets should be designed to move from the easier examples to more difficult application, so one can see the loopholes in understanding". (Mr Johnson-Interview)

Therefore, his plan to effectively address misconceptions was a matter of exposing it and then affording personal attention to the few that required it, instead of addressing the entire class. He imagined that this would be unproductive, while Mr Moodley was happy to address misconceptions with the entire class because he thought it could be equally beneficial to all in attendance. Mr Moodley comments:

> "I will address it with the entire class. Others could learn from these as well". (interview)

An example of where Mr Moodley tackles a possible misconception with the entire class is described earlier in chapter 4. He expands on his demonstration which showed the addition of sodium metal to water. Learners indicated that the sodium had dissolved; however, not all learners were confident that this represented a chemical change. Mr Moodley believed that learners would confuse the process of dissolving and classify this as a physical change, therefore, he emphasised that dissolving could indicate physical change if particles were rearranged. He stated, in the case of sodium reacting with water, a gas had been released; therefore, it represented a chemical change. In this instance, all the learners would have benefited from this discussion.

5.2.2 Subject matter representations

The manner in which the teacher communicates the subject matter is an important factor to consider. Geddis and Wood (1997) suggest that knowledge of examples, metaphors, illustrations, analogies, models and simulations contribute to the transformation of subject matter knowledge.

Both teachers used demonstrations to describe characteristics of physical change and chemical change. Mr Johnson's attempts included current, everyday analogies of macroscopic and microscopic properties of matter. He makes this comment:

> Quite often your students think very narrowly, they sort of have tunnel vision, …they don't really see the application of it (science) in everyday life, in their homes, and where they encounter these type of things.

He used a compact disc (CD), velcro and laser printer beads to show the "microscopic enlargements (pictures) of the macroscopic situation" as described by him. The theme of macro and micro visualisation was clearly high on his agenda, and he continually reiterated this theme acknowledging that learners do experience difficulty in navigating between both concepts.

Snapshots of the macro/micro illustrations

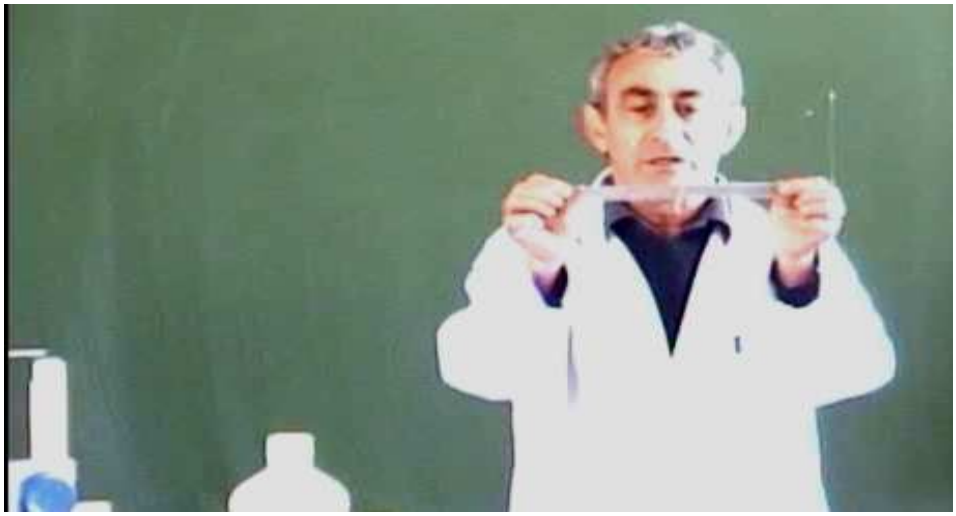
The compact disk – macro view



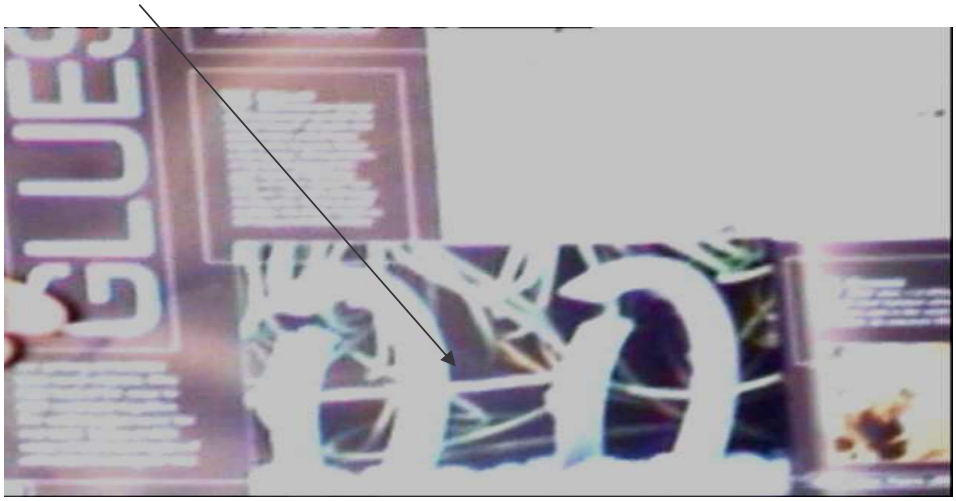
Micro view of compact disk showing tiny ‘bumps’



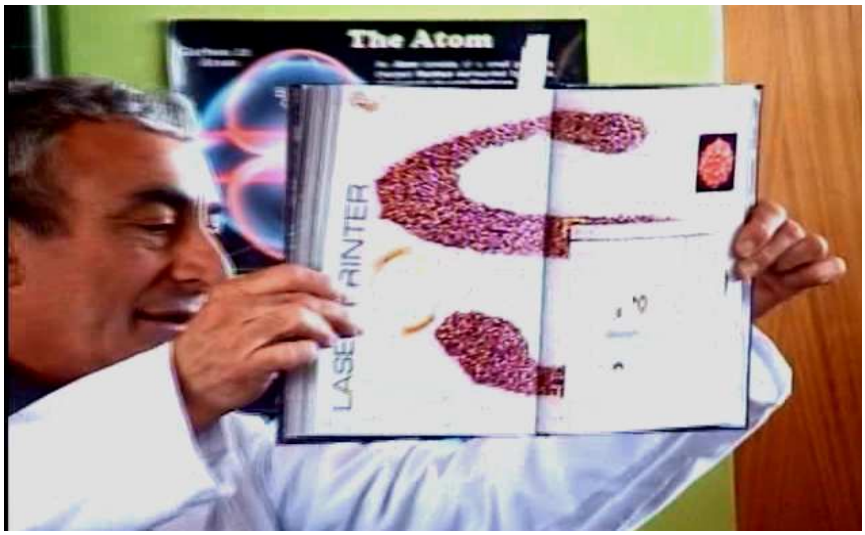
Velcro tape illustration – macro view



Micro view of velcro



Laser printer beads – microscopic view of letter 'S'



Mr Johnson was aware that the learners need to differentiate between physical change and chemical change and he emphasized key phrases that learners could identify as an indication of the type of change occurring.

For example,

> Descriptive words like "dissolving involves a physical change", "boiling is a physical change", "sublimation involves a physical change"…I'll discuss these now. Melting, condensing, these are some of the words one uses in describing a physical change. (class lesson)

Mr Johnson then proceeded to demonstrate many tangible examples of change in shape, form, state, temperature and the endothermic dissolving process of sodium chloride. Microscopic displays were represented diagrammatically with the aid of a transparency for both phase change and the dissolution process.

Mr Moodley concerned the learners with more content based examples (through learner practical work) that related strongly to 'classroom' chemistry, perhaps from the textbook that he was using. He wrote the order of the lesson on the chalkboard indicating the experiments the learners were to perform. All the experiments involved apparatus and chemicals that were typically located in the science laboratory.

The difference between the respective approaches is worth mentioning: while Mr Johnson made many attempts to employ various comparisons and demonstrations, Mr Moodley saw no need to contextualize the topic or use any introductory analogy – a mechanical approach that may be common in many schools. Beside the demonstration involving the reaction of sodium in water, he made no reference to an example or analogy in the first lesson. Mr Moodley did make the following comment in the third lesson before learners began practical work:

> "Physical and chemical change occurs all around us and even inside of every day. Cooking or tearing a piece of paper involves some kind of change."

The above comment may be construed as an attempt to include examples of everyday activities that learners may engage in, which could either symbolise a physical or chemical change. In the pre-interview, he does use the example of digestion in the following manner:

> "With regards to biochemistry, we can talk about chemical change that occurs, for example, digestion. Digestion is not actually a chemical change, but if you talk about glucose being converted to glycogen and things like that."

However, Mr Moodley's knowledge of digestion and the example quoted above was not mentioned during any of the lessons that ensued.

5.2.3 Instructional strategies

The instructional strategy that a teacher uses must suit the type of learners that he encounters according to Geddis and Wood (1997) framework. In addition, they maintain that knowledge of the learners' particular misconceptions; as well the underlying educational purpose must be considered.

While both teachers approached the topic of chemical change from opposing positions, there were degrees of commonality between them. They valued the approach of practical work that would result in cementing the learner's understanding of chemical change; however, while Mr Johnson used experimentation to consolidate his prior discussions of the concept, Mr Moodley began exposing the learners to a series of group investigations to uncover the criteria for defining the concept of chemical change.

Mr Johnson's approach involved using a number of varied practical demonstrations to highlight the difference between a physical change and a chemical change. As a result, he initially resorted to a lecture method presentation indicating the characteristics of physical change, and then allowed learners to continue to consolidate this with practical group work. That he made a concerted effort to relate subject matter to real life experiences enhances the relevance factor, furthermore, examples discussed related to the interests of the learners at that specific age group.

After the first round of practicals was complete, Mr Johnson noticed that there was uncertainty concerning the classification of events into chemical or physical change. He allowed the proceedings to pause and continued to review the learner responses. In a quest to reshape their constructions, he drew their attention to previous discussions and highlighted his transparency notes that contained the characteristics of physical and chemical change. His goal was to address the root of any misconceptions that were prevalent.

Mr Moodley did begin with his lesson with a demonstration of a chemical change but did not highlight any general criteria for determining a change of this nature. His statement: "You are going to be the scientists today" implies that he intended to use the discovery approach as his principal strategy. Learners were visibly excited at the mention of practical work. According to Mr Moodley, this had been a rare strategy that was used during the course of the year. However, he maintained that the purpose of practical work was twofold:

i) to aid the learning process, as learners tend to remember essential concepts

ii) to identify possible misconceptions in both physical and chemical change.

Interesting to me is the initial stance that Mr Moodley adopted when he spoke of practical work. He commented:

> "Practicals will probably have to be demonstrations because I don't trust them with the chemical that we are using. We suggested using sodium, so I don't want to let them handle that" (Mr Moodley – interview).

However, he had changed his approach during the planning of the lesson. Perhaps, he saw the value in allowing the learners to construct their own understanding of physical and chemical change.

While Mr Moodley did not display representations of physical change in the manner that was consistent with Mr Johnson, he did use worksheets to illustrate cases of physical and chemical change, which required learners to explain their classification. Thereafter, he reviewed the examples asking them to explain their classification each time.

Both teachers showed their intentions to make the difference between physical change and a chemical change explicit; however, it seemed that Mr Johnson's class was more aware of the differences. This could be attributed to repeated examples being visually experienced.

Illustrated below is unfolding of both Mr Johnson and Mr Moodley strategies as discussed above.

Figure 5.2: Mr Johnson's strategy

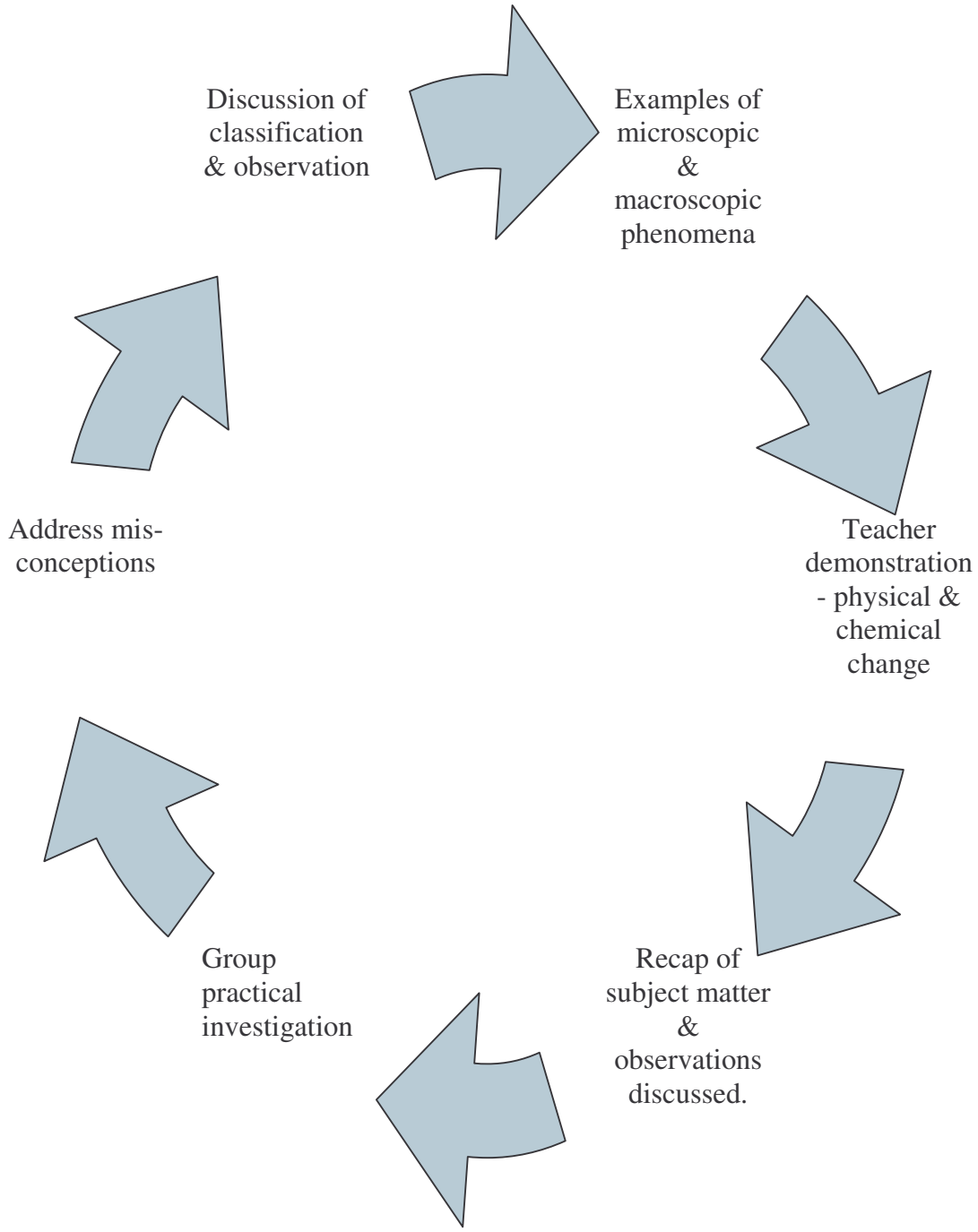
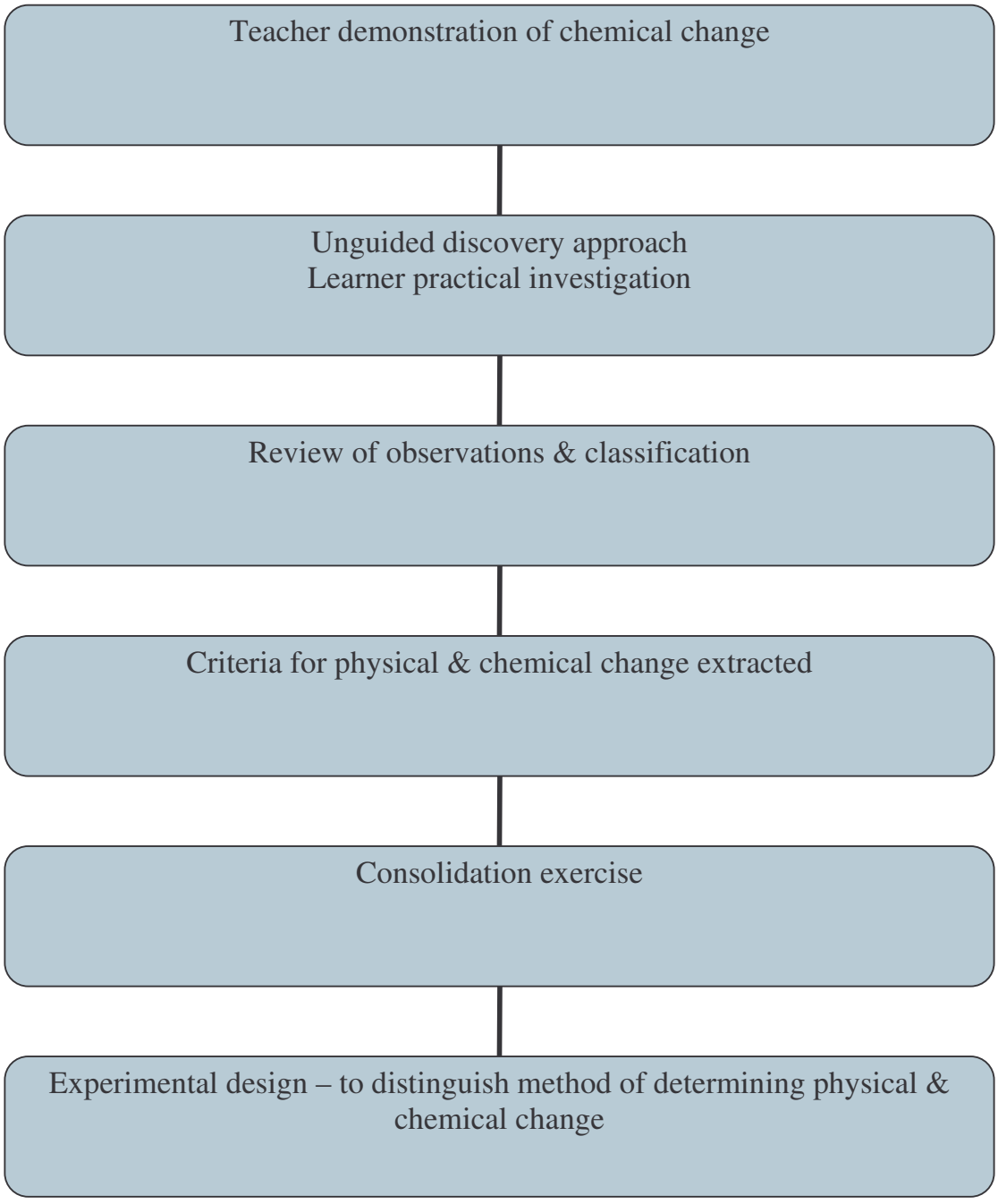


Figure 5.3: Mr Moodley's strategy



5.2.4 Curricular saliency

Another factor that influences subject matter transformation is curricular saliency. Geddis and Wood (1997) state that teachers' knowledge of the curriculum is a key factor which determines the nature of their PCK. Furthermore, the teachers' decision to include or omit sections of content may fall into this category, and is evidence of the teachers' ability to avoid misconceptions that may arise.

During the interviews, Mr Johnson and Mr Moodley suggested that their goal would be to emphasise the difference between physical and chemical change and this was evident in their lessons. The need to get the learners to operate initially on a classification level was foremost in their approach.

There was also evidence that Mr Johnson intentionally decided not to move beyond the boundaries of this section of work. He commented in the pre- interview that he would not discuss rates of reactions and the factors affecting it since it would be dealt with in the following year. During his video recorded lessons, he mentioned physical phenomena that would cause a physical change and confined it to this concept. Furthermore, Mr Johnson made no mention of reversibility of reactions as a criterion for distinguishing between physical or chemical change. However, Mr Moodley included this phenomenon in his transparency, showing a summary of the differences between physical and chemical change (illustrated in the PaP-eR in chapter 4). Perhaps, Mr Johnson intentionally decided to omit this criterion based on it being a generalisation rather than a certainty, which pronounces his knowledge of curricular saliency. Mr Moodley mentioned events that could be classified as either chemical or physical change and expressed his discomfort with his knowledge regarding this. He stated:

> "Looking at chemical change, the readings I've done spoke about some grey areas which should be tackled at a later stage…"

He agreed that learners were not at a level where they could understand or accept "grey areas" in this topic, thus he would exclude it in his discussion.

Both teachers mentioned that the understanding of physical change and chemical change would pave the way for teaching other chemical concepts that would follow. While Mr Moodley hinted in the pre-interview that the conservation of matter was a problematic area which he would address, Mr Johnson talked about other sections of examinable content that would hinge on the topic of chemical change. He stated:

> "Chemical change relates to chemical reactions; chemical word equations; balancing equations. It also helps learners to understand and do stoichiometric calculations". (pre-interview)

As expected, Mr Johnson displayed a wider knowledge of the breadth of the syllabus. His ability to identify relevant sections that relate directly to chemical change indicated the degree of experience that he had. In addition, he mentioned sections of work that learners would encounter in the following year of study which confirmed his attention to curricular saliency. Mr Johnson's knowledge of sections of work that would follow gave him more direction with regard to his lesson objectives. A teacher who has this knowledge will formulate their instruction so as to link present concepts to future knowledge. They will be aware of the depth of subject matter that is often difficult for a novice teacher to gauge; furthermore, they will emphasize understanding of concepts which learners will require in subsequent years.

Mr Johnson seemed to pay particular attention to the macro and micro properties of matter and then related it to physical change and chemical change. His continual repetition of this concept indicated that it was a salient feature of chemistry education, and a pre-requisite in order to make further progress. In addition, the National curriculum document (Department of education, 2003) did make reference to this concept, thus one could assume that he had knowledge of it; however, Mr Moodley rarely mentioned the terminology in class but did refer to the concept during the pre-interview. He stated:

> "Concept wise…I'm going to expect some problems on the topic of macro and microscopic changes. So they need to realize that if there is a change in the rearrangement of atoms, then you are getting a new substance being formed, but on a macro level, that might not be so".

His exclusion of the theme of macro and micro visualisation may be attributed to a lack of foresight with respect to forthcoming topics that required this interpretation. Furthermore, Mr Johnson was responsible for preparing notes and giving direction to Mr Moodley with regard to the subsequent content instruction, which may explain his diluted response.

Both teachers used the method of investigation to extract and consolidate the meaning of chemical change, however, Mr Moodley made an attempt to challenge the learners to practice Learning outcome 1 which encourages the use of process skills, critical thinking and scientific reasoning, as indicated in the National curriculum document (Department of education, 2003). He did this with the implementation of a task involving experimental design.

5.2.5 Curriculum materials

The creative teacher must make good use of resources and useful materials that enhance his presentation of the subject matter. Geddis and Wood (1997) suggest that the knowledge of appropriate curriculum materials, in relation to teaching strategies, add to the teachers' ability to transform subject matter.

The use of resources and materials were employed to different degrees in each classroom. Mr Moodley made extensive use of the chalkboard to communicate the procedure for the learner investigation and other information. He also used a transparency, briefly displaying the criteria to distinguish between chemical and physical change. Thereafter, he allowed learners to interact predominantly with laboratory equipment, with the exception of a sparkler which was burned.

Learners in Mr Moodley's class were uncertain about their classification of each event as physical or chemical change during the practical investigation, thus they instinctively resorted to textbooks to aid their understanding and decision. This resource was not recommended by the Mr Moodley. Perhaps he was not comfortable with the manner in which textbooks explained the subject matter; however, his practice was not congruent

with experienced chemistry teachers. Due to the abstract nature of the topic, the conventional method would involve exploring the meaning of chemical and physical change before engaging learners in practical investigations. This strategy would shed more light on the nature of their results and support their observations. In subsequent lessons, he used worksheets illustrating diagrams involving both physical and chemical changes, but he did not mention any defining characteristics of physical and chemical change in the first lesson.

Mr Johnson made use of a variety of resources which included everyday items that would be encountered outside the laboratory. These included a compact disc, books illustrating macro and micro representations, balloons, firecrackers, bulbs, heaters, different types of glue and a number of demonstrations using household substances. Furthermore, he used transparencies to illustrate microscopic models of physical and chemical phenomena. The chalkboard was implemented mainly to draw learner attention to symbols of chemicals that were being used. According to Gabel (1999), the threefold relationship of chemistry is central to the learners' ability to grasp this abstract subject. These include the macro, sub-micro and symbolic representations of matter.

The use of the respective resources drew attention to the different approaches used; furthermore, it indicated Mr Johnson's familiarity with the subject matter. He was able to draw on a number of materials to solidify the learning process and make it an exciting experience. Mr Moodley used the mundane resources that learners were accustomed to in a school environment.

5.3 Conclusion

There were many important differences in the PCK of each teacher within the framework that was used above.

Mr Johnson adopted a constructivist approach at the beginning of his lesson and made slight attempts to relate the section of chemical change to previous content that was covered, however, Mr Moodley did not rely on prior knowledge, and instead he approached the topic as an unrelated entity. While Mr Johnson made an effort to restructure his lessons to address misconceptions that emerged during the practical

investigation, Mr Moodley was not fazed by incorrect responses. However, he did resolve that the dissolution process indicated a physical change before learners perceived it differently. When Mr Moodley was asked how he would approach the issue of misconceptions, he stated:

> "I just propose to ask them questions at the end of the lesson and gauge from that. I'm going to know what to concentrate on….how to make them understand the differences between chemical change and physical change". (Interview)

The subject matter was predominantly represented with the use of experimental evidence. In the case of Mr Moodley, a single demonstration had been done and learners had to investigate further on their own. Mr Johnson was keen to represent both physical and chemical change in as many ways as he could, to the extent that he had run out of time in the first lesson. He used relevant comparisons; however, he limited these to macro/micro concepts. Mr Moodley attempted to link the subject matter on one occasion to household activities, for example, cooking. However, this was merely mentioned without any further elaboration.

Mr Johnson's attention to the macro/micro theme was remarkable. He ensured that relevant examples, for example, the Velcro tape, compact disc, and laser printer beads were used that captured learner attention at the very outset of the lesson. He was able to articulate his knowledge in a defined manner. Mr Moodley scarcely mentioned the concepts; in addition, no effort was made to elaborate with appropriate illustrations. Perhaps his focus on macro/micro concepts was inadequate since he did not exhibit a deep understanding of it. Furthermore, he may not have considered it as an important component of the learners' conceptual framework.

After transmitting important information, Mr Johnson's strategy involved the verification of a hypothesis regarding the classification of physical and chemical change. It seemed that Mr Moodley was comfortable with allowing his learners to formulate their own hypothesis after deducing criteria for a physical or chemical change to occur. The latter seemed to be more appealing as a scientist; however, it required good management and regular assistance.

Figure 5.3 indicated that Mr Moodley's approach was of a linear nature. He determined to stick to his plan, with slight deviation, if any. The nature of the classroom atmosphere indicated that Mr Moodley had difficulty managing practical investigations. Learners were rowdy and did not adhere to teacher instructions. Despite the fact that Mr Moodley was an experienced teacher, his practice depicted the behaviour of a novice teacher as described by Gess-Newsome & Lederman (1999b):

> "When experienced teachers are placed in a situation where they are asked to teach a topic outside their area of expertise, many of the characteristics found in novices re-emerge".

Mr Johnson's class was more focused on the task ahead and received instructions in an orderly manner. He was content to stop the learner investigation and address misconceptions; furthermore, he allowed time to recap on what he had discussed earlier. His approach seemed to cater more adequately for the "messy", non-linear nature of assimilation with respect to chemical concepts. Perhaps the balance between increased learner participation and limited teacher input was ineffective in Mr Moodley's strategy.

Both teachers were extremely single-minded about the objective of their instruction, that is, to differentiate between chemical change and physical change. Mr Johnson was more flexible with the content and was aware of links it would have to other topics for instruction at a later stage. He decided to confine his discussion to the present topic with the intention of avoiding unnecessary confusion. Mr Moodley had only engaged with the subject matter during his pre-service training, which had been 12 years ago. Therefore, he looked to Mr Johnson for direction regarding matters of curricular saliency.

Due to Mr Moodley's brief interaction with the topic, his resources, in comparison to Mr Johnson, who had been teaching chemistry for a number of years, were substantially limited. Furthermore, Mr Johnson's flexible knowledge and experience regarding the topic allowed him to compile a large amount of resource materials to demonstrate physical and chemical events. Mr Moodley initially utilized the chalkboard as his primary method of displaying information. Thereafter, he resorted to using worksheets. The variation of curriculum materials used by Mr Johnson served to pronounce the meaning of chemical change and physical change. Learners were exposed to colour-

coded transparency illustrations of ionic and molecular models, further enhancing the theme of microscopic interpretation.

CHAPTER 6

ASCERTAINING TEACHER AND LEARNER SUBJECT MATTER KNOWLEDGE

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6.1 Introduction

In 1986 Shulman reviewed the evaluation of teachers and noticed a loophole in the system, namely the absence of subject matter knowledge. He stated that a teacher needed to demonstrate knowledge of the subject matter; furthermore he suggests that subject matter knowledge is one of the critical prerequisite elements of pedagogical content knowledge.

Gess-Newsome and Lederman (1999b) suggest that an essential type of knowledge base for teachers is conceptual knowledge which is characterized by "facts, principles, concepts and procedures" that are typically taught in a secondary school. They describe the differences between experienced teachers who possess a strong conceptual knowledge and those that do not have expertise in the same area of certification, but may have pedagogical experience. This is detailed in table 2.1 in chapter 2.

This chapter deals with teacher and learner subject matter knowledge which was gleaned from pre-interviews, lesson observations, post-interviews and a diagnostic assessment. The diagnostic test was administered after instruction on the topic of physical and chemical change was complete. The learner scores are discussed and commonalities and differences are highlighted. Thereafter, teacher responses are discussed and possible links between teacher content knowledge and learner performance is explored. Finally, commentary with respect to the nature of learner learning, evident in their diagnostic assessments, is elaborated upon.

6.2 The diagnostic assessment

Most of the content of the diagnostic test (see appendix 6) was adapted from Taber (2002) where he described common chemical misconceptions that arose among learners. I chose to use Taber's (2002) examples because they had been used and piloted before, which served to contribute to the validity and the reliability of the instrument. Each of the test items were chosen in order to assess learner understanding in relation to

what was taught in previous lessons. The first question required an explanation of terminology, which is, differentiating between chemical and physical change. The second question required learners to explain the macroscopic view and microscopic interpretation regarding the melting of ice, while question 3 interrogated mass changes that were unique to the rusting process. Finally question 4 illustrated the dissolution of sodium chloride which required learners to write a symbolic chemical equation process and classify a precipitation reaction as a physical or chemical change. Questions 1 and 2 demanded low levels of cognition. These questions assessed the learners' ability to recall information. Question 2 and 4 necessitated an application of learner knowledge and required an understanding of microscopic and macroscopic concepts. Questions 3 required analysis and interpretation of a chemical reaction where the notion of mass conservation was challenged. All test items were familiar to learners to some degree and had been discussed as examples of physical or chemical change during prior lessons. The test was purely a diagnostic assessment and did not reflect any mark allocation in order to reduce performance anxiety.

The purpose of the diagnostic assessment was to ascertain the nature and level of learners' knowledge and the corresponding teacher knowledge after instruction. I wanted to find elements of learner answers that could be linked to specific actions that the teacher had made, hence to unpack their PCK. The teaching in this particular study was not seen as an intervention in which I tried to extract what knowledge gains the learner made during instruction, rather to establish learners' conceptions after instruction. Hence, a pre-post test was not considered, since the focus was on what the teacher did or said during instruction.

Two categories were assigned to learner responses, namely: correct and not attempted; for the purpose of highlighting trends in their performance. Where the possibility of two answers emerged (e.g. question 4.1), I assessed the justification for the corresponding classification and then categorized the answer as stated above. Furthermore, an effort was made to link their responses back to teacher content knowledge, an essential component of PCK as commented by Shulman (1986), among others.

6.3 Representations of learner responses for the diagnostic assessment

Table 6.1 and 6.2 show the percentage correct responses that learners achieved for the diagnostic test in Mr Moodley's class and Mr Johnson's class respectively. Most of questions 1 and 2 (with exception of question 2.3 in Mr Moodley's class) were answered well. Learners showed a competent understanding of differences between physical and chemical change and microscopic views of matter. Question 3 (rusting phenomenon) was answered poorly in both classes and is known to be a common area of difficulty for learners (Kind, 2004). Mr Moodley's class experienced more problems with question 4.1 which involved the dissolution of sodium chloride. This issue is highlighted later in the chapter. Finally question 4.2 was poorly approached in both classes due to their lack of knowledge with regard to ionisation reactions.

Table 6.1:Diagnostic test results for Mr Moodley's class

Question	Correct responses	Not attempted	Teacher response
	n (%)		
1.1	15 (83)	0	correct
1.2	17 (94)	0	correct
2.1	16 (89)	0	correct
2.2	15 (83)	0	correct
2.3	8 (44)	4	correct
3	8 (44)	2	incorrect
4.1	10 (56)	0	correct
4.2	0 (0)	2	incorrect
4.3	14 (78)	1	correct

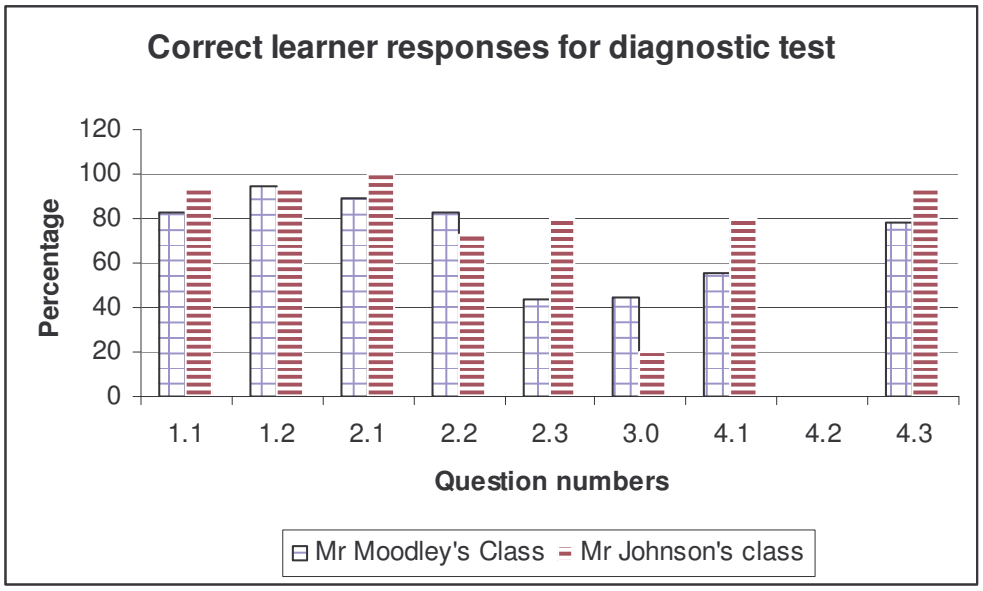
n = 18 learners

Table 6.2:Diagnostic test results for Mr Johnson's class

Question	Correct responses	Not attempted	Teacher response
	n (%)		
1.1	14 (93)	0	correct
1.2	14 (93)	0	correct
2.1	15 (100)	0	correct
2.2	11 (73)	0	correct
2.3	12 (80)	2	correct
3.	3 (20)	0	correct
4.1	12 (80)	0	correct
4.2	0 (0)	2	correct
4.3	14 (93)	1	correct

n = 15 learners

Figure 6.1: Graphical representation of learner results in both classes



The bar graph serves to give the reader a comparative glance at the learner responses in the diagnostic test. Mr Johnson's class gave a better account of themselves as described in the graph; however, his learners were not as certain with questions 2.2 and 3. If learners omitted a particular question, it was assumed that they could not do that question, as reflected for question 4.2. Learners' results and important similarities or differences will be discussed in more detail in the following paragraphs.

6.4 Learner responses - similarities and differences

Question 1: Do you know the difference?

1. Explain the meaning of each of the following terms (in your own words):

1.1. Physical change
1.2. Chemical change

The differentiation between physical change and chemical change was generally well answered in both classes. Learners expressed the meaning of the terms in a very similar fashion, using key words that had been used by their respective teachers. While the learner responses attracted a majority of accurate answers (an average of 91% across the grade), the phrasing of their answers were similar in many respects.

The use of similar phrases that was noticeable in learner responses to question 1 indicated evidence of rote learning, even though responses were suppose to be idiosyncratic as requested. Perhaps this practice is the norm among learners when stating definitions. Voelker (1975) conducted a study concerning physical and chemical change with grade 4-6 learners. He made the following conclusion with respect to their understanding of concepts:

> "Children are more able to reveal their understanding of the concepts physical change and chemical change through classifying phenomena rather than formulating definitions or applying concept definitions".

Therefore, question 1 ascertained their ability to simply recall or regurgitate their knowledge; understanding was not necessarily reflected. This practice was also evident in the practical investigations that learners engaged in prior to the diagnostic assessment. Consequently, some of their classifications were incorrect, for example, two groups in Mr Johnson's class considered the burning of magnesium to be a physical change since the product was a 'soft ash' (magnesium oxide). Their reason was that a change in form had resulted which was one of the characteristics that Mr Johnson had used to describe physical change in his transparency notes (illustrated in chapter 4).

Question 2: Melting Ice

2. Figure 1 shows a container of ice cubes that are in the process of melting and figure 2 indicates an illustration of the macroscopic and microscopic views of the ice cube.

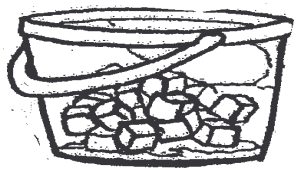


Fig. 1

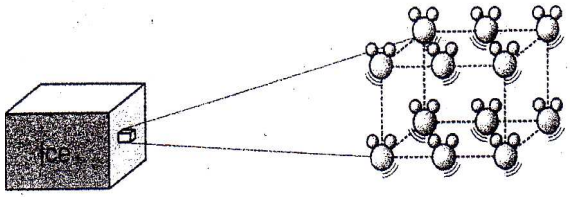


Fig. 2

2.1. Is the process of ice melting a chemical or physical change? Explain your answer.
2.2. Explain what happens on the microscopic level when ice melts.
2.3 What will be observed on the macroscopic level?

Question 2.1 was extremely well answered by Mr Johnson's class. All his learners maintained that a physical change had occurred, while 89% of Mr Moodley's class responded correctly, a slight difference. Both question 2.2 and 2.3 required understanding of macro/micro concepts. In question 2.2 learners had to explain what microscopic changes took place during the melting process and question 2.3 made reference to macroscopic observations that would result. 83% of Mr Moodley's learners made reference to microscopic changes while 73% of Mr Johnson's class was successful in this regard. Question 2.3 was poorly answered by Mr Moodley's class. Only 44% of the learners gave correct responses concerning macroscopic observations and 22% did not attempt the question. In this instance, Mr Johnson's class was more certain of the meaning of macroscopic and microscopic concepts.

With reference to question 2.2, Mr Moodley's class seemed to be more aware of microscopic implications; however, misconceptions were common to both classes. Of the four learners who answered incorrectly in Mr Johnson's class, 2 of them stated macroscopic views, while the other 2 learners commented on a microscopic view, but with incomplete responses that needed more clarity. These were their respective answers:

Peter: The bonds change but not the properties.

Sipho: Molecules change when ice melts.

Periodically, learners in both classes did confuse macroscopic observations with microscopic changes; consequently they swapped answers for questions 2.2 and 2.3, or else, they only spoke of microscopic observations in both instances. This phenomenon was more evident in Mr Moodley's class.

Two learners in Mr Moodley's class loosely commented that electrons or protons would move further apart when ice changed phase to liquid water. This was not the case in Mr Johnson's class. Six learners in Mr Moodley's class incorrectly referred to atoms of water in either question 2.2 or 2.3, while one learner in Mr Johnson's class made the same error. This evidence suggests that Mr Moodley's learners did not have a strong understanding of the difference between atoms, molecules and sub-atomic particles. However, a greater percentage of them were able to describe microscopic changes of ice.

Mr Moodley's class responded better to question 2.2 which was an unexpected outcome. Mr Johnson's illustrations of the difference between macro and micro views did achieve the expected result in 2.3, but not in 2.2. His instruction focused much attention on the difference between microscopic and macroscopic views. Many illustrations of the latter views were given during his lesson. As a result, learners may not have been aware of what microscopic interpretations entail, thus their inadequate result. Even though the data compares learner results accurately, it is risky to draw too many conclusions from their respective responses. Furthermore, both classes were not ability grouped, thus the variations in their respective responses.

Question 3: Rusty nails

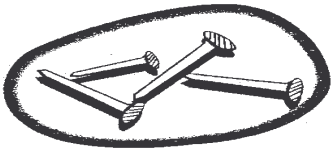
3. You have four nails made of pure iron. You record the total mass of the four dry nails. All the nails are put in a moist, open dish and exposed to air over several weeks. Weeks later you notice the nails are covered with rust. You let the nails dry completely and record the total mass of the rusted nails, being careful that no rust falls off as you mass them.

What do you predict will happen to the mass of the nails? Circle your prediction.

A *The mass of the dry, rusted nails will be more than the mass of the dry nails before they rusted.*

B *The mass of the dry, rusted nails will be less than the mass of the dry nails before they rusted.*

C *The mass of the dry, rusted nails will be the same as the mass of the dry nails before they rusted.*



Explain why you selected the respective prediction above

Question 3 involved the rusting process as described above. Dry nails had been exposed to moisture and air in an open system and allowed to rust. This question assumed that learners knew a chemical change had occurred (which had been discussed in class), however mass relationships between the reactants and products were fundamental to question 3. Mr Johnson's class performed poorly (20% correct) while Mr Moodley's

class achieved 44% of correct responses. Twelve learners in Mr Johnson's class gave incorrect responses. Six chose option B and 6 chose option C. Mr Moodley's class had 8 incorrect responses, of which, 3 chose option B and 5 chose option C. The correct answer was option A. The question had referred to an 'open dish' which would imply that the oxygen from the air would combine with the iron to form iron oxide. The additional mass of the oxygen atoms would result in a greater mass of the product.

Learners assumed that the Law of Conservation of Matter would hold true, thus option C was favourable, even though it was an open system. Two learners from Mr Moodley's class made reference to the above law and others indicated it was a physical change; therefore no 'new' products had formed. All Mr Johnson's learners referred to an unchanging mass. Option B was regularly selected since learners perceived the rusting process as a decay of iron nails, hence the resultant mass loss and decreased density was frequently mentioned in both classes. Kind (2004) speaks of learners' chemical misconceptions and suggests the following:

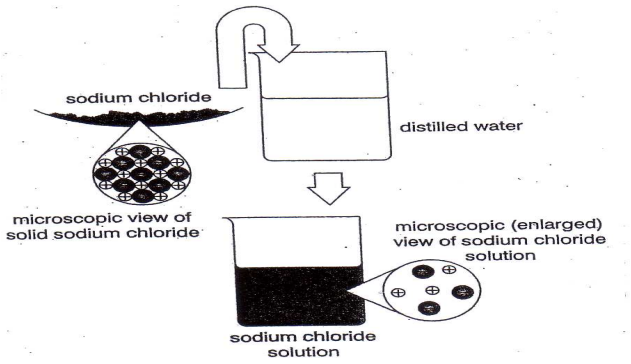
> "The atmosphere is invisible to the eye - and students' reliance on concrete, visible information means they therefore often avoid the role of oxygen in their explanations for open system reactions. Even if the role of oxygen is appreciated, the notion that gases do not have mass means that students do not realise that solid products of an oxidation reaction have more mass than the starting solid".

In their study with high school learners, Hesse and Anderson (1992) made the same observations as Kind (2004) regarding the inability of learners to understand the role of invisible gaseous reactants

During the pre-interview, Mr Moodley did make reference to the concept of mass conservation. His intention was to focus on this concept and he identified it as an area of difficulty for the learners. However, this was not mentioned during his instruction, perhaps this concept was elaborated upon after I had collected the data and before the diagnostic assessment was given. Nevertheless, his learners performed better in this question and their understanding was evident in their answers, thus the speculation above may be true.

Question 4: Salty water

4. Figure 4 shows solid sodium chloride that is dissolved in a beaker of distilled water.



4.1. Is the process illustrated above a chemical or physical change? Explain.
4.2. Write a simple chemical equation using chemical formulae that will represent the process in figure 4.
4.3. The salt solution is now added to silver nitrate solution. A white precipitate is formed as one of the products. Is this change physical or chemical? Explain your response.

With reference to question 4.1, Mr Johnson's class seemed to understand dissolving to be a physical change and could explain more readily why they thought so. Mr Moodley's class was insecure in their approach with many incorrectly substantiated choices. This question attracted poor responses from Mr Moodley's class. This may have been attributed to his attempts to portray the dissolving of salt as a 'grey area'. However, during the pre-interview, Mr Moodley maintained that he would not mention this uncertainty to his learners (see the CoRe in chapter 4). Most of his learners could not readily substantiate their classification of either physical or chemical change for this process, while Mr Johnson's class was confident with this question. He mentioned it as a 'grey area' to his learners as well (in chapter 4); however, he did not elaborate. He categorically indicated that it was a physical change during his instruction.

Both classes performed at identical levels in questions 4.2. None of the learners wrote the correct chemical equation to represent the dissolution process, even though they knew the reactant and had discussed this example in prior lessons, especially in Mr

Johnson's class. He had showed an illustration on transparency of the dissociated ions in sodium chloride. Writing the ionization equation for sodium chloride was clearly an area of difficulty. Most learners knew the reactant, however, they could not write the corresponding product. Both teachers had suggested that learners' chemistry background knowledge was inadequate (chapter 4), especially their ability to write chemical formulae, consequently chemical equations. However, neither teacher wrote the ionization equation on the chalkboard during the explanations.

All of Mr Johnson's learners correctly answered 4.3 with the exception of one learner who did not attempt it. Mr Moodley's class was less certain in comparison with 78% of the learners making correct conclusions. In this case, the correct classification was generally given; however, a minor contingent considered it a physical change because the substance had changed 'form'.

6.5 Teacher responses - similarities and differences

Both teachers expressed the same understanding of physical and chemical change by virtue of similar definitions of the concept, however, the depth of their understanding was reflected in the way they answered diagnostic questions on the topic. This could be attributed to the fact that each teacher was qualified in different disciplines of science (biology and physical science) thus the distinct difference between Mr Moodley and Mr Johnson's content knowledge. For example, when asked to explain the meaning of physical change, these were their respective responses:

Mr Moodley: Change when no new substance/product is formed.

Mr Johnson: Change in a physical state or form of the substance, that is, the identifying properties of substance remains unchanged – usually a change in temperature, pressure or phase.

To some degree, the detail of the above explanations indicates the depth of their understanding. However, their responses regarding chemical change (question 1.2) were almost identical, as was other test items, with the exceptions listed below.

The "Rusty nails" question in which nails were exposed to air and moisture in an open system attracted different responses from each teacher. Mr Moodley maintained that the

mass of the dry, rusted nails would be equal to the nails before rusting due to the Law of Conservation of Mass in a chemical change. He made the following claim:

> "The Law of Conservation of Mass states that in chemical reactions no mass is lost or gained. Above experiment involves a chemical change so no mass is lost or gained".

The above claim illustrates an almost rote learned response to the question and is common when misconceptions of open systems is evident. Mr Johnson maintained that the resulting mass would be greater after rusting occurred due to the addition of oxygen atoms (from the air) to form iron oxide.

Finally, the diagnostic test indicated a further discrepancy regarding the dissolving of sodium chloride (question 4.1). Mr Johnson maintained that it was a physical change and wrote the correct ionization reaction:

$$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$$

Mr Moodley's answer reflected that it was both a physical and chemical change. He referred to it as a 'grey area' and made the following comment:

> "Could be a physical change as when H_2O evaporates – salt is retrieved. Could be a chemical change as salt solution can conduct electricity and pure H_2O and salt cannot conduct electricity".

Furthermore, he did not write the ionization reaction for the dissolving of salt in the presence of water and proceeded to the next question. This response could be attributed to his uncertainty concerning the correct classification, or he may have not been familiar with the chemical equation.

The response regarding the dual characteristic of the dissolution of salt that Mr Moodley offers is in agreement with Gensler's perception (1970), cited in Kind (2004) and is mentioned in earlier chapter 2. He suggests that the process of dissolving may be classified as chemical change since sensory evidence supports this notion. Mr Moodley argued his standpoint well when referring to the electrical conductivity of a solution of sodium chloride, thus a sound justification for chemical change was given.

During the pre-interview, Mr Moodley did express that he was not confident with regard to his knowledge of physical and chemical change. He also stated that he did not have the relevant experience in teaching this concept, thus, by implication; his PCK was inadequate in this area. When asked what he thought chemical change was, he responded by saying:

> I think, from the readings I've done, it is the rearrangement of atoms where new bonds are formed.

While this is the correct interpretation of chemical change, his uncertainty was noticeable in his response. His response also showed that he made an effort to research the topic rather than depend on his more experienced colleague, Mr Johnson. However, Mr Moodley still gave an incorrect response to the 'rusty nails' question. Perhaps he did not explore this chemical change or his response could reflect his inherent knowledge regarding the rusting process.

6.6 Teacher content knowledge in relation to learner performance

The relationship between teacher content knowledge and learner achievement is not unique to this study. According to Gess-Newsome & Lederman (1999a), the "intuitive belief in the relationship between teacher knowledge and learner achievement has persisted", even though there have been weak associations in many instances.

There were certainly links between teacher subject matter knowledge and learner performance in the diagnostic assessment. Mr Moodley's uncertainty with respect to the dissolution of salt reflected in his learners' dual responses. Furthermore, his intention to focus on mass conservation was somewhat beneficial in relation to Mr Johnson's class, even though Mr Moodley interpreted the question incorrectly. Mr Johnson's class was more comfortable with their understanding of physical and chemical change and could readily differentiate between the two when required. He made this difference explicit by using a great deal of repetition accompanied with relevant teacher demonstrations.

Question 4.1 was a conceptually difficult question for learners. Mr Johnson's learners may have scored better results here, but this was due to his rigid classification of the dissolution process. In Mr Moodley's class, 10 learners explained it correctly, 7 as a

physical change and 3 as a chemical change with correct justifications in all cases. Eight learners answered incorrectly and all indicated that is had been a chemical change, but with inaccurate substantiations. The learners who answered incorrectly were unsure about the change that had occurred because Mr Moodley had not made it explicit in his explanation. Perhaps a demonstration of the dual nature of the dissolution process would be advisable at that stage in order to cement learner understanding.

The merits and demerits of creating ambiguity with respect to Mr Moodley's approach had an impact on learner performance. It was detrimental for learners who could not grasp the co-existence of physical and chemical change, while those who could gave insightful responses and justified their classification. Furthermore, it allowed learners to realize that science is not absolute and conclusive in all cases.

Question 4.2 attracted incorrect responses by all learners in both classes. Mr Johnson had made reference to the nature of the dissolution of sodium chloride in water; in addition, he showed his learners a transparency depicting the dissociated ions in solution as indicated before. However, he did not write the accompanying ionization equation for sodium chloride on the chalkboard. Mr Moodley did not write the ionisation reaction or make reference to the formations of ions in solution during his explanation of the process. The omission of the ionization reaction may be motivated by the fact that it was outside the scope of the curriculum at the grade 10 level. Therefore, since both teachers did not reflect it on the chalkboard, the learners did not retain this knowledge, hence their poor performance. Consequently, it was unfair of me to ask learners to reproduce a symbolic representation of the dissolution of sodium chloride.

There are instances where the connection between teacher content knowledge is not congruent with learner performance. Mr Johnson's knowledge of macro/micro concepts was repeatedly well illustrated in comparison to Mr Moodley. The corresponding learner performance indicated that they were more self-assured with the fundamental characteristics of chemical and physical change (see 2.1 & 4.1 results); in addition, their understanding of macroscopic views was richer. However, learner results in Mr Johnson's class did not reflect absolute certainty with microscopic interpretations. Gabel (1999) refers to the threefold relationship that teachers must be aware of, namely:

macro; sub-micro (particulate); and symbolic which is mentioned earlier in chapter 5. She maintains the following:

> "…it is important that teachers understand the threefold relationship so that it can be conveyed to their students. It is my experience after making presentations to high school teachers about integrating the three levels, that many teachers have not considered it in their own thinking".

Mr Johnson understood the three levels of chemistry and made a concerted effort to explore these representations, however, his learners may have not retained this knowledge in their long term memory.

Mr Moodley did not give any tangible attention to microscopic views, but his learners performed better in question 2.2. However, it is risky to rely solely on learner performance as an irrefutable indicator of teacher PCK as mentioned earlier, thus other characteristics must be cumulatively considered.

6.7 Conclusion

Mr Johnson's subject matter knowledge within the context of chemical change was flexible and extensive. His responses in the diagnostic assessment reflected a clear, definitive understanding of the topic and an ability to communicate this knowledge with ease. Each of his responses was accurate and complete, fulfilling the expectations of each question. Gess-Newsome & Lederman (1999b) describe the nature of Mr Johnson's knowledge in making the following comment regarding teacher conceptual knowledge:

> "Teachers with strong conceptual knowledge have more detailed knowledge of the topic, more connections and relationships to other topics, and can easily draw upon this knowledge in teaching and problem solving situations".

Mr Johnson maintained a structured approach because he knew the subject matter, thus he was less tentative. He stated earlier in chapter 5 that learner misconception would be minimised after instruction. This was not apparent in the learner results of the diagnostic test and was not a realistic expectation of an experienced teacher. Learners' misconceptions are unique and intrinsic and may be extremely difficult to replace with correct conceptions, even after a period of instruction. Some of his learners referred to "key words" in their responses. This indicates that they distinguished chemical and

physical change based on words used, which speaks of rigidity in approach. Perhaps, this may be the reason for their poor performance in some areas of the diagnostic test.

Generally, Mr Moodley's responses to the diagnostic test indicate that his knowledge was not as flexible. His concise answers showed that he did not have much to contribute; furthermore, some of his responses lacked depth. Thus, his content knowledge was more limited and convergent in comparison to Mr Johnson. Mr Moodley's response to question 3 ('rusting nails') was incorrect and he omitted another question regarding the ionization of sodium chloride. However, his class responded better in comparison to Mr Johnson's class in question 3. Mr Moodley may have interpreted question 3 as a closed system, hence his corresponding choice, but this is merely speculation on my part. Furthermore, he may have omitted the ionization equation due to his perception of dual classification of the event; however, this is an assumption as well.

Mr Moodley's approach was much more tentative and relaxed. His investigative approach may have been more beneficial since he allowed learners room for discovery and uncertainty, and kept his intervention to a minimum. His methodology indicated that he was more aware of the nature of science. This was the defining difference between the respective practices of Mr Moodley and Mr Johnson.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

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7.1 Introduction

This chapter begins with a brief overview of the research study and thereafter focuses on the critical reflection of the study, particularly on the methodology and proceeds to discuss the findings. A summary of the findings with respect to the research questions is elaborated upon, drawing conclusions where necessary. The limitations of the study with respect to relevant strengths and weaknesses are delineated. Finally recommendations of the research are detailed and directions for complementary research close the chapter.

7.2 Overview of the study

The study attempted to investigate how two teachers transform their subject matter knowledge regarding the topic of chemical change when teaching grade 10 learners. Mr Johnson has 33 years of experience in Physical Science teaching and Mr Moodley has 11 years of teaching experience, however, his area of expertise is Life Sciences (formerly referred to as Biology). The study captures and documents the manner in which each teacher expresses their PCK using Content Representations (CoRes) and relates their practice through the use of Pedagogical and Professional experience Repertoires (PaP-eRs). Salient features of each teacher's PCK are highlighted and corresponding conclusions are delineated with respect to how they manage to transform their subject matter knowledge for teaching. Recommendations and directions for complementary research are briefly discussed toward the end of the study.

7.3 Critical reflection of the study

7.3.1 The methodology

Many proponents of PCK have alluded to the notion that it is elusive, tacit and difficult to describe. While there are generic teaching skills that are common in the profession of educators, Bucat (2004) suggests that each chemistry teacher has a "unique knowledge of chemistry" and the prospect of duplication of this knowledge for students is unlikely. He maintains that science teaching is "afflicted with professional amnesia" due to the fact that their strategies are seldom captured and recorded for use of new teachers. Loughran et al. (2004) also suggest that PCK is difficult to articulate since it is an

internal construct that many teachers inherently possess, but rarely discuss among themselves.

This study has attempted to follow the Loughran et al. (2004) methodology of capturing and documenting PCK through the use of CoRes and PaP-eRs. The CoRe allowed me to form an outline of what each teacher represented as aspects of PCK, however, the CoRe alone was insufficient. The CoRe allowed for insight into "important features of the content" (Loughran et al., 2004) and the PaP-eRs delineated the actual classroom practice of each teacher. They were instrumental and complementary to the CoRe, thus producing a more complete portrayal of their respective PCK. It is also important to note that both the CoRes and PaP-eRs are not solely the utterances of each teacher; they were constructed by me using insights extracted from discussions and field notes of lesson observations.

This study was based on the content knowledge of two teachers and their related practice, unlike the Loughran et al. (2004) study that used a number of expert science teachers. Therefore, a richer reflection of PCK for chemical change would have been forthcoming if I used a larger sample of experienced chemistry teachers and non-chemistry teachers.

The diagnostic test was administered after the instruction. If I repeated the study, I would administer it before the instruction to both teachers and learners and post instruction as well. This would enable me to track changes in teacher and learner understanding and content knowledge, making the respective differences more explicit.

7.3.2 Discussion of the findings

Chemical change is conceptually difficult for learners due to the abstract nature of chemistry. Evidence of this is reflected in the learner performance in the diagnostic tests. Generally answers reflected an average understanding of chemical change; however, there were instances where serious misunderstandings and misconceptions were evident. Mr Johnson's class gave a better holistic account of themselves in the diagnostic tests; however, the difference between both classes was marginal.

Gabel (1999) suggests that various instructional barriers hinder the understanding of chemical change as mentioned earlier in chapter 2. She includes the link between macro, micro, and symbolic levels as one of the factors. Mr Johnson perceived the connection between macro, micro, and symbolic as an important part of his instruction. He used illustrations and examples to describe the macro/micro characteristics and wrote the symbolic notation on the chalkboard when referring to a compound that he was using. In contrast, Mr Moodley admitted that it would be problematic for learners to understand the links between the three representations of matter; however, he did not give this relationship the attention it warranted. Nevertheless, his learners did grasp the concept of microscopic descriptions as indicated in their test results. Common to both classes was their inability to write the ionisation equation for the dissolution of sodium chloride in symbolic form. However, this representation was not a prerequisite in their syllabus at that level of study and it was not indicated by either teacher, hence the poor learner performance.

The second factor that Gabel (1999) suggests is the use of practical work that is not successfully integrated. Both teachers employed a practical approach in their instructions, but in disparate ways. Mr Moodley used it as an introduction into chemical change, with an unguided discovery approach, and integrated it in his subsequent lessons. He expected his learners to formulate a hypothesis and then verify whether it was true or false. Learners were not adequately experienced in this type of investigation, thus it was an unfair expectation. Mr Johnson used practical work to consolidate his teaching of chemical change. He facilitated the practical work and gave explicit instructions to his learners. He expected learners to verify a hypothesis as opposed to Mr Moodley's strategy. The integration of practical work was consistent with common practice at this point in the instruction and was linked to his prior 'lecture'.

Gabel's (1999) third factor which serves to be an instructional barrier is the use of unfamiliar chemicals. Mr Moodley used familiar chemicals and elements in the practical work as well as his instruction, that would be expected at the grade 10 level. However, they were mostly related to classroom type materials. Mr Johnson also used substances that were commonly located in the laboratory; however, his demonstrations included the precipitation reaction resulting from mercury chloride and potassium iodide, an obscure choice at that level. The bright orange precipitate surprised learners,

but they did not understand why it had occurred, or what product had formed, but they recognised it as a chemical change by virtue of Mr Johnson's definition. Consequently, his learners were more confident with the precipitation question in the diagnostic test and classified it correctly as a chemical change.

Mr Johnson began his lesson on chemical change with a constructivist approach. He recalled prior discussions relating to chemical bonding and made reference to the Periodic table of elements and the likelihood of bonding between certain elements. Both Scott et al. (1994) and Hewson & Hewson (1984) comment that constructivist approaches make the learning process meaningful, furthermore essential links are created by the learners. The ability to move from the known to the unknown is an important skill for teachers to master. Mr Moodley made little attempt to contextualise the topic and establish links between the known and unfamiliar. He expected learners to accumulate this knowledge through their interaction with each other and himself. Thus, Mr Johnson's learners were more capable of applying their knowledge on chemical change after a long period of time as indicated in the diagnostic test, which was a common finding in the study conducted by Scott et al. (1994).

Both teachers displayed typical pedagogical knowledge in the classroom. Bucat (2004) refers to pedagogical knowledge as one's "understanding of teaching and learning processes independent of subject matter". With regard to PCK, he maintains that it incorporates the teaching and learning demands of specific subject matter and includes the learning demands within that subject matter. There is a tendency of the data to suggest that Mr Johnson's PCK was richer than Mr Moodley's in most respects. However, Mr Moodley's strengths were in fact Mr Johnson's weaknesses. Mr Johnson's approach illustrates a tightly packaged subject matter that is rigid. Rigidity expels lateral thinking and leaves no space for explorative learning. He did not allow learners to wrestle with their constructions of knowledge and neglected to discuss 'grey areas' within the topic. Mr Moodley allowed his learners to behave as 'scientists' in their approach to uncovering criteria for chemical change and physical change. They were expected to formulate a hypothesis and test it. He was content to acknowledge his dissonance with the dissolution of sodium chloride as a physical change and discussed his views with his learners, unlike Mr Johnson. Mr Moodley was more tentative in his approach and permitted an unrestricted, liberal learning atmosphere in his classroom.

7.4 Summary of the findings

The aim of the study was to examine the PCK of two teachers involved in the instruction of chemical change at a grade 10 level (15-16 year old). This section presents the main research findings and attempts to answer the research questions of the study.

7.4.1 Research question 1:

What are the distinct features of PCK of an experienced physical science teacher and a non-specialist chemistry teacher when teaching chemical change?

Both teachers were familiar with general pedagogical knowledge; however, there were important distinctions in their PCK with respect to the instruction of chemical change.

Mr Johnson's approach was influenced by his flexible knowledge of the content and he navigated with ease through the salient elements included in the topic, especially his unpacking of the macroscopic view and related microscopic interpretations. His initial strategy was teacher-centred and did not leave much room for learners to engage with him if their understanding was incomplete. However, he adjusted his approach in subsequent lessons and allowed for learner investigation and experiential learning. Furthermore, he was able to gauge learners' uncertainty with their knowledge of chemical and physical change and intuitively decided to halt proceedings and address misconceptions and alternate conceptions that emerged. He also used a constructivist approach in the introduction of the topic and consistently used prior learner conceptions as a support for new knowledge. Mr Johnson's awareness of the curriculum ensured that he was able to emphasise particular aspects of the topic of chemical change since he knew that it would form a foundation for subsequent topics that learners would engage in. Therefore, curricular saliency formed an instrumental part of his PCK and allowed him to position his strategy more effectively.

Mr Moodley adopted a much looser approach and allowed learners to decide the depth of their understanding with respect to chemical change using an unguided discovery strategy. Learners engaged in an investigation in order to uncover the criteria that would distinguish between chemical change and physical change. The lack of teacher

intervention presented more discipline issues for Mr Moodley, consequently much time was wasted dealing with related matters, however, his approach suggests that he was more aware of the nature of science. His classroom practice indicated lack of awareness of curricular saliency and a lack of confidence in his subject matter knowledge was illustrated in the diagnostic test. Furthermore, shallow attempts were made to address misconceptions and no attention was given to learners' prior knowledge as a means to consolidate their understanding. Mr Moodley's mechanical approach was evident in his use of limited subject matter representations. Examples of physical and chemical change were limited to the classroom context, which were conducted by the learners in their initial investigation.

7.4.2 Research question 2:

What impact does subject matter knowledge have on PCK?

Subject matter knowledge is an essential component for good PCK as alluded to by van Driel et al (2002), Shulman (1986), and other proponents of PCK.

Mr Johnson exhibited significant subject matter knowledge. His content knowledge was primarily evident in his responses to the diagnostic test and his answers showed a greater certainty and insight regarding the topic. His utilisation of a wide range of examples and resources during his lesson indicated a strong awareness of the topic. Mr Johnson had flexibility in his knowledge of content that allowed him to navigate more effectively. Gess-Newsome & Lederman (1999a) suggest that teachers uncertain about their conceptual knowledge show reduced flexibility in teaching, while experienced teachers have coherently structured rich subject matter structures. Mr Johnson's confidence directed his structured methodology and allowed for purposeful teaching and learning, essentially, a grounded PCK.

Mr Moodley's content knowledge was noticeably inadequate by his own admission and may be expected due to his novice status with respect to the subject matter. His diagnostic test answers were less insightful and detailed. However, he was content to express uncertainty with his knowledge and embraced the tentative nature of science. As mentioned earlier, his strengths were evident in his instructional strategy.

7.4.3 Research question 3:

How does each teacher transform their subject matter knowledge into accessible forms?

The use of appropriate teaching methods assists the teacher in effective transformation of subject matter knowledge. Both teachers used a practical approach (macro observations) in order to facilitate their transformation of the subject matter into a comprehensible form. Mr Johnson illustrated many familiar macro examples to communicate the essence of chemical change before allowing any practical investigation to ensue. His consistent linking of macro views and micro interpretations helped to facilitate the process of assimilation. He chose a series of investigations that would cement the learners' understanding of the topic and carefully focused his attention on the justification for the respective classification of each chemical or physical event.

Mr Johnson's constructivist approach assisted the transformation of subject matter. He used learner prior knowledge to introduce the difference between macro and micro interpretations and regularly used this link to form a vivid understanding of concepts. Bond-Robinson (2005) suggests that 'transforming explanations' must incorporate prior knowledge, that is, a constructivist approach. Furthermore, his experience and expertise allowed him to instinctively guide the learning process. He recapped important concepts after each lesson which allowed for consolidation and exposure of inherent misconceptions.

Mr Moodley began his first lesson with an unguided discovery practical approach with examples of physical and chemical change that were strongly based on 'classroom chemistry'. This approach did not enable an effective transformation of subject matter knowledge since learners had no background knowledge of the concepts. Consequently, they were uncertain about their observations and inferences during the investigation; furthermore, Mr Moodley did not offer much guidance.

There was no evidence of consistent linking of learners' macro experiences with the microscopic world of chemistry. It was explicit in his notes, however, tacit in his

practice. He did not refer to any prior knowledge that learners may have had, instead he approached the topic as a foreign concept. In some instances, his subject matter knowledge resembled a rote-learned understanding of physical and chemical change (indicated in the diagnostic test); therefore the transformation was not as effective as in Mr Johnson's case. This factor was also evident, to a small extent, in the learner results of the diagnostic tests.

The CoRe and PaP-eRs were crucial tools that enabled me to record each teacher's practice and it provided a means of making the PCK explicit rather than tacit.

7.5 Limitations of the study

The section examines some of the factors that constrained the research study. Reflection of the study is an important component to be considered since it allows the researcher the platform to be critical about their work and objectively highlight the strengths and weaknesses that may be inherent in the study. Opie (2004) maintains that limitations in any study are inevitable and the admission of these does not suggest a shortfall, but does illustrate that one is thinking critically about one's work.

The research methods followed in this study were mainly of a qualitative nature which examined the pedagogical content knowledge (PCK) of two teachers. While such an approach allows for a sharp focus on the practice of teachers in a closed system, the sample is small. Therefore, the tendency to make generalizations of all the findings is compromised to a certain extent.

Conducting research may change the behaviour of the respondent. Due to the nature of a case study, respondents may be influenced to portray an inaccurate account of their actual teaching strategy in the presence of the researcher. Thus, a learner centered approach may have not been a usual occurrence in the daily practice of each teacher, as implied by Mr Moodley in the pre-interview. However, a teacher-centered approach may be necessary due to the length of the present curriculum and the pressure to complete it in the allocated time.

The construction of the Content Representations (CoRes) that were formed by Loughran et al. (2004) consisted of the interactions of many in-service science teachers who were experienced and grounded in the PCK as mentioned earlier in chapter 2. Thus richer Pedagogical and Professional experience Repertoires (PaP-eRs) were extracted from their collective practice with more 'big ideas' in the CoRe which are reflected. The present study highlights the CoRe for each teacher which was constructed from their practice and interviews, in addition the CoRe comprises of one big idea as illustrated in chapter 4.

The diagnostic tests were administered to both classes after a significant period (2 weeks) with respect to the instruction. This may have allowed for responses that were an untrue reflection of the learners' knowledge, however, the time gap between the instruction and diagnostic test could be perceived as an indicator of whether learners retained the information accurately and showed a secure understanding of the topic as implied in chapter 3.

Alternatively, the time delay between the conclusion of the instruction and the administering of the diagnostic test could have been a source of ambiguity in the results. The learner's conceptual understanding as well as the teacher's understanding could have improved as a result of further instruction that may have occurred as intimated in chapter 6. This would have had a greater impact on the non-specialist's understanding of chemical change. However, I maintain that the time which elapsed was instrumental in ascertaining the learner's ability to accurately recall and apply their knowledge as expressed in the former paragraph. If the test was administered immediately after the instruction, rote learned responses may have been reflected by both teachers and learners.

I must also be noted that some learners did not reflect their names or the names of their respective teachers, thus their tests could not be included in the analysis of responses which is presented in chapter 6.

Finally, due to time constraints, I was able to allocate a week for the collection of data according to their timetable restrictions. The module of chemical change was incomplete at that stage and, only part of the unit was documented and captured. A

richer study would be forthcoming with an extended period of observation and interaction.

7.6 Recommendations

The following recommendations arise from the study:

- Chemical change is a conceptually laden/abstract concept for learners to understand, thus effective transformations must be employed.

- The macro/micro theme is an essential component in the mastery of chemistry and, teachers should not concentrate on the symbolic level in isolation.

- Learners' prior knowledge forms a crucial part of their ability to transform subject matter knowledge into accessible forms and must be explored.

- In-service training should be made available to non-chemistry teachers who will engage in the practice of chemistry teaching in order to develop their subject matter knowledge for teaching and address teacher capacity and supply.

- Non- specialist chemistry teachers should shadow experienced chemistry teachers before they engage with learners on their own.

- Documented PCK should be made available to novice science teachers and non-chemistry specialists in order to effectively transform subject matter.

- A greater degree of collaboration is necessary between chemistry teachers and non-science teachers when their goal becomes a common one.

7.7 Directions for future research

South Africa is a developing country that requires a skilled workforce which is largely dependent the quality of instruction that the Education department is able to offer, in the areas of mathematics and science. However, the lack of appropriately qualified human resources interrupts the learning process and fosters poor learner results in key areas. If the focus of poor learner performance is the lack of adequately qualified teachers, then the role of subject matter knowledge of the teacher and the corresponding impact that it has on learner performance needs to be more clearly defined.

The use of qualified teachers who are employed to teach outside their area of specialization must be carefully explored. If this possibility exists, perhaps it will help alleviate the shortage where skills are scarce. A similar study may be conducted to explore the impact of PCK on learner performance and affirm the current findings.

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APPENDICES

Appendix 1: Learner consent form

Dear Grade 10 Student

Information for participation in the scientific content knowledge for teaching chemical change research project and consent form

I am currently studying for a Masters of Science degree in Science Education at the University of the Witwatersrand in Johannesburg. As part of my thesis, I am investigating the expert knowledge that teachers have and their ability to package that knowledge in order to teach well. This letter is to request your consent for your participation in the above mentioned research project.

In this phase of the project the focus will be on classroom teaching of the section of chemical change in grade 10. I plan to observe lessons that are dedicated to the teaching of chemical change. Furthermore, I plan to videotape these lessons as well as have access to and collect copies of some of the materials produced by you during this time. Since you are one of the students in this class, I ask your consent to appear as part of the videotext and where necessary to have access to copies of materials that you might produce. Lessons will continue as normal and as scheduled, with my presence in the back of the classroom.

All data collected will only be used for research purposes. There is a possibility that the research could be reported at appropriate conferences or in relevant journals. I assure you that anonymity and confidentiality will be protected in all written and verbal reports by making use of a pseudonym to refer to the school, teacher, and students. Video extracts, where anonymity cannot be provided, will only be used with your consent. Upon completion of the project, all data collected will be archived and securely stored at the University of the Witwatersrand for a maximum period of five years. The findings of my study will be communicated with you, if you so desire, upon completion of my study.

Please note that if consent is not granted, I will respect your decision. Therefore you together with any other students not participating in the study will be seated on one side of the classroom and will not be videotaped. Furthermore, any material that you may produce will not be used in the project. In addition, if at any point you wish to withdraw your consent, you may do so without any penalty or prejudice.

Please complete the attached form and return it to your teacher at your earliest convenience. I will gladly answer any questions or queries that you may have and appreciate your co-operation in this study.

Yours sincerely,

_____

Mark Naidoo

CONSENT FORM (STUDENT):

I, _____ (please print full name), a student in grade 10, give consent to the following:

1. Videotaping of lessons on chemical change in which I might appear as part of the videotext.

YES [ ] NO [ ] ***please tick***

2. Copies made of classwork, homework or assessments that I might produce as part of these lessons.

YES [ ] NO [ ] ***please tick***

Signed: _____

Date: _____

Appendix 2: Parent consent letter

Dear Parent/Guardian

Information for participation in the scientific content knowledge for teaching chemical change research project and consent form

I am currently studying for a Masters of Science degree in Science Education at the University of the Witwatersrand in Johannesburg. As part of my thesis, I am investigating the expert knowledge that teachers have and their ability to package that knowledge in order to teach well. This letter is to request your consent for your child/ward to participation in the above mentioned research project.

In this phase of the project the focus will be on classroom teaching of the section of chemical change in grade 10. I plan to observe lessons that are dedicated to the teaching of chemical change. Furthermore, I plan to videotape these lessons as well as have access to and collect copies of some of the materials produced by your child/ward during this time. Since you are one of the parent/guardian of a student in this class, I ask your consent to allow your child/ward to appear as part of the videotext and where necessary to have access to copies of materials that your child/ward might produce. Lessons will continue as normal and as scheduled, with my presence in the back of the classroom.

All data collected will only be used for research purposes. There is a possibility that the research could be reported at appropriate conferences or in relevant journals. I assure you that anonymity and confidentiality will be protected in all written and verbal reports by making use of a pseudonym to refer to the school, teacher, and students. Video extracts, where anonymity cannot be provided, will only be used with your child/ward's consent. Upon completion of the project, all data collected will be archived and securely stored at the University of the Witwatersrand for a maximum period of five years. The findings of my study will be communicated with you, if you so desire, upon completion of my study.

Please note that if consent is not granted, I will respect your decision. Therefore your child/ward, together with any other children not participating in the study, will be seated on one side of the classroom and will not be videotaped. Furthermore, any material that your child/ward may produce will not be used in the project. In addition, if at any point you wish to withdraw your consent, you may do so without any penalty or prejudice.

Please complete the attached form and return it to the teacher at your earliest convenience. I will gladly answer any questions or queries that you may have and appreciate your co-operation in this study.

Yours sincerely,

_____

Mark Naidoo

CONSENT FORM (PARENTS):

I, _____ (please print full

name), parent/guardian of _____

(full name of child/ward)

give consent to the following:

1. Videotaping of lessons on chemical change in which my child/ward may appear as part of the videotext.

   YES [ ] NO [ ] ***please tick***

2. Copies made of classwork, homework or assessments that your child/ward may produce as part of these lessons.

   YES [ ] NO [ ] ***please tick***

Signed: _____

Date: _____

Appendix 3: Teacher consent form

Dear Teacher

Information for participation in a research project and consent form

I am currently studying for a Masters of Science degree in Science Education at the University of the Witwatersrand in Johannesburg. As part of my research project, I am investigating the expert knowledge that teachers have and their ability to package that knowledge in order to teach well. This letter is to request your consent for your participation in the above mentioned research project.

In this phase of the project the focus will be on classroom teaching on a section of Chemistry in Grade 10, more specifically chemical change. I plan to conduct an interview, observe and videotape a few lessons as well as have access to and collect copies of some of the materials produced by you and your learners. A diagnostic test will be conducted at the end of this section to ascertain the strengths and weaknesses of the learners.

All data collected will only be used for research purposes. I assure you that anonymity and confidentiality will be protected in all written and verbal reports. Video extracts, where anonymity cannot be provided, will only be used with your consent. Upon completion of the project, all data collected will be archived and securely stored at the University of the Witwatersrand for a maximum period of five years, thereafter destroyed.

Please complete the attached form to indicate your consent. I will gladly answer any questions or queries that you may have and greatly appreciate your co-operation in this study.

Yours sincerely,

_____

Mark Naidoo

CONSENT FORM:

I, _____ (please print full name), give consent to the following:

3. An audio-recorded interview.

YES [ ] NO [ ] ***please tick***

4. Videotaping of lessons and discussion of the content recorded which will be audio-recorded.

YES [ ] NO [ ] ***please tick***

5. Copies made of class work, homework or assessments that may be produced as part of these lessons.

YES [ ] NO [ ] ***please tick***

Signed: _____

Date: _____

Appendix 4: Principal consent form

The research project to be conducted is entitled:

Transforming Content Knowledge: Learning to teach about chemical change

Mark Naidoo
031 6728J

Aim of this study

The aim of the study is to investigate how two teachers transform their content knowledge when teaching the section of chemical change, in particular chemical reactions, in order to make the subject matter understandable for their learners.

Approach

I believe that each teacher has their own distinct way in which they transform the subject matter concerned into something that is meaningful and comprehensible to their learners. This professional knowledge base incorporates knowledge of science and science teaching with knowledge of students and how students learn. This characteristic is not expected of any layperson or even a professional scientist.

Audience

This research report will be submitted in partial fulfillment of a Masters Degree programme in Science education. Furthermore, it may be presented at conferences and used in specific publications.

It may also be used by help novice and experienced science teachers when teaching chemical change at the Grade 10 level as support material, thus enriching their professional knowledge base.

Participation

Data gathering involves:

- videoing 4-6 lessons and using it as a mechanism for stimulating discussion.
- recorded interviews (probably 2 x 45 min) to explore influences and decision making.
- a recorded focus group with group of learners to gather the ‘learner voice’.
- A diagnostic test to gather learner strengths and weaknesses.

Confidentiality

All transcript data and video material will remain confidential and anonymous.

Benefits

As teachers, we need to feel that we want to develop our ability to articulate what we do. As a consequence of involvement in the discourse of science education I hope they you will become aware of a wide variety of influences which may help you in your own professional development. This opportunity may be seen as a means of reflecting on your teaching practice and sharing your experience with the wider science community.

Dear principal, the above is essentially an outline of the research project. Please confirm your consent by signing in the space provided below.

Yours truly,

_____
Mark Naidoo

CONSENT

I, _____ (please print full name), the principal of (school's name), give consent to Mark Naidoo to conduct the above research project as outlined above.

_____
Principal

Date: ____/_____/_____

Appendix 5: Letter regarding piloting of diagnostic test

Re: Piloting of diagnostic assessment

My name is Mark Naidoo and I am currently studying for a Masters of Science degree in Science Education at the University of the Witwatersrand in Johannesburg. As part of my research project, I am investigating the expert knowledge that teachers have and their ability to package that knowledge in order to teach effectively.

The focus of my project deals with the section of Physical and chemical change at grade 10 level, with particular emphasis on chemical change. I plan to administer the test to two groups of grade 10 learners. I would like you to complete each of the following tasks:

- Answer the questions that follow.
- Suggest how I can improve the questions where necessary (you may indicate this above the relevant question).
- Recommend an appropriate time allocation for this assessment.

Please note that this information, including your identity, will treated with absolute confidentiality and pseudonyms will be used where necessary.

I wish to thank you for taking the time to complete this assessment. Your recommendations are valued and will be given due consideration.

Mark Naidoo

Please fill in the details below.

Name of teacher: _____

Date: _____

Appendix 6: Diagnostic test

Science diagnostic assessment on chemical change

Question 1: Do you know the difference?

1. Explain the meaning of each of the following terms (in your own words):

1.1. Physical change

_____

_____

_____

1.2. Chemical change

_____

_____

_____

Question 2: Melting Ice

2. Figure 1 shows a container of ice cubes that are in the process of melting and figure 2 indicates an illustration of the macroscopic and microscopic views of the ice cube.

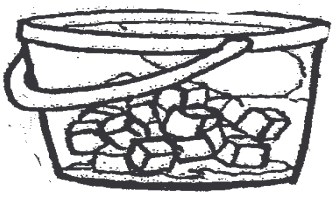


FIG 1

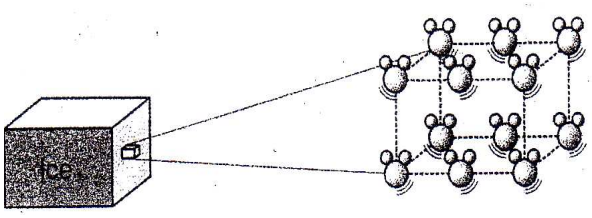


FIG 2

2.1. Is the process of ice melting a chemical or physical change? Explain your answer.

_____

_____

_____

_____

2.2. Explain what happens on the microscopic level when ice melts.

_____

_____

_____

2.3 What will be observed on the macroscopic level?

_____

_____

_____

Question 3: Rusty nails

3. You have four nails made of pure iron. You record the total mass of the four dry nails. All the nails are put in a moist, open dish and exposed to air over several weeks. Weeks later you notice the nails are covered with rust. You let the nails dry completely and record the total mass of the rusted nails, being careful that no rust falls off as you mass them.

What do you predict will happen to the mass of the nails? Circle your prediction.

A The mass of the dry, rusted nails will be more than the mass of the dry nails before they rusted.

B The mass of the dry, rusted nails will be less than the mass of the dry nails before they rusted.

C The mass of the dry, rusted nails will be the same as the mass of the dry nails before they rusted.

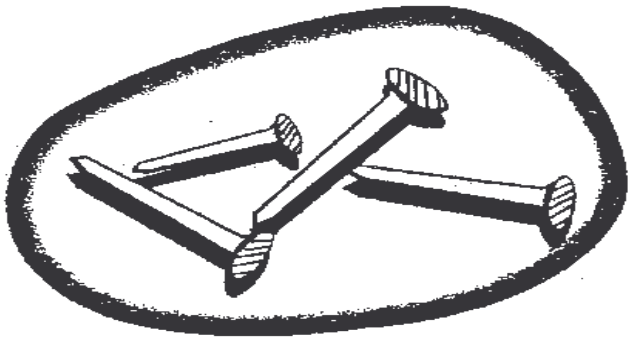


FIG 3

Explain why you selected the respective prediction above

_____

_____

_____

_____

_____

_____

_____

_____

_____

Question 4: Salty water

4. Figure 4 shows solid table salt that is dissolved in a beaker of distilled water.

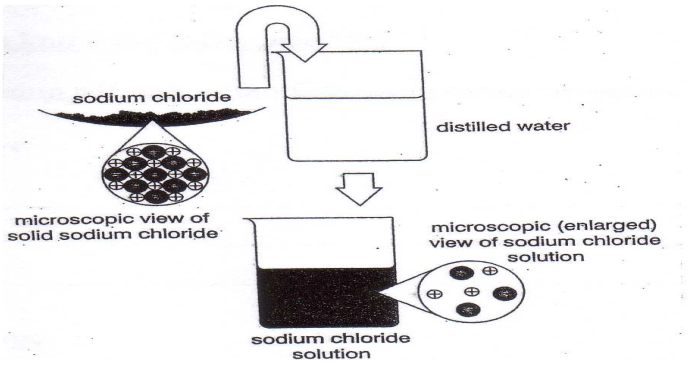


FIG 4

4.1. Is the process illustrated above a chemical or physical change? Explain.

_____

_____

_____

_____

_____

4.2. Write a simple chemical equation using chemical formulae that will represent the process in figure 4.

_____

4.3. The salt solution is now added to silver nitrate solution. A white precipitate is formed as one of the products. Is this change physical or chemical? Explain your response.

_____

_____

_____

_____

Once again, many thanks you for your time and effort with this exercise. Results of this research can be made available to you if required.

Sincerely,

Mark Naidoo

Appendix 7: Memorandum for diagnostic test

MEMORANDUM

Question 1: Do you know the difference?

1. Explain the meaning of each of the following terms (in your own words):

1.1. Physical change

A physical change is the process whereby a substance changes its state/phase or appearance but not its chemical composition. It is usually a reversible process.

1.2. Chemical change

A chemical change is a process whereby a substance changes chemical composition and new products are formed. It is indicated by a change in temperature, colour, gas is liberated or a precipitate is formed.

Question 2: Melting Ice

2.1. Is the process of ice melting a chemical or physical change? Explain your answer.

Physical change. The ice merely changes phase to liquid then gas if heating continues.

The molecules are rearranged and not changed.

2.2. Explain what happens on the microscopic level when ice melts.

The molecules gain kinetic energy and move in a random manner. Therefore, phase change occurs with the increased energy.

2.3 What will be observed on the macroscopic level?

The solid ice melts into a liquid water phase which occupies a greater volume.

Question 3: Rusty nails

What do you predict will happen to the mass of the nails? Circle your prediction.

A The mass of the dry, rusted nails will be more than the mass of the dry nails before they rusted.

B The mass of the dry, rusted nails will be less than the mass of the dry nails before they rusted.

C The mass of the dry, rusted nails will be the same as the mass of the dry nails before they rusted.

Explain why you selected the respective prediction above

The process of rusting involves a chemical change. The oxygen in the air chemically combines with the iron. As a result, the additional mass from the oxygen is added to the mass of the iron to form a new compound, iron oxide.

NB. Mass is only conserved in a closed system.

Question 4: Salty water

4.1. Is the process illustrated above a chemical or physical change? Explain

Physical change
The dissolving process is simply a rearrangement of the ions in water that break out of the crystal lattice. No new substance has formed.

4.2. Write a simple chemical equation using chemical formulae that will represent the process in figure 4.

$$NaCl\,(s) \longrightarrow Na^{+}\,(aq) + Cl^{-}\,(aq)$$

4.3. The salt solution is now added to silver nitrate solution. A white precipitate is formed as one of the products. Is this change physical or chemical? Explain your response.

Chemical change.

The formation of a new substance (silver chloride), a white precipitate, confirms that a chemical change has occurred.

Appendix 8: Semi-structured interview schedule

Section A: Biographical Data

1. What is your age?
2. What qualifications do you have? Are there any studies that you have undertaken outside of teaching?
3. How long have you been teaching?
4. What subject(s) and what grade(s) do you teach?

Section B: Content of Representation (CoRe) on chemical change
(Adapted from Loughran et al., 2004).

1. In your opinion, what content would you select and concentrate on in chemical change? Why?
2. What do you intend the students to learn about this idea?
3. Why do you think it is important for students to know this?
4. What else do you know about this idea that you would not share with the students yet?
5. What are the difficulties associated with teaching this idea?
6. What knowledge can you share about student's thinking that influences your teaching of this idea?
7. Are there any other factors that would influence your teaching of this idea?
8. What teaching procedures would you employ?
9. Why would you use these procedures?
10. What strategies could you use to ascertain student's conceptions/misconceptions of this idea?

Appendix 9: Content of Representation (CoRe)

(Adapted from Loughran et al., 2004).

Prompts/Questions	CoRes		
	Big Idea 1	Big Idea 2	Big Idea 3
1 What do you intend the students to learn about this idea?			
2. Why do you think it is important for students to know this?			
3. What else do you know about this idea that you would not share with the students yet?			
4. What are the difficulties associated with teaching this idea?			
5. What knowledge can you share about student's thinking that influences your teaching of this idea?			
6. Are there any other factors that would influence your teaching of this idea?			
7. What teaching procedures would you employ?			
8. Why would you use these procedures?			
9. What strategies could you use to ascertain student's conceptions/misconceptions of this idea?			

APPENDIX 10: SAMPLE OF FIELD NOTES

Teacher: Mr Moodley
Time: 10:10 – 10:45 am
Topic: Chemical change (CC) & physical change (PC)
Purpose: Field notes of lesson 1

---

1. T uses investigative/inductive approach – purpose is to let L discover the criteria for determining the difference between CC and PC. "L will be scientists for today". T shows Na + H_2O as demo to illustrate what he means. He does not commit himself to filling in table on whether the demo was pc or cc….interesting!!

2. L are enthusiastic about practical work – copy result sheet from chalkboard. Perhaps should have appointed a scribe in each group of 5-6 L.

3. Na & water demo to illustrate CC – T does not elaborate on products, merely informs L of products. He asks L to state the gas formed in this experiment?? He states that it makes a popping sound – H_2 (g)??. "A large piece will cause an explosion because of the heat released". No probing into other concepts is forthcoming eg. "Basic subst. formed".

4. T reads out extract on CC or PC in everyday life – gives L an indication that science is relevant in their lives. He states that the accuracy of their conclusions are unimportant, however, the criteria for deciding whether its pc or cc is assessable and the main focus.

5. L participate in 4- 5 practs that were laid out already. Basic precautions are stated by T. Group work follows.

6. L do not follow instructions on board eg. Heat foil over flame; heat test-tube with ammonium nitrate soln. then touch test tube; melt ice over flame – basically they heat all materials.

7. Comments that sparklers work on the basis of burning chemicals (clue??), namely Mg dust; steel dust, etc. White light indicated Mg was used.

7. Very little attention given to basic precautions that should be followed. T did not seem to notice or mind. He commented that he never did chem. Pract with L before.

8. L asked to complete copied worksheet at home and will be discussed at next lesson.

9. The overall atmosphere was one where L conversed freely and did experiments with little regard for the importance of the scientific principles that were at work. The impression created that many were unsure about what should be done & why.

10. Large class of 32 made it difficult for T to control what was happening all the time, thus class was rowdy quite often during practical.

Teacher: Mr Johnson
Time: 11:37 am
Topic: chemical change (CC) & physical change (PC)
Purpose: Field notes of lesson 1

---

1. T reminds class of P.T from previous discussions – metals & non-metals, etc.

2. Transparency on meaning of PC & CC is presented with special reference to macro/micro properties as indicated in the NCS for FET phase. Demonstrates three examples of macro/micro using visual aids to enhance difference.

3. Class is attentive & T method is T-centered for now. Introduces PC with a number of examples and highlights the meaning of phase and change in form.

4. T returns to discuss micro scale with relevant transparency and briefly comments on bonding that occurs in salt & water – reference to previous lessons. Uses nichrome wire as a link to electricity that L were busy with prior to CC.

5. Summary on board indicates important substances used with chemical formula reflected. Only demo's used and L are not asked to interact or questioned on any of the observations made – lecture method is predominant.

6. T moves on to CC & clarifies that it is the focus of the section. Uses lighter, Na in water; Zn in HCl & writes reactions on board in some cases – spontaneous reactions alluded to.

7. A variety of demo's illustrating PC and CC serve to enhance/concrete the difference between the above. L seem to be aware that there is a distinct difference.

8. T stops just before end of lesson to do a brief re-cap of the characteristics of CC & PC. Finally, the L are questioned about what was discussed on the overhead earlier.

9. T informs L that they will continue with CC and do some classification on their own in the next lesson.

10. L were attentive throughout lesson but little/no interaction during lesson was evident.

APPENDIX 11: SAMPLE OF INTERVIEW TRANSCRIPT

Mr Moodley
Age: 36 yrs
Qualification: HDE; Completing 2nd yr BSc Hons in Science Education
Experience: 10 yrs – presently teaching – grade 8, 9 (natural science) & 12 (life science); grade 10 science (1st yr)

I: What do you think that cc is?

M: I think, from the readings I've done, it is the rearrangement of atoms where new bonds are formed.

I: Lots of people refer to it as this, new bonds are formed, and this is exactly correct. In this section of cc, this is a new section with many subsections in there, what do you think is the most important thing or what would you select as the section to concentrate on?
Pause..(M coughs)…I mean there is chemical rxns, chem equ, mass conservation, ur reactions with experiments…

M: I would concentrate on experiments to show the pupils the difference between cc and pc, and then probably deal with the Law of Conservation of Matter, to show them that the weight doesn't change, because lots of people think that when it changes from a liquid to a solid, there is an increase in weight. Some of the misconceptions we have to deal with.

I: Yah, we'll probably discuss those misconceptions later, but um, why do you think it is necessary to differentiate between cc & pc? Because you going to start off saying this is pc and cc. Do you think the kids understand the difference between the two?

M: They don't really understand it now, but I don't have much experience in this so…

I: So you wouldn't know…

M: It's the first time, yah…I have no idea about what the students think at the moment.

I: Ok, so it would be quite difficult to answer all the questions that are set out here. Well, in your experience then, what wouldn't you talk about when teaching cc? What do you think that they are not ready to know, if you looking at their level of maturity, right now?

M: *Pause…(coughs)…*looking at cc, the readings I've done spoke about some grey areas which should be tackled at a later stage, so we talk about some the cc and pc scientists have acknowledged and mention as grey areas, one of those is the sodium chloride. Although you end up with salt because of the evaporation, you still have a rearrangement of atoms, so I'm not sure about that.

chemical change (cc) & physical change (pc)

Appendix 12: Wits Ethics committee and protocol number

Faculty of Humanities: Education Campus

Room 208/9, Administration Block, 27 St. Andrews Road, Parktown • Tel: +27 11 717-3021/18 • Fax: +27 11 717-3219
E-mail: senamelam@hse.wits.ac.za / moshabesham@hse.wits.ac.za

Professor M Rollnick
Marang Centre
Wits School of Education
2050

Protocol 2007ECE03

20 March 2007

Dear Professor Rollnick

Application for Ethics Clearance

I have pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled: **Understanding of subject matter for learning and teaching of science in South Africa today.**

The following comments were made:

- The subject information sheet needs to be more comprehensive and should stipulate the limitations of confidentiality and anonymity, as well as data destruction procedures after completion of the study, especially given the data collection methods employed;
- Furthermore, informed consent must be separately obtained for participation, interviews, audio-recordings and video-recording for teachers and learners alike;
- You need to make it clear that audio-visual material will not be released beyond what is agreed;
- This is a minimal risk study that is non-invasive, and requires minimal technical adjustments in order to comply with ethical standards.

RECOMMENDATIONS:

You may proceed with the research after the integration of the recommendations done to the principal investigator's satisfaction.

Yours sincerely

Mathoto Senamela
Senior Faculty Officer for Faculty Registrar
cc Ethics File
Supervisor:
HDethics clearance

Faculty of Humanities: Education Campus

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E-mail: senamelam@hse.wits.ac.za / moshabesham@hse.wits.ac.za

Mr M Naidoo
PO Box 2929
Bromhof
2154

STUDENT NUMBER 0316728J
Protocol 2006ECE26

03 October 2006

Dear Mr Naidoo

Application for Ethics Clearance: Master of Science

I have pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of Senate has considered your application for ethics clearance submitted for the degree of Master of Science for your proposal entitled: **Transforming content knowledge: Learning to teach about chemical change.**

The Committee has recommended that you may proceed with your research project.

Yours sincerely

Matholo Senamela
Senior Faculty Officer for Faculty Registrar
Faculty of Humanities

oc GSEC file
Ethics File
Supervisor: Professor M Rollnick
HDethics clearance