CHAPTER 1

INTRODUCTION

1.1 Introduction

Learning how to teach is not a simple undertaking. Abell (2008, p1414) maintains that “learning to teach science is not about acquiring a bag of tricks based on a set of general pedagogical strategies. It is about developing a complex and contextualized set of knowledge to apply to specific problems to practice”. This means that knowledge needed for teaching science is different from the knowledge needed to teach, for example literature. Teachers do not only need to know their subject matter knowledge (SMK) very well but to also be able to change it into SMK for teaching.

Teacher knowledge of subject matter has been a major concern in education research for some time. Shulman (1986) argues that SMK is a crucial component of the knowledge base for teaching and he regarded SMK as “the amount and organization of knowledge per se in the mind of the teacher” (p9). A teacher is required to have knowledge which is beyond the concepts in a particular topic. This means that teachers have to understand how SMK within the topic is structured and why it is structured in that particular manner. Hashweh (1987) shares the same sentiment, saying that one needs to know what he or she has to teach and also to teach it adequately.

Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu, (2008) mentioned that when teachers have nuanced SMK, they display more powerful ways of teaching. It was found that teachers become flexible in terms of approaches they use in their teaching. Teachers become confident and combine their general pedagogical knowledge with understanding of learners as well as SMK to produce subject matter knowledge for teaching that is communicated to others. Hence, this study attempts to find out how my SMK changes into SMK for teaching purposes.

1.2 Rationale for the study

The Department of Education (DoE, 2003) in the Republic of South Africa has introduced a new curriculum called National Senior Certificate (NSC). Implementation started for the first time in 2006 for grade 10, in 2007 for grade 11 and finally in 2008 for grade 12. My study is based on the physical sciences content which is guided by the National Curriculum Statement (NCS) document (DoE, 2003) (See Appendix 13). The chemistry content in the NCS appears in three knowledge areas of "chemical change and chemical systems and matter & materials". This study focuses on NCS content of grade12 chemistry in the knowledge area of chemical systems. The idea of a chemical system is a new invention and aims to take chemistry out of the school classroom and provide learners a chance to taste a bit of the real chemistry action. Hence in grade 12 the global perspective is extended to the chemical industry (DoE, 2003).

I decided to look into the case of the 'chloralkali' industry under the topic of chemical industry which forms part of knowledge area of chemical systems in grade 12. The reason I chose the chloralkali industry is that it is a new topic and from what I know there has not been a study done on this topic in South Africa. Another reason is that I am interested as a teacher to learn more by doing a self study and learn from my experience on this topic as I have taught it once in 2008. In the NCS, the chloralkali industry has been specified as an examinable topic (DoE, Examination guidelines, 2009). By doing this study I might favourably affect my learners' grade 12 result at the end of the year. Another reason for engaging in this study is hopefully to contribute to the knowledge base of teaching in line with Opie (2004) indicated that one of the reasons for doing educational research is to come up with outcomes that could be shared and used by others and in that way teachers may improve.

The chloralkali industry is one of the largest electrochemical technologies in the world (Euro Chlor, 2002). I also felt that learners will be interested in learning more about this industry because it is within their context. There is a site plant at Chloorkop, which is close to Johannesburg, the industrial heartland of South Africa. Learners will not only depend on the information from textbooks and internet but can also have access to the plant site and see how strong bases like sodium hydroxide are produced in making soap products.

1.3 Statement of the problem

The problem was that I lack confidence when teaching the chloralkali industry. This is due to the fact that my content knowledge of this section is very poor. What contributes to the problem is the fact that textbooks do not give adequate information on the content of this topic for teachers. I am doing this study hoping to improve my content knowledge on the chloralkali industry so that I can be flexible when teaching it to my learners.

1.4 Aim of the study

In this study, I aim to develop and understand my classroom practice. From my teaching of this topic in 2008, I felt that I needed to be more knowledgeable about the chemical industry teaching in order to be confident when teaching it. Hence my main reason for doing this study is to develop and hopefully to improve my classroom practice and understanding of the content.

1.5 Research questions

I conducted a self study of my teaching of post matric learners in an attempt to see what I teach and why I teach the way I do. The study was guided by the following questions:

1.5.1 How do my ideas on teaching chloralkali industry develop as I prepare to teach the topic?

1.5.2 How do I capture and portray my ideas or thinking when teaching about chloralkali industry?

1.5.3 How does my knowledge on the chloralkali industry transform into teachable knowledge?

1.6 Researcher and Positionality

I am currently living in Johannesburg, South Africa but originally from Ga-Matlala Mahoai, small village which in the Limpopo province, Polokwane. After completing my grade 12 in 1995, I studied at the East Rand College of Education, one of the education colleges most disadvantaged by the apartheid system, where, I graduated with a teaching diploma. Pedagogical skills were the only strong focus in this college of education; content knowledge was seriously neglected and weak. This I realised, let me down over my teaching career and prompted me to further study at the former Pretoria Technikon, which is now known as Tshwane University of Technology where I graduated with the a B-Tech degree in Education.

I taught in two different former white Johannesburg city schools, which now has a majority of black students over a period of 8 years as a physical and natural science educator. Prior to the introduction of the new curriculum in grade 10, I registered for a BSc honours degree at the University of the Witwatersrand, in the school of education, where I engaged extensively with content knowledge issues, interacted with senior subject matter knowledge and pedagogical content knowledge experts with the aim of becoming an expert in science education. From 2008, I was employed at the RADMASTE Centre, University of the Witwatersrand, where I developed microscience teaching materials, train teachers and learners in rural and urban areas.

I believe what constitute good teaching is the reflection of methodology and teaching style I employ when teaching. For this to be successful better understanding of the content knowledge in a particular domain is needed. Once better understanding of the content is achieved, this would allow me the flexibility in my teaching which may result in different teaching strategies. This might lead to all learners to have an equal ability to learn.

1.7 Outline of the research report

Chapter one gives an overview on the introduction to the study. This includes the rationale for the study, summarises aim and statement of the problem of the study for the study, as well as stating the research questions.

Chapter two reviews literature that is relevant to the study. Here, I selectively review literature about the pedagogical content knowledge and some literature related to the chloralkali industry. The chapter ends with a discussion on directions from the literature.

Chapter three outlines the research design and methodology. It describes the participants, research instruments, ethical considerations and data collection process of the study.

Furthermore, it addresses matters of validity and reliability, triangulation and also shows that limitations encountered in the study.

Chapter four shows the findings revealed by analysis of concept maps in an attempt to develop my subject matter knowledge. This serves to answer research question 1.5.1.

Chapter five highlights the capturing and documenting of my PCK with the use of Content Representations (Co-Res) and Pedagogical-experience Repertoires (PaP-eRs). The narrative of my teaching practice for 2009 relative to 2008 teaching is given and compared in a view to answer research question 1.5.2.

Chapter six looks at the features of domains and manifestations of teacher knowledge which constitute my PCK that emerges from my teaching. Rollnick *et al.* (2008) tailored model of PCK is used and the chapter serves to answer research question 1.5.3.

Chapter seven consolidates the findings from the analysis of the research project. It concludes the study by giving critical reflections on the study, as well as the recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter deals with different views from the literature. Below, I gave a description of the theoretical framework used and motivate why it may be useful in my study. I looked at what the literature says about the content relevant to the topic chloralkali industry. Finally, I looked at how chloralkali industry is linked to the issues around science-technology in society (STS).

2.2 Theoretical Framework

2.2.1 What is Pedagogical Content Knowledge?

Teacher knowledge of subject matter had been a major concern in education research for some time. When teachers teach, they draw upon knowledge of their subject matter, general pedagogy as well as context. Teachers' understanding of and agility with content knowledge does affect the quality of their teaching (Ball, Bass & Hill 2004). Research has shown that they also draw upon knowledge that is specific to teaching certain subject matter (Grossman, 1990). Working with mathematical concepts, Ball *et al*. (2004) expressed the same sentiment that development of a better understanding of mathematical knowledge for teaching is required.

From the science teaching perspective this means that teachers need to be in a position to convert their pure science content into science content for teaching. This could be enhanced by the contribution of the concept of pedagogical content knowledge (PCK) where content and pedagogy are blended. Hence the reason I have chosen PCK as a theoretical framework in my study is that I will be looking at how my content knowledge can be transformed into content knowledge for teaching.

The notion of PCK was first conceptualized by Shulman (1986, p9) as "the most powerful analogies, illustrations, examples, explanations and demonstrations- in a word, the ways of representing and formulating the subject that make it comprehensible to others" According to Shulman, PCK takes into consideration how pure subject matter is transformed for communication with learners. It takes into consideration the understanding of learners' difficulties in a particular topic, the conceptions and pre-conceptions that learners bring to the classroom as well as knowledge of the strategies to reorganize learners' understanding in case those preconceptions are misconceptions.

Shulman (1987) identified seven categories of the teacher knowledge base as content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational context and knowledge of educational ends, purposes, values, philosophical and historical grounds. However, among these categories PCK turned out to be of special interest and most important because it identifies the distinctive body of knowledge for teaching content (Shulman, 1987).

2.2.2 Other perspectives on PCK researchers

Shulman's notion of PCK created responses and different scholars have interpreted them in different ways. Below, I look at how the notion of PCK has been further interpreted.

I decided to look at how different scholars (e.g. Geddis & Wood, 1997; Magnusson, Krajcik & Borko, 1999; Cochran, DeRuiter & King, 1993; van Driel, Verloop & de Vos 1998; Loughran, Mulhall & Berry, 2004; Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu, 2008) extended the notion of PCK. The reason I chose these scholars is that, all of their views put together form part of the Rollnick *et al*'s (2008) model which I intend to use in my data analysis.

Geddis and Wood (1997) identified seven categories of teacher knowledge as proposed by Shulman. Their PCK model consists of the following kinds of knowledge: learners' prior concepts, subject matter representations, instructional strategies, curriculum materials and curricular saliency. The first three components of their PCK correspond with Shulman's categories of teacher knowledge. However, the last two (curriculum materials and curricular saliency) could be classified under Shulman's knowledge of curriculum. Geddis & Wood (1997) defined PCK "as a broad category of those kinds of knowledge involved in pedagogical transformations of subject matter" p 612. Hence PCK is seen as the knowledge that plays a role in transforming subject matter knowledge into ways that will be more accessible to the learners.

Magnusson *et al*. (1999, p96) defined PCK as "a teacher's understanding of how to help students understand specific subject matter". Magnusson *et al*. (1999) conceptualized PCK as consisting of the following five components: orientation towards science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about students' understanding of specific science topics, knowledge and beliefs about assessment in science and knowledge and beliefs about instructional strategies for teaching science. They extend Shulman's model of PCK by including orientation towards science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about assessment in science in their PCK model.

Cochran *et al*. (1993) introduced a constructivist version of PCK called pedagogical content knowing (PCKg). They use the term 'knowing' instead of 'knowledge' in describing their concept of PCK to emphasise the dynamic nature of their PCK. Cochran *et al*.'s models integrated four components of teacher knowledge, which are knowledge of subject matter, knowledge of students, knowledge of pedagogy and knowledge of environmental contexts. PCKg model amalgamated all the seven components of teacher knowledge identified by Shulman. However, components such as knowledge of the curriculum and knowledge of educational goals and goals were included under pedagogical knowledge. Cochran *et al.* (1993) also included in their SMK for PCK model teachers' content knowledge not directly related to the topic under discussion (non-target content) hence it is an essential source for preconceptions. Cochran *et al.* (1993) uses the terms such as synthesis, integration and transformation to explain the changes occurring in PCKg.

Unlike Geddis & Wood (1997) and Magnusson *et al*. (1999), the PCK model of Cochran *et al*. (1993) makes subject matter, knowledge of pedagogy and contexts explicitly part of their PCK.

To find out more on how other scholars extended the notion of Shulman' PCK see table 2.1 which illustrates more on how different scholars' integrated components of PCK based on the findings from their studies.

Table: 2.1 Components of pedagogical content knowledge from different conceptualizations [extended from Van Driel *et al*. (1998)

Knowledge of:						
Scholars	**Subject matter**	**Representations and strategies**	**Students learning and conceptions**	**General pedagogy**	**Curriculum and media**	**Context**
Shulman(1987)	a	PCK	PCK	a	a	a
Magnusson *et al*. (1999)	a	PCK	PCK	a	PCK	a
Geddis & Wood (1997)	b	PCK	PCK	b	PCK	b
Fernandez-Balboa & Stiehl (1995)	PCK	PCK	PCK	b	b	PCK
Cochran *et al*. (1993)	PCKg	B	PCKg	PCKg	b	PCKg
Loughran *et al*., (2001)	b	PCK	PCK	b	PCK	b
Bishop and Denley (2007)	PCK	B	PCK	PCK	PCK	PCK
Rollnick *et al*. (2008)	PCK	PCK	PCK	PCK	b	PCK

Notes: **a**, distinct category in the knowledge base for teaching; **b**, not discussed explicitly; PCK, pedagogical content knowledge; PCKg, pedagogical content knowing.

In this study I adopted Rollnick *et al.'s* (2008)'s tailored model for PCK to look at how elements of my PCK were transformed during my own practice (figure 1.1).

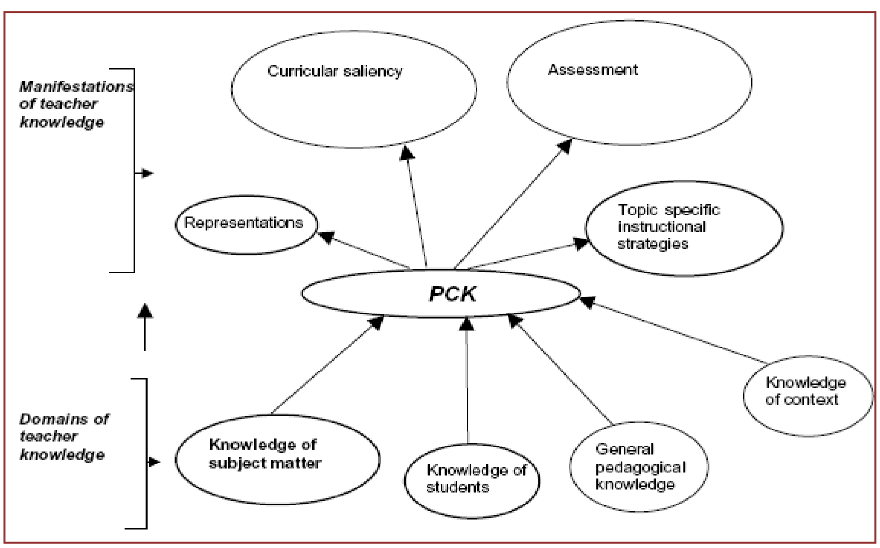

Figure 2.1: Tailored model for PCK

Rollnick *et al*.'s (2008) model separates domains of teacher knowledge from their manifestations. The domains refer to teachers' knowledge and the categories were drawn from Cochran *et al*. (1993), consisting of four fundamental domains of knowledge for teaching which are knowledge of subject matter, knowledge of students, general pedagogic knowledge and knowledge of context. When these four fundamental domains of teacher knowledge are integrated, observable products are produced in the classroom, referred to as manifestations. Manifestations may include any visible products like subject matter representations, topic-specific instructional strategies, curricular saliency and assessment of teaching that may be observed during teaching in the classroom. Some of these manifestations were extracted from Geddis and Wood (1997) and (Rollnick *et al*., 2008) and may vary according to context. Below is the description of each component in the model for both manifestations of teacher knowledge and teachers knowledge domains.

Components of manifestations of teacher knowledge are:

- **Representations**- refers to the forms of representation that can be shown by the use of most powerful analogies, illustration, examples, explanations, simulations and demonstrations (Shulman 1986). In order to produce effective representations that will be linked to the knowledge intended, the blending of subject matter knowledge (SMK) with the other three domains is required (Rollnick *et al*., 2008) Hence a deeper knowledge of SMK is essential.
- **Curricular saliency**- is about "providing perspectives on the dilemma of breadth versus depth of coverage" (Geddis and Wood 1997, p. 612). It refers to how deep the teacher decides to go when teaching a specific topic and also what not to teach. Curricular saliency is in most cases influenced by the curriculum in terms of its guidelines and also by what is most likely to be in the learners' final examinations or what may be useful to the learners. The other aspect that plays an important role in curricular saliency is the experience that a teacher has in teaching that particular subject (Geddis, Onslow, Beynon and Oesch, 1993). Hence it will be easy for him or her to understand what comes before and after in the topic in hand (Rollnick *et al*., 2008).

- **Topic-specific instructional strategies-** refers to different approaches that teachers use like whole class teaching, problem-first strategy, group work, question and answer strategy. However, according to Geddis *et al*., (1993) the strategy used should be able to help the teachers in focusing on more on the development of conceptual knowledge rather than on the development of procedural knowledge.
- **Assessment-** may be in the form of formative or summative tasks. Formative assessment may include the type of questions asked during the teaching period and also the type of questions asked in the exercise to consolidate what was learnt during the teaching.

Components of domains of teacher knowledge are:

- **Knowledge of subject matter**- is the teacher's pure untransformed SMK.
- **Knowledge of students-** refers to appreciation of learners' prior knowledge, how they learn, their interests and aspirations as well as considering their linguistic abilities.
- **General pedagogical knowledge-** is about having an understanding of what constitutes good teaching, taking into consideration the best teaching approaches in a given context, which is informed by appropriate learning theories.
- **Knowledge of context**- refers to all contextual factors influencing the teaching condition like resources, class size, learners' socio-economic background, curriculum, conditions in the classroom and availability of time for teaching and learning. (Rollnick *et al*., 2008).

The reason I chose the model of Rollnick *et al*.'s (2008) is that it draws some of its components from Cochran *et al.* (1993) and Geddis and Wood (1997) models to further elaborate on what is PCK. The Cochran *et al*. (1993) model indeed claims that the integration of domains in teacher knowledge produce PCK. However, it examines only the underlying knowledge without showing how this knowledge is combined to produce what happens in the classroom (Rollnick *et al*., 2008). On the other hand, Geddis and Wood (1997) describe PCK as "a broad category of those kinds of knowledge involved in pedagogical transformations of subject matter" (p.162). This includes amongst others subject matter representations, instructional materials, curricular saliency, which are observable products called manifestations in the Rollnick *et al*. (2008) model.

All teachers have knowledge that is informative towards their classroom practice. van Driel *et al*. (1998) refers to this knowledge as craft knowledge. Craft knowledge is defined as "integrated knowledge, which represents teachers' accumulated wisdom with respect to their teaching practice" (p 674). How teachers teach as well as the knowledge and beliefs they have about the topic's aspects such as pedagogy, learners, subject matter and the curriculum is directed by this craft knowledge. van Driel *et al*. (1998) describe PCK as the specific form of craft knowledge. They extend the explanation of Shulman's PCK as a transformation of subject matter, which is needed to be used effectively during the classroom practice. Hence PCK is embedded in classroom practice and teachers may develop PCK from their own teaching practice (van Driel *et al*., 1998). Scholars like Loughran *et al*. (2007) and Mortimer (1995) came up with ways in which teachers' PCK can be developed and captured and will be explained in more detail below.

2.2.3 How teachers' PCK can be presented and portrayed.

The complexity of capturing PCK was highlighted by Loughran *et al*. (2004) and referred to the knowledge as tacit. This means that, it is difficult to articulate links between practice and ideas that influence a particular way of teaching. Ways in which one can gain access to this tacit nature of PCK, were developed by Mortimer (1995) and Loughran *et al*. (2004). Mortimer (1995) came up with a Conceptual Profile Model (CPM) for the learner which is defined as "superindividual system of forms of thought" (p270). CPM is an instrument used to describe different ways of thinking, which tries to explain one concept. According to Mortimer (1995) the use of conceptual profile makes it possible to deal with conceptual evolution in the classroom. However, in my study I have used Loughran *et al*. (2004)'s two interactive elements to capture and document my PCK.

Loughran *et al*. (2004) came up with two elements of capturing and representing one's PCK in meaningful ways called Content Representation (Co-Re) and Pedagogical and Professional experience Repertoires (PaP-eRs). The Co-Re is a representation of teacher knowledge either singly or in groups. These include rationales and how the concepts might be taught e.g. what content is taught, how and why (Loughran *et al*., 2004). PaP-eRs emerge from the teachers' practice illustrating aspects of the Co-Res. This may come from comments made by the teacher during interviews, teaching journals, lesson plans, teacher analysis of learners' work and observer's voice (Loughran *et al*., 2004). All of the PaP-eRs focus on teacher's pedagogical reasoning behind a particular teaching decision (Loughran *et al*., 2004). These explain the different types of strategies used and how they were enacted during practice.

Both the Co-Res and PaP-eRs are seen as complementary representations of successful teachers' PCK about teaching a particular topic to learners. According to Loughran *et al*. (2004) the two elements gives a framework for unpacking and representing PCK in a way that will allow teachers to share their knowledge for teaching. Both Co-Res and Pap-eRs are linked to Rollnick's *et al*. (2008) model in that they will contribute to the manifestations of teacher knowledge, which are representations, curricular saliency, assessment and topic specific instructional strategies.

2.3 Background on the chloralkali industry

The chloralkali industry "is a new topic in the South African NCS curriculum (DoE, 2003)"(see Appendix 13). It forms part of a knowledge area "chemical systems" in grade 12 and amongst others it is a case study on chemical industry. The chloralkali industry is one of the largest electrochemical technologies in the world where aqueous sodium chloride (brine) electrolysis takes place which result in production of sodium hydroxide and chlorine (Euro Chlor, 2002).

2.3.1 A context based approach

The chloralkali industry involves the science, technology and societal (STS) approach of teaching. The context-based or an STS orientation to teaching is incorporated in this study mainly because chemical systems in general including the chloralkali industry integrates science, technology and society. Bennett, Lubben & Hogarth (2006) define context-based approach as the approach that uses contexts and applications of science as the starting point in order to develop scientific ideas. This relates well to learning outcome (LO3) that emphasizes the idea that learners should have a broader understanding of how the science learnt in school relates to their everyday lives, to their environment and to a sustainable future (DoE, 2003). The context-based approach is in contrast with the traditional approach that covers scientific ideas first, before looking at the applications. Aikenhead (1994) gave a definition of STS as teaching about a concept in a manner that it embeds science in the technological and social environments of the learner. This simply indicates that this is the approach that uses the surroundings of the learner to try and explain the relevant science and technology that has been used in that environment.

However, explanation on why the terms context-based and STS are being used interchangeably is needed in this case. According to Bennett *et al*. (2006) both STS and context-based approaches make common reference to the term scientific literacy. They argue that scientific literacy encompasses the knowledge, understanding and skills that learners need to develop in order to think appropriately on scientific matters which may affect their lives or lives of other members of local, national and global communities of which they are part of. Once learners are aware of and acknowledge the effects, according to LO3, this will contribute to active debates and responsible decision making on the issues related to technological development, environmental management, lifestyle choices, economics, human health and social and human development (DoE, 2003).

Kasanda, Lubben, Gaoseb, Kanjeo-Marenga, Kapenda & Campbell (2005) grouped Aikenhead's original categories of STS science in spectrum of possible curricula, namely: context-infused curricula, context-based and context-focused curricula. However, in this study I am going to teach about the chloralkali industry by using everyday context-infused into my science teaching. Kasanda *et al*. (2005: 1805) defined contexts infused curricular as the "science courses that incorporate issues from society (and/or technology)". Since the chloralkali industry forms part of the chemical industry, the type of everyday contexts that I will be using will be referring to industry. Application about the chemical industry on its own brings in the issue of technology (for example, how production of sodium hydroxide and/or chlorine takes place on a large scale) and the issue of society for example, what are the impacts of chloralkali industry in the society in terms of pollution and the economy).

Although content based teaching helps develop scientific ideas, both Bennett *et al*. (2006) and Bennett & Lubben (2006) found that that when learners are taught using a context-based approach, they develop scientific ideas and were able to understand scientific concepts. If learners developed more scientific concepts and ideas, this will mean that the context was used as a vehicle for them to understand the content well. Hence the use of context-based teaching by teachers is for content knowledge. However, Campbell, Lubben & Dlamini (2000) indicate that teachers using a contextualized approach should not assume that by including everyday instances in their science teaching on its own will be enough to help learners to be in a position to recognize the social and economic implications of science in their surroundings. This means that better selection of everyday context may be selected. Campbell *et al*. (2000) further indicate that in order for learners to use their science understanding to solve problems in their everyday life, there should not be science teaching through context only but teachers should also engage learners in project work related to everyday problems. This project work may train learners in selecting relevant science concepts both learned at home and school to address these particular problems (Campbell *et al*., 2000).

Bennett *et al*. (2006) further argue that once learners start to be motivated and interested by the experiences they are having in their particular lessons, there will be an increase in their engagement, which might result in improved and meaningful learning. Bennett & Lubben (2006) also share the sentiment that learners become interested and have a desire to study chemistry at university.

There are challenges faced by the teachers as far as STS or context-based approach is concerned. Bennett & Lubben (2006) argue that teachers found the course more demanding to teach. This means that context-based or STS approach itself needs a lot of time when using it and in South Africa for example teachers might not have this time. Ramsey (1993, p254) share the same sentiment that “the larger the context, the more difficult it is to implement the investigation and decision making”. This might result in teachers losing focus on the goals that they have to achieve in terms of content and concentrate on trying to finish the task or identifying the issue.

George and Lubben (2002) indicate that teachers who are not familiar with STS approach of teaching find it difficult to make a transition to a contextualized teaching approach from traditional teaching. Relating this to a South African context and from my perspective, this will mean that well qualified science teachers, proper in-service training and resources have to be priorities. According to Bennett and Lubben (2006) in-service support played an important. From my experience as a teacher, teachers’ experience is influenced by the workshop. Teachers reported that the in-service support build their confidence, which had a lot of impact on the success of the course.

The chloralkali industry is important because it makes learners aware of the reality that the science they learn in class does apply to technology and also affects society. For example, the topics of redox reactions and electrochemistry they learn in chemistry play an important role during electrolysis of brine in the industry. Therefore learners can relate what they learn in class to the outside world. However, Lennon, Freer, Winfield, Landon & Reid (2002) argue that the manufacture of the PVC gutters uses for houses make use of chlorine make and that paper processing requires large quantities of sodium hydroxide. This clearly shows that learners are unable to see the relevance of science studied in classroom. The topic affects society in both good and bad ways. The good aspect of it is that sodium hydroxide produced is sold for production of soap while chlorine is responsible for production of many things like bleach and detergents and it is used in water treatment not production. However, the bad aspect of it is that both chemicals are capable of causing environmental problems like pollution, which learners can relate to (Euro Chlor, 2002).

There are prerequisite topics that learners need to understand conceptually before the topic chloralkali can be taught. These include redox reactions and knowledge on the concept of electrochemistry. Below, I will describe what is known about the prerequisite concepts.

2.3.2 Redox reactions

Ringnes (1995) indicates that the manner in which teachers introduce learners to oxidation and reduction might not promote understanding of the concepts. Conflict with linguistic reasoning and historical development (which is seldom given to learners) are the two factors identified by Ringnes as the barrier to learning of oxidation and reduction. Learners do have problems with chemistry terms like reduce which means to gain electrons which differ from their everyday language meaning to decrease. This leads to learners not understanding chemical terms (Schmidt, 2000).

It is important for learners to know the history of oxidation and reduction and how it is changing (Ringnes, 1995). This would mean that teachers should inform learners about the way in which oxidation and reduction had started from Lavoisier, Arrhenius to the Lewis explanation of the concepts. Once learners start to know and understand the history of this concept, they will then be able to understand conceptually different definitions of oxidation-reduction by different chemists.

Ringnes (1995) argue that when learners fail to understand terms like oxidation, this shows that there is no understanding of phenomenon and eventually resort to rote learning. If learners understand the history behind the concept, full understanding and interpretation of the models (oxygen/hydrogen model, electron transfer model and oxidation number change model) will also be accomplished. The interpretation of models will remediate misconceptions that learners found (Ringnes, 1995). For example, when defining oxidation using the electron transfer model (loss of electrons), learners can come up with the balanced equation of redox reaction. This means that the oxidation number model may be the best one to use with learners when teaching. However, Schmidt (2000) mentioned that confusion happens because chemists often use different definitions in parallel containing old and new aspects. He claims that learners tend to stick to the historical meanings hence this is what they have learnt in chemistry class.

It was also found by both Schmidt (2000) and Ringnes (1995) that the best model to use was the oxidation number change model which defined increase in oxidation number as oxidation and decrease in oxidation number is defined as reduction. The other three models resulted in learners having misconceptions. Schmidt (2000) found that one learner believed that any equation that has oxygen was a redox reaction. This clearly shows that the learner does not know much about other models of this concept hence resorting to his or her alternative conceptions is an option. Schmidt (2000) did show in the study that the hydrogen/oxygen model failed because in some equations even if oxygen is involved, there may not be a redox reaction, no electrons are transferred and there is no change in oxidation numbers. Hence Schmidt (2000, p18) said "oxygen does not necessarily take part in this process: there are many redox reactions in which oxygen is not involved". Ringnes (1995) on the other hand found that when learners use the electron transfer model to identify whether an equation representing a reaction is redox or not and are given an equation without visible charges and electrons, they face difficulties. Hence the electron transfer model was found to be inconsistent. Below are some difficulties that learners encounter in the oxidation and reduction topic (Ringnes, 1995: 77):

- Oxidation does not only refer to reaction with oxygen. Learners conclude that 'ox' in redox means that oxygen is involved in all redox reactions
- In chemistry "reduce"- means "gains electrons". In contrast with the meaning of decrease in everyday language.
- The transfer of electrons is not shown in the overall equation.
- Electrons are not actually transferred in every redox reaction.
- In addition to the electron model, three other models are in parallel use in schools
- Uncertainty may occur when assigning which atom is to be reduced or oxidised
- An increase in the overall charge of ions is not always accompanied by oxidation.

2.3.3 Electrolysis

Redox reactions can either be spontaneous or non-spontaneous. In the case of the chloralkali process, the reaction has a negative cell reduction potential and therefore would not occur spontaneously**.** This process is called electrolysis. Electrolysis uses electrical energy to drive a non-spontaneous chemical reaction. Electrolysis is a prerequisite topic needed in order for learners to understand the whole procedure in the chloralkali process as it involves the electrolysis of brine. There is not much research done on difficulties in learning electrolysis. Since both electrolytic and electrochemical cells use electrodes connected to an electrolyte and both accompanied by redox reactions, I assumed that reviewing the literature about electrochemistry would be relevant. Below I look at the misconceptions associated with the teaching and learning of electrochemistry and the causes of these misconceptions as well as how to improve the teaching of electrochemistry.

Sanger and Greenbowe (1997) mention that the main reason why there is so much interest in the study of electrochemistry is because surveys show that teachers suggested that students find this topic difficult. Huddle, White & Rogers (2000) further elaborated on this notion by indicating that there are two major reasons why students experience problems with electrochemistry: 1) topics are very abstract, 2) the chemistry language, which is new to them. Both Sanger and

Greenbowe (1997) and Huddle *et al.* (2000) share the same sentiment by saying that if learners find that the concept is very complex, tends to affect their performance when learning. In many abstract topics, learners tend to manifest alternative conceptions (misconceptions) which are resistant to remediation (Hewson, Beeth & Thorley, 1998).

Below are the common misconceptions in electrochemistry found by different researchers and reported by Sanger and Greenbowe, 1997, p819)

- Electrons move through solution by being attracted from one ion to the other.
- Electrons move through solution by attaching themselves to ions at the cathode and are carried by that ion to the anode.
- Electrons enter the solution from the cathode, travel through the solutions and the salt bridge, and emerge at the anode to complete the circuit.
- Anions in the salt bridge and the electrolyte transfer electrons from the cathode to the anode.
- Cations in the salt bridge and the electrolyte accept electrons and transfer them from cathode to the anode.
- Electrons can flow through aqueous solutions without assistance from the ions.
- Only negatively charged ions constitute a flow of current in the electrolyte and the salt bridge.
- The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons.

I therefore assume that, some of the misconceptions identified by Sanger and Greenbowe, 1997) might also apply in terms of teaching electrolysis to learners. Possible misconceptions included are:

- Electrons move through solution by being attracted from one ion to the other.
- Electrons move through solution by attaching themselves to ions at the cathode and are carried by that ion to the anode.
- Electrons can flow through aqueous solutions without assistance from the ions.
- As in electrochemical cells, anode is negatively charged and cathode is positively charged. Learners might assume that the same applies in electrolytic cells.

- The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons.

Different researchers like Sanger and Greenbowe (1997), Huddle *et al.* (2000), Niaz (2002) and Ogude and Bradley (1996) amongst others attempted to come up with suggestions on how to prevent or overcome misconceptions in electrochemistry. Sanger and Greenbowe (1997) investigated the effects of computer animations, which are used as a tool to enhance learners' ability to visualize and understand chemical concepts on the molecular level. By using animations, learners may be in a position to visualize migration if ions in solution in electrolytic cells. Teachers will also be able to see whether learners have connection of the macroscopic, symbolic and microscopic representation of chemical process (Sanger and Greenbowe 1997).

According to Schmidt, Marohn & Harrison (2007) and Sanger and Greenbowe (1997), only conceptual change teaching or active teaching had a positive effect on confronting learners' misconceptions. Hence the study of Huddle *et al*. (2000) showed that using analogies in the form of concrete models when teaching helps in remediating misconceptions. It was found that the use of analogies 1) provide learners a level of comfort and security 2) help learners to connect and visualize what they know with the world of theories and abstractions. (Huddle *et al*., 2000). The study also showed some strength in using a concrete model which was suggested by the learners. Other learners noted that a model can be a good tool to explain why batteries run down and can also be good in showing the swapping around of the electrodes in both electrochemical and electrolytic cells (Huddle *et al*., 2000). However, limitations on the use of their concrete model were taken into consideration. According to Huddle *et al*. (2000) the main limitation of their model is that actions are sequential not simultaneous. This means that it was impossible for learners to see the movement of both charges taking place simultaneously. However, other models may be able to do this.

Niaz (2000) recommended the use of teaching experiments as a way of helping learners to better understand electrochemical processes. According to Niaz (2000) "an experimental treatment based on 'teaching experiments' improved the performance of the experimental group as compared to the control group" (p 435). However, Niaz argued that for improvement to occur, learners should be provided with correct responses as well as alternative responses that will create some conflicting situation. In that way learners will grapple with those alternative responses (even the incorrect ones) hence cognitive conflict will take place. All learners will get an opportunity to experience the conflicts and the possibility to resolve them (Niaz, 2000). To facilitate conceptual change, teaching experiments are to be designed for particular aspect of a problem situation (Niaz, 2000).

It is also mentioned by Garnett and Treagust (1992) in Sanger and Greenbowe (1997) that careful attention should be given to language used in science by both teachers and learners. Learners tend to interpret the terminology used by the teachers or books into the everyday language usage which is inconsistent with scientific usage. This relates to the example I used in the previous section of redox reaction of reduction meaning to gain. Whilst Ogude and Bradley (1996) argued that teachers should also be careful when discussing electrode processes, where terminology like negative and positive electrodes may be avoided, hence is not crucial when interpreting electrode process. Lastly is the issue related to textbooks. Both Ogude and Bradley (1996) and Garnett and Treagust (1992) in Sanger and Greenbowe (1997) suggested that textbooks contain misleading statements which result in learners' misconceptions. Ogude and Bradley (1996) argued that phrase like "continuity of current" does give an implication to learners that current is uniform throughout the electrochemical cell.

2.4 Summary

This study is intended to find out more about how I transform my content knowledge into forms that are accessible to learners. This chapter described the research related to the pedagogical content knowledge (PCK). The literature has indeed informed me more about what different researchers' views are about the notion of PCK. Others also suggested how PCK can be documented and portrayed into meaningful ways.

The chapter also gave an overview of some prerequisite concepts needed for teaching about the chloralkali industry. It is worth noting that, not much literature on teaching about the chloralkali process was done before. I gained a lot of insight from the literature about teaching the topic which involve the context based approach. I also found the literature on redox reactions and electrochemistry was useful when teaching about the electrolysis of brine in the chloralkali industry. In the next chapter I discuss the research design and methodology that facilitated the process of data collection and analysis.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter provides a discussion on how the research was carried out, including methods of data collection for my study. This includes the explanation of the type of research approach, the sample, instruments that will be used as well as ethical issues. The limitations of both research approach and instruments are also discussed. Finally, the issue around reliability and validity is also discussed.

3.2 Research approach

This study is a qualitative case study which is a self study focusing on my own teaching of the chloralkali industry to post matric learners in the North West Province. Amongst other reasons Bullough and Pinnegar, (2001) argue that a self study approach enables educator voices to be heard and will help them to better understand their teaching and their learners when teaching. However, a self study should not be of self per se but self in relation to practice and others sharing the practice setting (Bullough and Pinnegar, 2001). Hence in my study I involved learners and experts in the topic at hand.

Self study can be linked to action research. They have both similarities and differences. The first similarity between a self study and action research is that they both engage in cycle of research where there is collection as well as analysis of data (Samaras and Freese, 2006). The second similarity is that a researcher tries to inquire into a particular problem which might be related to one's practice to improve one's teaching. In my study I intended to seehow my teaching of the topic unfolds in terms of my PCK and hopefully to improve my practice as a teacher. The third similarity is that the methods such as narrative inquiry, autobiographies & biographies (Bullough and Pinnegar, 2001) used in action research are also incorporated in a self study research. The difference between the two research methods is that action research focuses on the relationship between "action" and "research" whilst self study focuses on the relationship between "self" and "study" and "self" is the focus of the study (Samaras and Freese, 2006). A self study differs from action research in that 1) it focuses on improving both personal and professional levels 2) takes the entire processes and makes them public hence it is not done in isolation as it collaboratively involves learners, colleague in order to build new understanding through dialogue (Samaras and Freese, 2006). The last difference between the two types of research is that action research is more about what the teacher is doing whilst self study is more about who the teacher is (Samaras and Freese, 2006).

The reason for choosing a self study approach is that it is relevant and appropriate for research questions in this study. For example my research question 1 and 2 intend to seehow my ideas on teaching the topic developed as I prepare to teach and how I captured and portrayed the knowledge. In doing self study, these questions need to answer how I generate the knowledge and its understanding, which relates to epistemology. Opie (2004) argue that the reason one does a research is to acquire knowledge and to be able to communicate that knowledge. According to LaBoskey (2007) the reason for doing self study needs to extend beyond epistemological reasoning into learning theory. This is supported by research question 3 of my study in that, it is attempting to answer how my content knowledge transforms into knowledge for teaching. This question will not rely only on the basis of research evidence but also based on my beliefs and values about teaching and learning in line with LaBoskey (2007).

3.3 Participants/ Sample

Since this study is self study research I was the focus of the study. Convenience sampling of learners was used. According to Opie (2004) a convenience sample is good for a case study, and a self study is a case study. However, I must make it explicit that no generalization will be made because this type of sample is small. This was a group of the post matric learners who came mostly fromNorth West province. These learners were doing matric for the second time and were on a special upgrading project. They were hoping to improve their physical science and mathematics symbols in order to obtain university entrance. The reason I chose this sample is that they were highly motivated learners. There were about 45 learners divided into two groups of 23 and 22. Both groups were used for data collection. The learners in the two groups were between ages of 18 and 20 years. They came from five different provinces (North West, Gauteng, Northern Cape, Limpopo and Mpumalanga Province). In terms of the school background, some came from township schools, rural village schools, former white schools and private schools. Finally, 30% of them obtained B symbol, 50% C and 20% D in their matric physical science in 2008. In other words, all passed but were seeking to upgrade themselves.

3.4 Instruments

Data were collected in the form of concept maps, journals, CoRe, PaP-eRs, lesson plan videotaped and audio tape lessons and learners' activities. However, it is worth acknowledging that, since this study is a self study there was no piloting of instruments. Below is the explanation on how each instrument was used.

3.4.1 Concept Maps

I developed three concept maps which served both diagnostic and formative purposes. Since my study is a self-study, I thought that diagnostic tests would not be suitable to use as I would know the answers to the questions. This is the reason I decided to use concept maps and assumed that they would work well. The first concept map was constructed based on what I knew at the start of the study about the topic as well as my 2008 teaching reflections. According to Adamczyk and Wilson (1996) concept maps show a basic understanding of one's content, gaps in knowledge and misconceptions which can be assessed. This first concept map (see Appendix 2) was intended to diagnose about how much I knew this topic as I had only taught the topic once before. The map indicated the prior knowledge and misconceptions I had about the topic hence the map served as a diagnostic tool. This function is in line with an assertion by Samaras & Freese (2006, p73) that "concept maps are artistic and cognitive tools that allow you to discover and demonstrate conceptual connections between and within concepts in a self study".

My first concept map was made public to three chemistry experts in order to elicit comment and input. Based on the feedback, I constructed my second concept map (see Appendix 3). However, my visit to the chloralkali plant and research done on electrolysis also played a role in its development. In doing so, my concept maps also served as a formative tool.

Although concept maps were found to be a useful research tool, they also have disadvantages. According to Adamczyk and Wilson (1996), the main disadvantage with the net structure concept maps is that, detailed analysis can take relatively long. Hilbert and Renkl (2008), argue that even though concept maps promote learning and understanding in teaching, beginners still find that to construct concept map demands more time.

The third concept map (see Appendix 3) was constructed after I had done my actual teaching. This concept map was influenced by comments from experts about the second concept map and my teaching reflections. Kinchin and Hay (2000) argue that differentiation between concept maps have been more on the quantitative aspect of research and they suggest that it is time concept maps are viewed qualitatively and also become a formative tool rather a than research tool.

In my study, the concept maps were analaysed both quantitatively and qualitatively using a rubric developed by O'Rode, Terman & Weissglass (2007) and adapted by Rollnick, Mundalamo & Booth (2008). The rubric used the constructs of correctness, connectedness and complexity to score the concept maps (See Appendix 1 for detailed rubric).

3.4.2 Journal

A journal (see Appendix 5) was kept to document and reflect on all the processes of my journey when learning and teaching about the chloralkali industry. Hoban, Butler & Lesslie (2007) argue that a journal should be a reflection of a researcher's events and thinking. I was in a position to document in my journal what I have learnt. This included my thinking, personal reflections, questions for myself, issues discussed, comments on my thoughts and things like what was learnt. In terms of my study, this included the following:

- My reflections on the first time teaching reflections of the topic.
- My thinking when creating all the concept maps.
- Experience from the choralkali plant visit.
- Inputs from the Self-Study group.

- Planning of lessons.
- Reflection of my second teaching lessons experiences etc.

Samaras & Freese (2006) argue that when doing a self study, it is important for a researcher to question his or her position or those of others. Hence this applied in my study before and after I got input from experts (individuals who assessed my content knowledge, colleagues (self-study group member) etc, as I tried to develop new understanding. Similarly on the visit to the site in the chloralkali industry; I was to transform what I observed from the actual plant site into learners' context.

Since I was looking into my own practice, reflecting was the most important aspect in this study. I used a journal mostly for reflecting on what had gathered. However, a journal also has its disadvantages in that it is subjective. According to Opie (2004) a subjective knowledge belongs to the individual as a result of his or her own thoughts and consciousness. I catered for subjectivity by linking what was in my journal to what was obtained from the other instruments such as concept maps, teaching lessons from the video-tape, learner feedback. In the process triangulation was fulfilled.

3.4.3 CoRe, PaP-eRs and Lesson plan

The two elements CoRe & PaP-eRs (See Table 5.1 in chapter 5) indicated by Loughran *et al.* (2004) for capturing and representing my PCK in meaningful ways were used as instruments in this study. It is worth mentioning that more about these elements were discussed fully in the chapter 2. The CoRe played an important role in guiding me how and why I go about planning my lesson which was brought to life by the PaP-eRs. The CoRe represented more of the content knowledge for teaching while the PaP-eRs reflected my teaching. A retrospective CoRe for 2008 teaching was developed and compared to the 2009 CoRe in an attempt to assess how my PCK develops. The CoRe for preparation of 2009 lessons was exposed to a Self-Study group in order to get input and for refinement. This approach was different from Loughran *et al.*'s (2004) who constructed the CoRes with the help of experienced teachers.

Lesson plans were another source of data in a self study as indicated by Samaras & Freese (2006). As I needed to know learners' prior knowledge on salt, I adapted the first two activities of 2009 lesson plan (see Appendix 7) from Rollnick and McBride. A practical activity on electrolysis of brine was taken from RADMASTE materials with a view of showing learners how brine is electrolysed. In order to explain to learners the impact of the plant on society, I adapted the flow diagram, three cell processes and debate activities (see Appendix 7).

In my study, all the experiences and reflections from the lesson plan were made part of my journal. According to Geddis and Wood (1997) when teachers plan their lesson, they take into consideration the development of that lesson. Questions like what type of strategies are to be used, what learners bring from their experiences, where I think they would have difficulties and how those problems would be avoided. The lesson plan in my study should however go hand in hand with the CoRe designed.

3.4.4 Videotaped and audiotape lessons

My teaching of the five hours lessons was video and audio taped so that I could analyse the lessons taught. The advantage of videoing is that it can be re-analysed later and it is less affected by distance. I also used a tape recorder for learners' work in groups but could not hear what they were saying to each other. Opie (2004) argues that an active classroom is not conducive for a tape recorder though tape-recorder may work in relatively close situations such as in small groups. On the other hand, videoing has technical problems of focusing and quality of sound. This was addressed by finding a trained person to do the videoing. Another disadvantage of video- recording is that it is intrusive and may influence the behaviour of both learners and a teacher. In support to this Opie (2004: 122) argues that "people /*learners* [Italics added] consciously or unconsciously, may change the way they behave when being observed". I addressed this by video-taping at least two lessons prior to the actual lesson for data collection as a way of getting learners to be familiar with the situation of being videoed.

3.4.5 Learners' activities

A written activity, Activity 4 (see Appendix 7) was given to the learners after the teaching the first lesson. The activity was in the form of a worksheet and it helped me to analyse and consolidate their understanding of the chloralkali process. Ball, Bass & Hill (2004) argue that teaching is about more than recognizing that learners' answers are wrong. This means that as a teacher one needs to be able to analyse where the problem is and the cause or origin of that particular error. This was done explicitly through my second lesson which was started with feedback on the activity prior to continuation of the rest of the lessons. When a teacher is in a position to do the analysis on learners' written work, he or she has portrayed deeper and more explicit knowledge of the content (Ball *et al*. 2004). Rollnick *et al.*'s tailored model of PCK that I used takes into account the knowledge of subject matter, hence understanding the content is crucial. This knowledge of subject matter plays a role in production of suitable tasks (Rollnick *et al*., 2008) that will promote conceptual understanding rather than procedural understanding.

3.5 Data collection

Data was collected in 2009. Since this was a self study aimed at improving both my content knowledge and content knowledge for teaching, I first reflected on lessons taught in 2008 for the chloralkali process. This has led to the construction of the CoRe for 2008 (Table 5.1 in chapter 5) lesson as well construction of my first concept map (see Appendix 2). My concept map was presented to the chemistry experts for comment and inputs on for validation and accuracy of content knowledge shown.

Concept map 2 was then constructed (see Appendix 3). This was based on the comments and input from the experts and my visit to the chloralkali plant in "Chlorchem" site in Chloorkop, Kempton Park, Johannesburg. Concept map two was also presented to the experts. Construction and development of my 2009 CoRe (see Table 5.1) began. I incorporated all the inputs and comments for my concept map two from the experts in my CoRe 2009 (see Table 5.1). This CoRe was taken to the Self-Study group for more inputs. After refining the CoRe, development of the lesson plan to be used in my teaching started.

I delivered the lessons to two different groups over two days and they were video and audio taped. Learners were given a class activity between the lessons to do, which was marked and were analysed (Appendix 9). Shortly after my teaching, I constructed the final concept map and the PaP-eR which were both influenced by my teaching of the topic. It is important to mention that in the whole data collection process, a written journal was kept. I found difficulties in capturing the six hours lessons for each class, due to the size of the memory card. Therefore, I was unable to videotape all the lessons. All these was analysed and validated. Shown below is explanation on how the data was validated.

3.6 Rigour

Rigour refers to the quality of the findings. In a qualitative research study, few measures are made therefore, trustworthiness, believability, credibility and consistency would replace accuracy as a warrant for validity (Feldman, 2003). Validity refers to the correctness of conclusions we draw from the data collected. This means that I had to give reasons why other people should trust my findings. According to Opie (2004) the data gathering procedure is to be carefully explained and biases are to be acknowledged.

The validity was ensured by getting comments from chemistry experts. I incorporated theses comments when developing the concept maps in the process improved my content knowledge. This is in line with Feldman (2003), who argue that, in a self study a researcher should pay attention to and make his or her work public for validity purposes. All written comments from experts provided in Appendix 8 as evidence. The scoring of concept maps was peer validated, and where uncertainties arose due to different opinions, a final decision was taken.

Validation of the CoRe was achieved through exposing it to the Self-Study group of four members. Three members of this group were masters students engaged in self study research and currently teaching physical science at high school and the other member was our supervisor who is also a specialist in this field. The comments and input that came from the group were valuable and added in the CoRe for refinement. Since my teaching was video recorded, I believe that this validated the content of the lesson plan. I included some of the learners' written activity in the Appendix in order to validate what I have analysed in my chapter 6 for manifestation of teacher knowledge in assessment. Feldman (2003) and Opie (2004) both argue that there must be extent of triangulation beyond multiple sources of data. In my study, this came out between my concept maps, actual teaching lesson, journal, self-study group, and visit to the plant. All information that came as evidence was included in the study.

Reliability refers to the extent to which an instrument gives consistent results under similar conditions. Opie (2004) views reliability as a property of a whole data collection process. Since this study is not scientific, reliability will be judged by the data gathering procedure (Opie, 2004). For example, I looked for the similarities in the comments from experts about my concept maps hence inter-rater reliability.

3.7 Data Analysis

Data collected in my study were in the form of concept maps, CoRes and PaP-eRs; video recorded teaching lesson and journal. The literature and experience gained from the continuous interaction with the data was used.

Concept maps were scored and tables of marks were displayed. Both quantitative and qualitative analysis was employed in analysing concept maps to show the development and improvement of content and content for teaching. I also analysed through comparing my CoRe for 2008 and 2009. I depicted the differences between two the CoRes in an attempt to find out how my PCK improved. This was further seen from the narrative in PaP-eRs. I transcribed some of the data from the video recorded lesson and my journals to further seehow elements of my PCK emerged.

3.8 Ethical considerations

In educational research, ethics is about process and power. Opie (2004) argues that research ethics should apply through the study. In undertaking the study, I conformed to the requirements of Ethics Committee in Education of the Faculty of Science, University of Witwatersrand (See Appendix 10). I made explicit to the Ethics Committee that there were no risks involved and no harm would be done to the participants. There were parties whose permission I had to seek prior to data collection. They were the head of school and the grade 12 learners (SeeAppendix 11 & 12). I made it clear to the head of school that, this would not interfere with the programme as the topic made part of grade 12 knowledge area in the National Curriculum.

I made it clear to learners that their anonymity was guaranteed. This implied that their faces would be obscured and I used pseudonyms in the transcripts to identify them. I also mentioned that the information collected would be used purely for study purposes, however, some clips of video may be shared with fellow researchers at seminars and conferences. The information will be kept in safe and secure place for up to the period of 10 years before it is destroyed.

3.9 Concluding remarks

The methodology highlighted above has attempted to facilitate both my content knowledge and content knowledge for teaching. All the instruments used measured what was intended. The collection of data generally went well. The next chapter presents the data analysis and the discussion of the results of the study.

CHAPTER 4

CONCEPT MAPS

4.1 Introduction

This chapter illustrates how the construction and use of concept maps helped me in developing and analysing my content knowledge and my content knowledge for teaching about the chloralkali industry. In this chapter, I describe concept map as data sources and the procedure followed for analysing the concept maps. I also give an overview of concept map scoring process and the findings , which is followed by an in-depth discussion, and a conclusion.

4.2 Concept as data sources

The data analysed in this chapter emerged from three concept maps I constructed. The first map was based on what I knew about the content before teaching. The map was later given to the experts for comments and input , which influenced the construction of my second concept map. After teaching had taken place, the third concept map was constructed. These concept maps served both diagnostic and formative purposes for development of my content knowledge. Novak and Gowin (1984, p101) argue that “concept maps are a simple tool for assessing where the learners are”. I expect the use of concept maps in my study to inform me and others about how much I knew about the content at the beginning as I prepared to teach and after teaching the chloralkali topic. Thus the maps served as a diagnostic tool. I also expected the use of concept map to have an effect on my teaching of the topic and thus the maps will serve a formative purpose.

I scored all the concept maps using a rubric used by Hough *et al.* (2007) and adapted by Rollnick, Mundalamo & Booth (2008) (See Appendix 1 for the detailed rubric). The rubric used the constructs of correctness, connectedness and complexity to score the concept maps. I outline below the essential elements scored in the three constructs in line with Rollnick’s *et al*. (2008) approach:

- *Correctness* – the accuracy of *all* of the links that are written down. This area addresses the question: What does the teacher know accurately? In assessing correctness myself and the peers looked at the number of correct links made in relation to the quality of the link statements and the number of nodes.
- *Connectedness* – an evaluation of the correct cross-links and chunks within the concept map. This area addresses the question: What is the sophistication of the linkages between the correct ideas? This score involved looking at correct chunks and cross linkages between the chunks.
- *Complexity* – an evaluation of the structure of the presented knowledge, with no regard to correctness. This score takes into account the number of concepts on the same level, the number of links in the longest chain, and cross linkages. Where there were no cross linkages, this led to a score of 0.

The scoring was peer validated using the same concept maps. The peers consisted of three of my colleagues whom in most cases used concept maps in their teaching and are also experts in high school chemistry. However, these peers were not the same experts who critiqued and gave input in the concept maps. I first requested them as a group if they would like to assess and score the maps. Upon agreeing I supplied them with the rubric to study it. This was followed by the first two concept maps. They only received the third concept map after my teaching was done. I then got together with the peers to compare the scoring. There were elements of uncertainty within the peers. We had different opinions about classifications of different links. For example, I decided to classify a particular link as superficial whilst peers considered it scientifically correct. Eventually, we came to an agreement and the final decision was taken. This was influenced by the agreement among peers based on the explanation given in a particular context. The scoring of the concept maps was decided among the peers. Since the scoring involves some calculations, I decided to approach one colleague in the mathematics department for validation of the final scoring process.

4.3 Results and Analysis

I analysed the three concept maps both quantitatively and qualitatively. Table 4.1 below shows the scores of the various maps obtained using the rubric. However, the detailed calculations of the scores are in Appendix 1.

Table 4.1: My scores on concept maps at different stages of the study project

Concept map number	Correctness	Connectedness	Complexity
1	383	23	432
2	426	25	325
3	427	34	784

The following points emerged from Table 4.1.

- A large increase in correctness from concept map 1 and 2 is observed but a negligible improvement from concept map 2 to 3.
- Although there seems to be a steady increase in connectedness overall, there was a negligible improvement between concept map 1 and 2. The third concept map has a large improvement relative to the second and first concept maps.
- Interestingly, the complexity of the second map was lower than the first. However, the complexity of the third map was double the second and was higher than the first (concept map).

In the following section, I explain more qualitatively the factors that could have affected the increase or decrease in scores in terms of the correctness, connectedness and complexity perspectives.

4.3.1 Correctness

In this study, I assumed that assessing correctness would help me to comprehend both the improvement in the quality of my content knowledge and the level of accuracy of my knowledge. I intended to identify new things I have learnt, the misconceptions I had and explain how I remediated them. I also have looked at how my content knowledge on this topic influenced my content knowledge for teaching. The discussion that follows attempts to accounts for the growth in my content's correctness and accuracy in all the three concept maps as plotted in Figure 4.1

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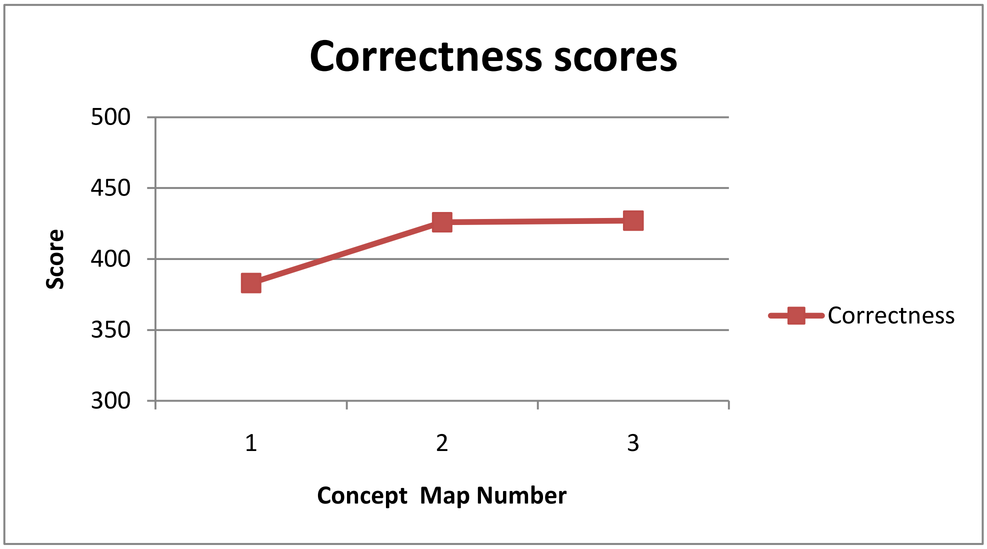


Figure 4.1: Plot of Correctness Scores

Table 4.2 provides more detail on the scoring procedure, together with the breakdown for each map

Table 4.2: Criteria for scoring correctness

CORRECTNESS						
	Missing or incorrect link	Link with no linking word	Link that represent superficial idea	Link representing an idea that is scientifically acceptable but could be clarified	Link with detailed and sophisticated understanding that is scientifically rich	Total number of nodes
CM 1	3	3	2	3	31	37
CM 2	1	1	0	2	26	26
CM 3	0	0	0	6	38	37

From Figure 4.1, it can be seen that concept map 1 has the lowest score in correctness. This is because the map had many lower quality links , which are: incorrect links, links with no linking words, links that represent superficial ideas, , which contained the lowest score (See Table 4.2 and Appendix 1 rubric). Figure 4.1, shows the second concept map to have a higher score relative to the first concept map. This is because concept map 2 contained more links of higher quality and fewer links of lower quality. This has resulted in a higher score. Concept map 3 displayed the highest score in correctness as most of its links are of a higher quality. There were fewer low quality links therefore the map's correctness was greater.

One may wonder how come concept map 1 had a lower score in correctness even though it contained a greater number of nodes (37) than concept map 2 (See Table 4.2). It has to be taken into consideration that, the formula for scoring correctness is:

Correctness = (L1) + (L2)…)/total number of nodes

Taking this formula into account, concept map 2 had fewer nodes; therefore its average was higher. It can also be seen in Table 4.2 that, in the case of concept map 1 and concept map 3 with an equal number of nodes (37), the correctness score differed. This was influenced by not only the number of links but also the quality of those links. Concept map 3 contained 44 links in total and concept map 1 42. The difference between the total number of links is so small that it could not have made such a big difference in overall score (see Table 4.1). But what has made this big difference, is the higher quality of links in concept map 3 (see Table 4.2).

It is worth mentioning that nodes are concepts linked to one or more other concepts. Nodes are not the total number of links. For example, concept map 3 has a total of 42 links but 37 nodes in total. The number of nodes is less than the number of links. This implied that, somewhere in concept map 3, there was a concept connected to different links or cross-links.

In the next paragraphs, I will discuss the relationship between the links and correctness in the concept maps one, two and three summarised in the Table 4.2.

To illustrate this point, I will focus on three examples: incorrect links, links with no linking words and links representing superficial ideas. Some concrete example of the incorrect links from the concept maps are represented in Figure 4.2 below: For example concept map 1 contained the following incorrect link:

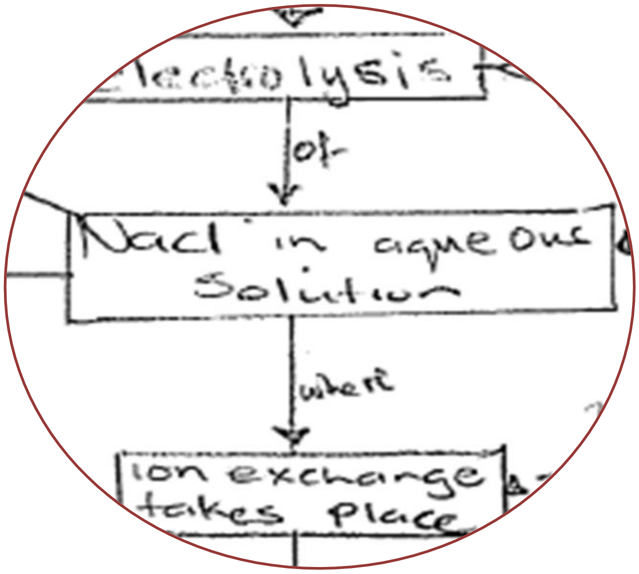


Figure 4.2: Sample from Concept Map 1

One incorrect link is the concept of ion exchange in Figure 4.2. This idea is incorrect because I had the misconception that in order to have sodium ions (Na^{+}) and chloride ions ($C\ell^{-}$), there must be exchange of ions coming from the sodium chloride solution. This was wrong because in an aqueous solution of sodium chloride, dissociation of $NaC\ell$ takes place leading to the presence of sodium ions, chloride ions and water molecules. This was suggested by one of the experts that I consulted, who commented that:

"Ion exchange leaves me puzzled. What is it and what is its place in the map? It would be better to just state that the solution contains sodium and chloride ions and water molecules." (The full comment from this expert can be found in Appendix 8)

I must make it clear that I did know about the dissociation process. I needed to find a way of bringing in the sodium and chloride ions in order to lead to the part where redox reaction occurs. With lack of understanding of content knowledge then, I was unable to find flexibility. When I brought in the concept of ion exchange, I was thinking of the membrane used in the process of electrolysis of sodium chloride. Hence I had a misconception that the membrane is responsible for allowing the ion exchange. This did not make sense because there is no membrane mentioned in Figure 4.2. Since I attempted to show what was happening in the cathode and anode compartment, the second expert gave the following comment:

"The major reaction type is redox, not ion-exchange" (The full comment from this excerpt can be found in Appendix 8)

Based on the two different comments from the experts, it was clear that the part of ion exchange was either not correct or was put in the wrong place on the map. Taking these comments into account, I then decided to correct that misconception as can be seen in Figure 4.3 taken from my second concept map:

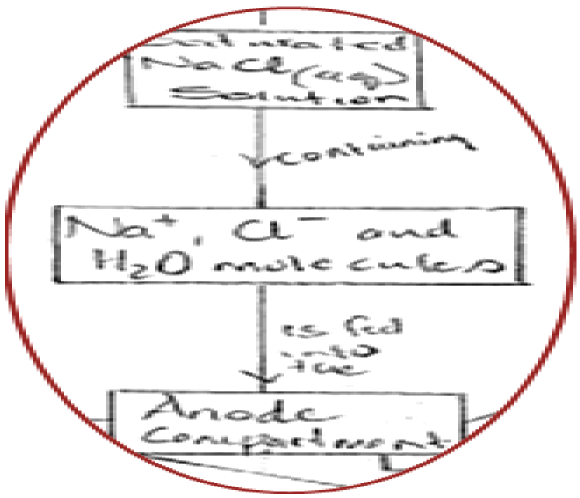


Figure 4.3: Sample from Concept Map 2

As can be seen in Figure 4.3, I have replaced ion exchange with Na^+ ions, $C\ell^-$ ions, and H_2O molecules. I decided to utilise the comment from the first expert only, but was also influenced further by my understanding of this topic, which led me to re-construct the concepts. By the time I was constructing this concept map, I already had a better understanding of how the electrolysis occurs relative to my understanding on the first concept map. Therefore, to show explicitly that Na^+, $C\ell^-$, and H_2O molecules are available helped me to illustrate that these are fed into the anode compartment as shown in Figure 4.3 and there was no need for ion exchange in order to have these ions available. I must emphasise that my understanding of the topic also played a role in constructing this map. I was already starting to develop ideas about how I will be teaching this topic. This is the reason I was able to choose which expert comment to use and if so where.

Another incorrect link spotted by the two experts appears in Figure 4.4 below:

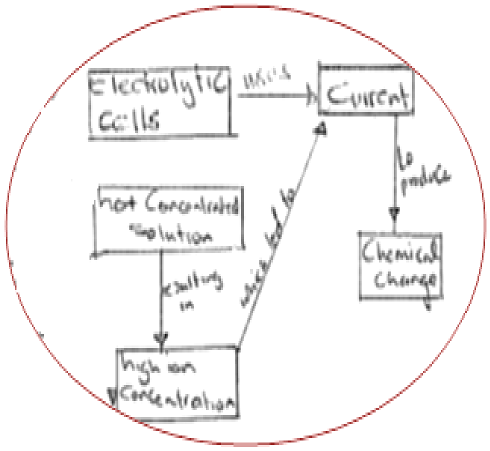


Figure: 4.4 Sample from Concept map 1

The concept of current in Figure 4.4 contributed to the incorrect link in the map. When constructing concept map 1, I believed that electrolytic cells use current in order to produce a redox reaction. This was shown to be incorrect by the experts who looked at the concept map from a different perspective. The first expert commented as follows:

"Electrolytic cells use electrical energy (rather than current) to produce chemical change" (The full comment from this expert can be found in Appendix 8)

This comment had made me think further about the difference between current and electrical energy. According to what I have written on the concept map, I thought the function of electrolytic cells depended on the flow of electrons only. This is not true because energy is required to be converted to work so that chemical change may occur. What further supports this, is the fact that electrolysis requires energy input since the reaction is non spontaneous. I found this idea to be very informative for my teaching since my learners would be engaging in a practical investigation of electrolysis of brine. Learners would notice that for a practical investigation, a power source will be included as part of the apparatus. I am hoping that when they make use of a power source, they would be able to link it to the fact that the reaction requires energy input.

Another expert commented about this from point of view of high ion concentration and said the following:

"The high concentration of ions in solutions leads to good conductivity, not current" (The full comment from this expert can be found in Appendix 8)

This comment made me to think deeper about the relationship between current and conductivity in solution. From the teaching point of view, I believe that a distinction between the two should be made explicit to learners. Learners should be aware that "current" is the flow of charge. However, a good conductivity of a solution like an expert indicated implied the concentration of ions in solution is high, which easily allow conduction to occur and has effect on the current. All these comments point to one thing that the concept of current does not apply in this context. The term "electrical energy" is more suitable hence energy is needed in order to have production of hydrogen, chlorine and caustic soda.

Concept map 1 had the highest number of links without linking words (See Table 4.1). Illustrated below in Figure 4.5 is an example of a link with no linking word

The number of links without linking words or propositions also contributed to the low score in correctness. The presence of links with no words or propositions could be due to the fact that I did not have enough content knowledge on this topic and hence I was unable to show flexibility when constructing the map. However, this does not mean that I did not have some working of content knowledge on the topic. For example in concept map 1, I was trying to show the link between cathode compartment and water molecules as shown below:

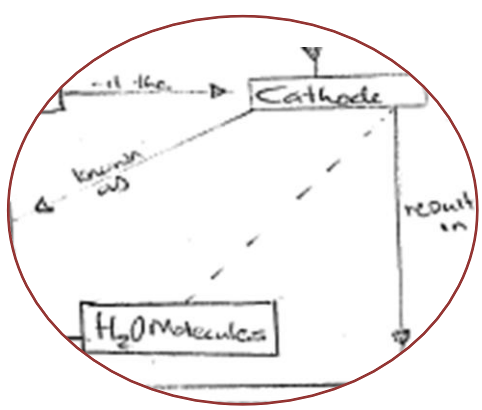


Figure: 4.5 Sample from Concept map 1

The link is correct because water molecules are indeed found in the cathode compartment during the electrolysis of brine and they are reduced. Although I knew that I was supposed to use words, what was actually not clear was the organisation of my ideas , which lead to difficulties in finding a suitable word or proposition to use and this had led me to use a dotted line. This dotted line mean “implied that” the cathode could be linked to water. I believe that absence of linking word in Figure 4.5 was due to lack of content knowledge. This can be supported by a statement from my journal (see Appendix 5) entry below when I was constructing the first concept map.

> “From the little knowledge I have on the topic, I had to do the concept map that will cover all I know about it….. It was little bit difficult to put down what I know in a concept map form”.

Another expert spotted that I wrote “H_2O molecules” in concept map 1. She recommended that, I should take into account and make distinction between the three levels of chemistry, which are: macro, micro and symbolic. In this perspective I put the symbolic level (H_2O) and micro (molecules), which is at particulate level. I found this comment very useful as I have always used the two interchangeably without noticing.

However, in my second concept map I was able to replace this with a correct linking word. This was influenced by the fact that I was getting to understand the content better. I now know that water is fed into the cathode compartment so that it can undergo reduction. This can be seen from Figure 4.6 , which shows a position of my concept map 2 below:

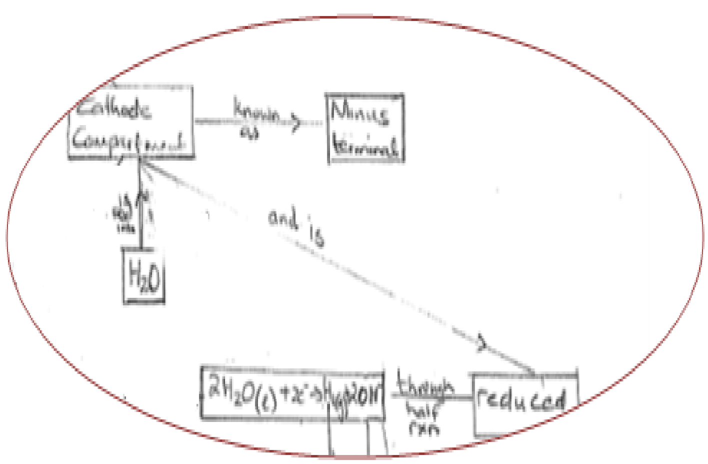


Figure: 4.6 Sample from Concept map 2

As shown in Table 4.2 both concept map 2 and 3 did not contain links with superficial ideas as specified in the rubric (see Appendix 1). However, concept map 1 had two links with superficial ideas, which is a lower quality link. For example one was hinted by an expert who thought that the way I made the Na^+ explicit on the map (see Figure 4.7 below) made it look as if it participates (is reduced) in the redox reaction.

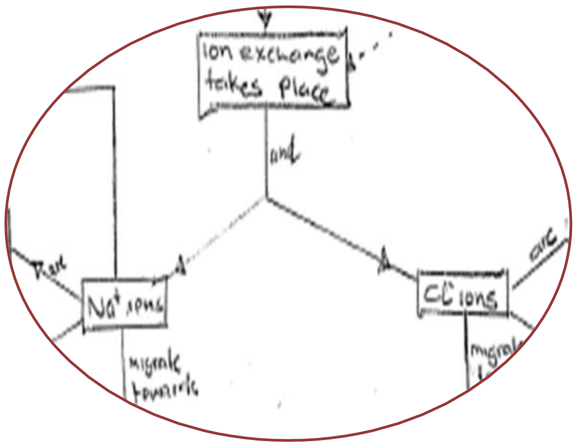


Figure: 4.7 Sample from Concept map 1

The expert's comment prompted me to learn more about the concept of reduction ability of different substances. I then understood that sodium ions were not reduced because they have a lower reducing ability compared to water molecules. This implied that water molecules were reduced in preference to Na^+ ions. Therefore, representing the reduction of water during the electrolysis of sodium chloride as shown in Figure 4.6 should be considered the more appropriate representation.

I also found out that the use and construction of concept maps was influenced by my content knowledge and content knowledge for my teaching (PCK). For example when I was preparing to teach the topic, I had constructed up to two concept maps. There is a part on my second map (see the circled part in Figure 4.8 below), which is constructed in the way that I directed my lesson when explaining the electrolysis of sodium chloride in a membrane cell.

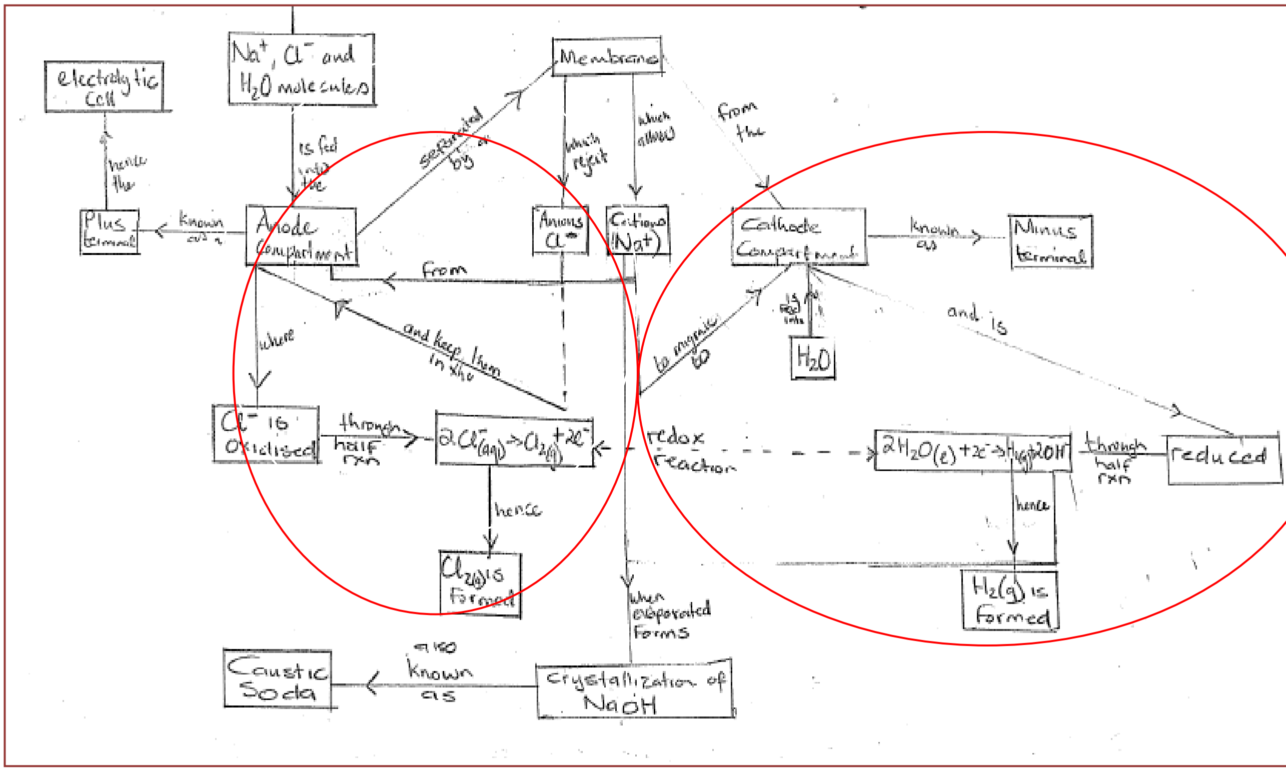


Figure: 4.8 Sample from Concept map 2

One aspect that shows that the map helped me in both acquiring content knowledge and knowledge for teaching came from my first concept map. My first concept map shows my content knowledge about the idea: sodium ions and hydroxyl ions combine to form sodium hydroxide. One expert advised me that it was wrong because ions in aqueous solution do not lead to solid formation directly. The product remains aqueous and forms a solid when the water is evaporated. I found this to be useful for my subject matter knowledge and also helping me in refining my pedagogical content knowledge. Hence I had also made it explicit to learners that in the plant further evaporation has to take place in order to obtain the solid sodium hydroxide.

As I mentioned earlier, I followed concept map 2 (see part of it in Figure 4.8) in explaining the cell membrane process when teaching my lesson. During my teaching, one learner asked me what the membrane is made of. As can be seen from Figure 4.8, I only indicated that the anode compartment is separated by a membrane from the cathode compartment and this is all I knew before my teaching. I was not sure of what to say to the learner. The question drove me to find out further the composition of membrane. I later learnt that the membrane is made from polymers, which can be giant molecules, for example like plastic. I found this to not only have broadened my knowledge of content but also refined my PCK. Even if I had to teach the topic again in future and a learner happened to ask me the same question related to membrane, I would be prepared. This is the reason I decided to include polymers in my third concept map because it was influenced by my teaching of the lesson. (See Figure 4.9)

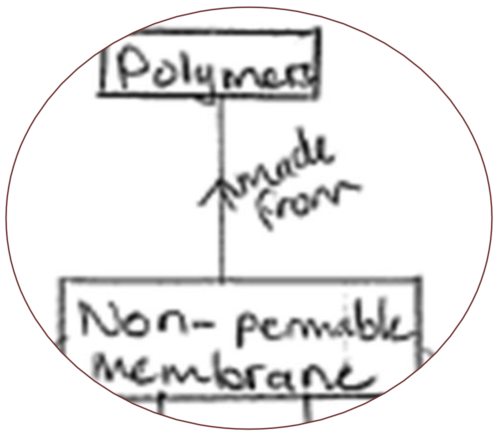


Figure: 4.9 Sample from Concept map 3

After learning from experts' comment that electrical energy is required during electrolysis process, I reflected on my teaching of the lesson and decided to relate that to the fact that the reaction is non spontaneous, therefore need to require energy so that the redox reaction can take place. Below in Figure 4.10, I have shown how my ideas on this topic changed from concept map 1 to concept map 2.

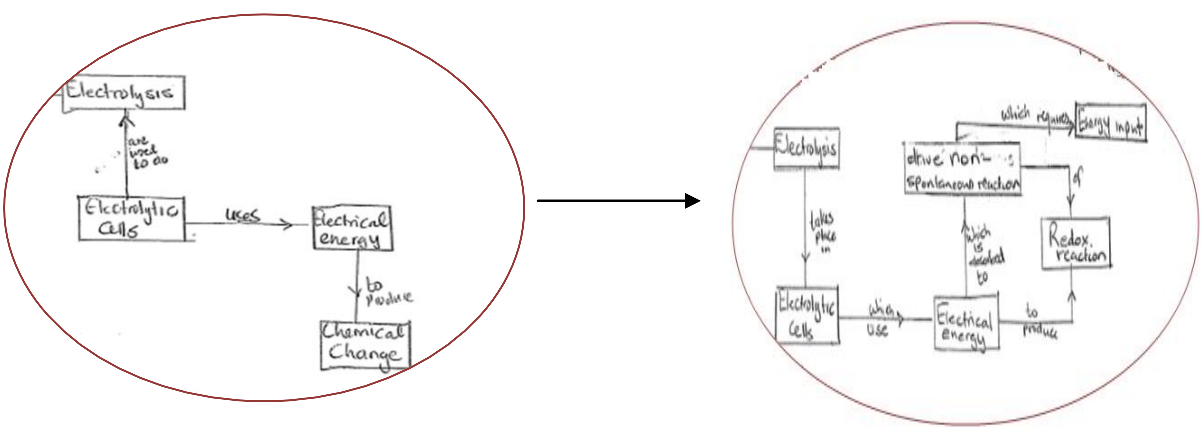


Figure: 4.10: Sample from Concept map 2 and Concept map 3

4.3.2 Connectedness

The assessment of connectedness will be able to show how well I recognized the concept linkage between sets of concepts. According to Novak and Gowin (1984) when a learner starts to show valid links between concepts from different levels from the map (cross-links), this implies learner's integrative reconciliation of concepts. Figure 4.11 represents the connectedness scores for all three concept maps.

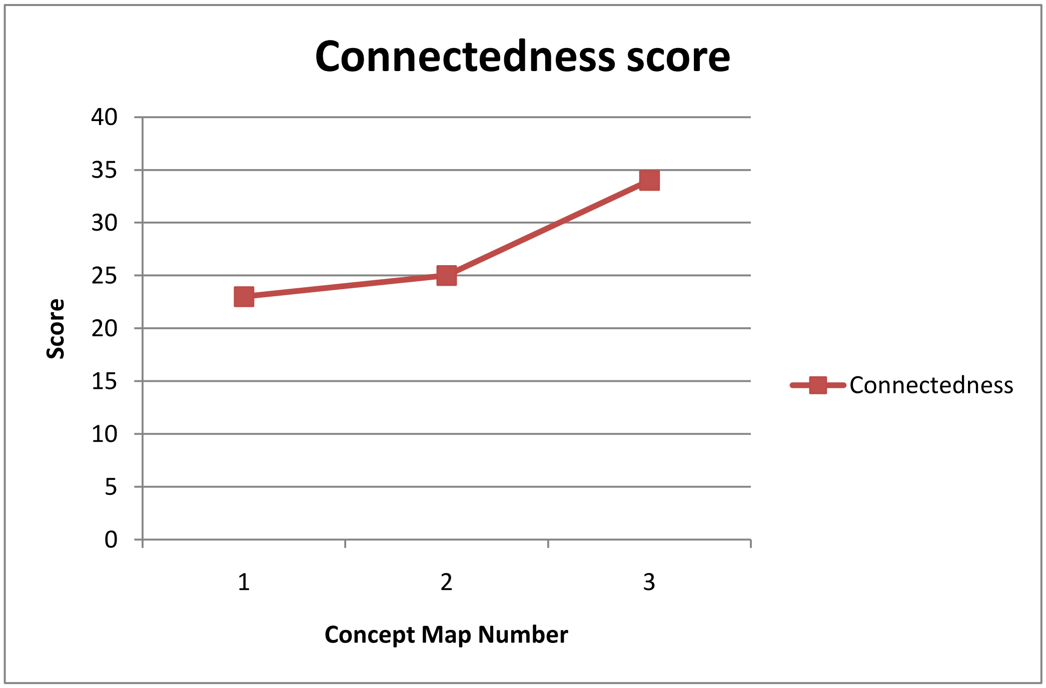


Figure 4.11: Plot of Connectedness Scores

As can be seen in Figure 4.11, concept map 1 displayed the lowest score in connectedness because it had fewer correct links relative to concept map 2. The breakdown of links can be seen from Table 4.3 below:

Table 4.3: Criteria for scoring connectedness and scores of connectedness

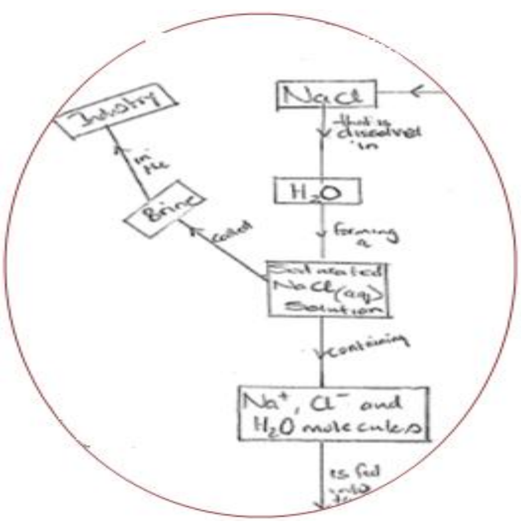
CONNECTEDNESS			
Number of correct links		Number of correct cross links	Number of correct chunks
CM 1	17	6	6
CM 2	18	5	5
CM 3	27	7	9

The other reason for the lowest score on concept map 1 could be the fact that there were more incorrect links. As a result, chunks for those links were not counted. However, if one looks closely at the score for connectedness of concept map 1 and two, one will see that there is a difference of only two in their scores in Table 4.1. From the qualitative perspective, there is a difference of only one in their number of correct links and also in the number of cross links. I assumed the small difference in score account for the score of 23 for concept map 1 and 25 for concept map 2 as shown in Table 4.1 This gives an indication that there was some knowledge about the chloralkali industry topic that I knew before the construction of concept map 1. Hence I had indicated in my journal that I had actually taught the lesson before (see below).

> "I was very confused and scared and I could not get the sense of what I was actually doing. All I taught was the electrolysis of NaCl and nothing much was said about the chloralkali industry in detail".

Table 4.3 shows that the two concept maps had equal numbers of correct chunks, but concept map 1 had fewer correct links within those chunks than to concept map 2. However, one important factor that came out of the maps was that concept map 2 had fewer cross-links than concept map 1.

Looking at the two sample maps (see Figure 4.12) one can see that in concept map 2 there was a part where I followed more of a chain structured in the map.



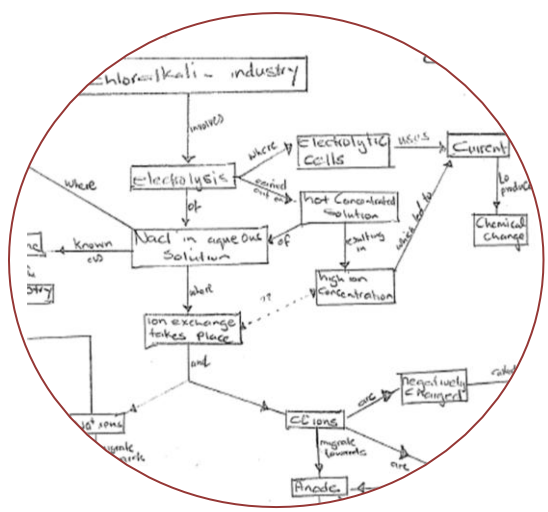


Figure 4.12: Sample from concept map 2-chain structure **Sample from concept map 1 -net structure**

I presumed that this kind of structure made it difficult for me to link different concepts hence they were no cross- links on the chain structure. This accounts for the lower number of cross links in Table 4.3. Kinchin and Hay (2000) found in their study that for learners with chain structured concept maps, addition of new knowledge could only happen if there was a break in their sequence. This could in turn be a problem if a sequence that is working for them is already in place therefore adding some concepts may appear superfluous. As a result one can see from the Figure 4.11 above that there was a gradual increase of connectivity from concept map 1 to 2, which was influenced by more correct links in concept map 2. However, there were few valid cross-links. I also had more gaps in my understanding of the content knowledge of the chloralkali industry, which led to the poor connections of concepts within the map and less flexibility.

Of all three concept maps, the third map was the most connected (see Appendix 4 in Table 4.1 and Figure 4.13) for more clearer and detailed concept map. As can be seen in Table 4.3, there were about 9 valid chunks with 18 correct links and 7 correct cross-links, which all gave the total score of 34 for connectedness in Table 4.1. Concept map 3 reflected a net structure.

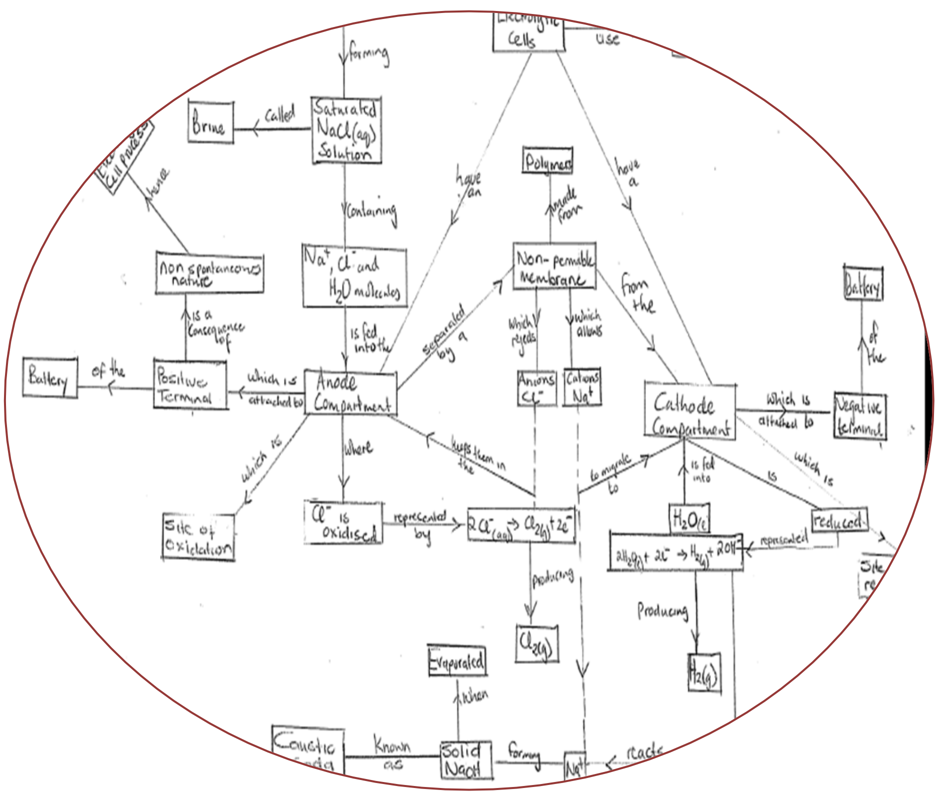


Figure: 4.13: Sample from Concept map 3-net structure

According to Kinchin and Hay (2000), in a net structure, access to some of the concepts may be achieved through a number of routes and in a way it is makes the knowledge flexible. The higher score in number of cross-links showed my integrative reconciliation of concepts by Novak and Gowin (1984) pointed out. These authors added that learners' ability to link concepts in the form of cross-links indicates that they did not learn by rote learning but constructed their knowledge. Kinchin and Kay (2000) share the same view.

4.3.3 Complexity

Complexity refers to the structure of the knowledge presented without regard to correctness. As can be seen from the rubric outlined in Appendix 1, the number of concepts from the same level, the longest chain on the map, as well as the cross links are taken into account when scoring the concept maps. Figure 4.14 represents the comparison of complexity of all three concept maps.

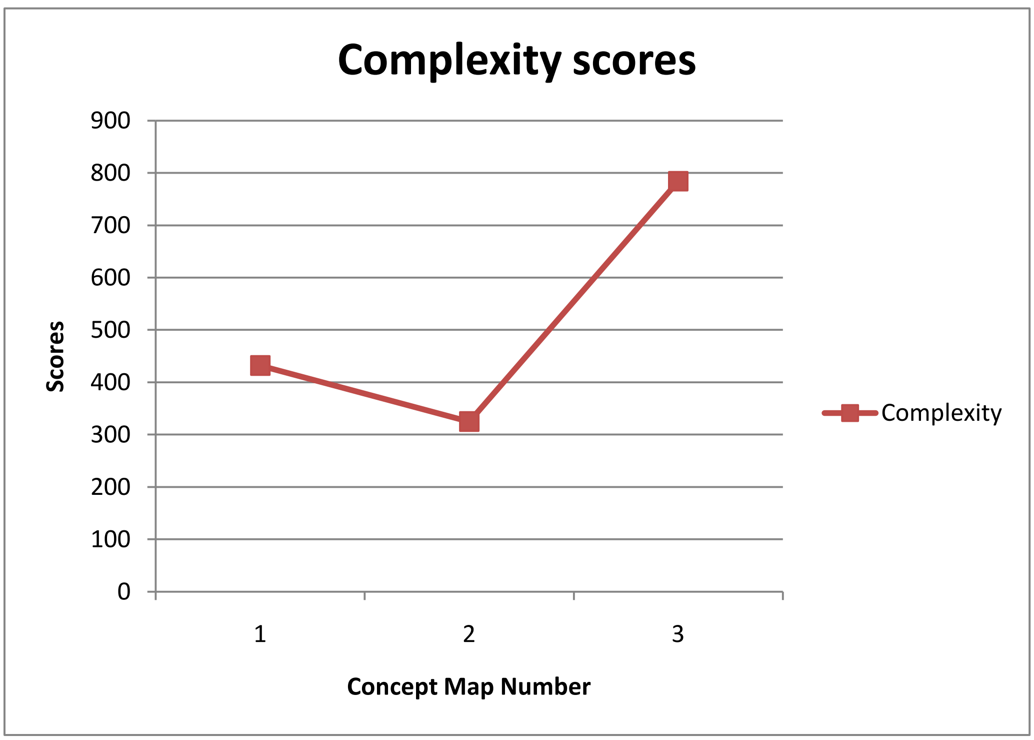


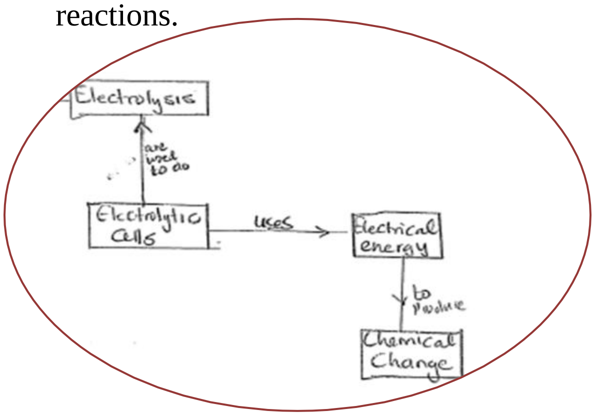
Figure 4.14: Plot of Complexity Scores

Figure 4.14 shows that concept map 2 is less complex compared to concept map 1. The reason is that concept map 2 had fewer concepts at one particular level (width) and fewer cross-links and therefore resulted in a less complex structure than concept map 1 (See Table 4.3 & Table 4.4). I would then assume, based on the results that the complexity of the map, has nothing to do with the depth of the map. The reason for this is that even though concept map 1 had the lowest score in depth, it remained more complex than concept map 2. This can be seen from Figure 4.14 and Table 4.1. It is worth noting that incorrect links and cross-links are taken into consideration when analysing complexity of the map. Therefore another factor could be that even if concept map 1's accuracy score was low, the map contained more of a net structure than concept map 2 as shown earlier in Figure 4.12 and this resulted in a higher number of concepts in more concepts from a certain level on the concept map 1.

Table 4.4: Criteria for scoring complexity

COMPLEXITY		
	Width (greatest number of concepts at one particular level on the map	Depth (the length of the longest chain)
CM 1	8	9
CM 2	5	13
CM 3	8	14

Concept map 3 was more complex than all the other maps. There was a large increase from concept map 2 to concept map 3. The greater width and depth, greater number of nodes and greater number of cross-links accounts for the map's complexity (See Figure 4.14 & Table 4.3). Kinchin and Hay (2000) argue that high complexity of the map implies that the map type is net structured; its integrity is high and adding concepts would not affect results because there are other routes available through the map. Illustrated below in Figure 4.15, is an example from part of my concept map 3 showing how complex it became as I was attempting to relate electrolysis to electrolytic cells, electrical energy, non spontaneous reactions, energy input and redox reactions.



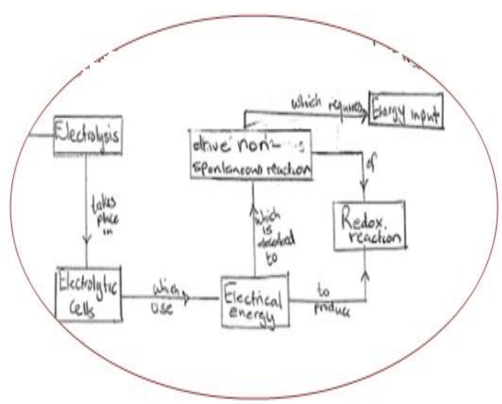


Figure: 4.15 Sample from Concept map 2

Figure 4.16 Sample from Concept map 3

In Figure 4.15 of concept map 2 I related the concepts in a form of a chain structured map only there were no cross-links. However, in Figure 4.16 of concept map 3, I was able to use the same concepts used in Figure 4.15 to further link them with other concepts and by showing the cross-links. I also found Figure 4.16 useful during my teaching of the topic as I had already incorporated from experts prior to teaching the topic. I used it to explain what electrolysis is. It is worth mentioning that additional complexity in Figure 4.16 suggests that I display wider understanding. It also suggests I am now more flexible with respect to my content knowledge.

I found in my study that concept maps' correctness does not imply that the maps' complexity will be greater. This was observed in concept map 2, which was more correct compared to concept map 1 but its complexity was lower. Another finding that came out from my study is that, the extent of connectedness of the map does not automatically imply that the complexity of the map will be greater (since correctness is excluded). This can be seen from concept map2, which is more connected than concept map 1 but was less complex. The more complex the map will be depends on how the correct links are connected. Hence concept map 3 had a score of 784 for complexity. This means that there were more links that were correct and also well connected within the map.

4.4 Conclusions

The use of concept map according to Kinchin and Hay (2000) is to promote understanding in a way that newly developed knowledge interacts with learners' existing cognitive structure. This was seen in my study when I first constructed my concept map 1 by putting down all I knew about the chloralkali industry and presented the maps to experts for comment about my understanding of the content knowledge of the topic. The idea of getting comments from others, while constructing the concept maps is supported by Kinchin and Hay (2000) in that when one constructs a concept map, he or she discloses his or her mental models to others. Based on the comments received from the experts as well as the information that I personally researched about the topic helped me to show some interactions between new and existing knowledge , which led to further develop the second and third concept maps. This was shown clearly where misconceptions were spotted and corrected new linkage. The reason for replacing misconceptions is supported by Novak and Gowin (1984) who argue that misconceptions interfere with establishing desired new knowledge unless certain steps are taken to help learners re-organise their concept maps. According to Novak and Gowin (1984) faulty linkages may be misconceptions that according to Kinchin and Hay (2000) reflects one's understanding of the topic. This validates Kinchin and Hay (2000)'s view that concept maps are good metacognitive tools.

According to Kinchin and Hay, (2000) a concept map that displays a high level of connectedness shows the ability in understanding the two following two properties.

- The representation of one's mental model
- The organization of ideas.

The fact that I had more valid links and cross-links in the third concept map, which led to more connectedness, suggests that I was able to think more deepely about the content. Based on this analysis, it can reasonably be argued that the use of concept maps promoted the development of my thinking skills. I had to think of what I know about the content knowledge, make it explicit by representing them in a concept map form. Hence the structure of a map reflects one's experiences, beliefs and biases in addition one's understanding of the topic (Kinchin and Hay, 2000). Reflection of my experience was observed during the change in meaning in every stage of the three maps whereby some of my existing knowledge, which included some misconceptions, was displaced by the new more accurate ideas, which led to meaningful learning.

Undoubtedly, it was not easy for me to follow one level of concepts in all my maps because my maps' hierarchical structures were not clear and this did not make things easy for me to assess the width and the depth of the maps. This is in line with Novak and Gowin's (1984) study that, the hierarchical structure allows one to easily do assessment on the map. Because I could easily see hierarchies of relationships from the nodes in all the concept maps; the fact that hierarchical structure was not clear in all my maps did not stop me from identifying the number of concept in one level as well as the longest chain. I had to re-arrange the levels in all my maps into numbers in order identify all the levels. For me to come up with the levels shows that I had to think of what I make out to be the most inclusive, less inclusive and least inclusive concepts in the subject matter , which leads to active cognitive thinking in line with Novak and Gowin (1984).

I must indicate that during the development and construction of my concept maps, I did not know, which model I would be using to analyse them. These could be illustrated by an example of hierarchies I mentioned above. For example, in order to find complexity of the map, there is a need for visibility in levels of hierarchy. Unfortunately, hierarchical levels in my concept maps are not clear. In order to find a score for complexity, I had to re-arrange concepts in all my concept maps. This had led me to eventually know the width and depth of my concept maps.

The use of concept maps had also influenced the manner in, which I presented my teaching lesson. There were parts in the maps that I used as they were as I was teaching my lesson. I found that the content knowledge gained during the construction of my concept maps helped me in refining my PCK. My teaching of the topic also played a role in refining my PCK because there were other ideas that emerged after my teaching lesson. I believe that they have also influenced my PCK on the lesson, which could be implemented in the future lessons. This shows that development of PCK is a continuous process that depends on teacher’s experience on the topic.

CHAPTER 5

CAPTURING AND DOCUMENTING PEDAGOGICAL CONTENT KNOWLEDGE

5.1 Introduction

This Chapter shows how I represent my pedagogical content knowledge (PCK) about the teaching of chloralkali process. For this representation, I have two different but complementary elements below, following Loughra *et al*. (2004) approach:

- The CoRe which stands for Content Representation
- The PaP-eR which stands for Pedagogical and Professional-experience Repertoire.

As was indicated in Chapter 2, these two elements capture and represent one's PCK in meaningful ways. Loughran *et al*. (2004) argue that a CoRe is an overview of the particular content taught when teaching a topic to a particular group of learners. It gives a general idea of how teachers approach their teaching of the whole topic and the reasons for that approach i.e. what content is taught, how and why in the form of propositions (Mulhall, Berry & Loughran, 2003). The PaP-eR intends to illustrate aspects of the CoRe in a particular classroom context (Loughran *et al*., 2004). Based on his or her experience of the content, a teacher unpacks his or her thinking to illustrate aspects of PCK. The PaP-eR thus emerges from teachers' actual practice with the intention of making teachers' tacit knowledge clearer.

5.2 Construction of the Co-Re

A CoRe is made up of 'Big Ideas' and Prompts (See Table 5.1). Mulhall, Berry & Loughran (2003, p7) describe 'Big Idea' and Prompts as follows:

- *Big Idea* is an idea that has a profound impact on the way scientists understand the world and teachers see it as being at the heart of understanding the topic for a particular class at hand.

- Prompt 1: *<u>What you intend students to learn about this idea</u>*

  This Prompt emphasise the fact that as a teacher, I should be specific about what learners should be able to learn hence is an important aspect of well developed PCK.

- Prompt 2: *<u>Why is it important for students to know this</u>*

  In order to make decisions on what to teach, teachers knowledge on what science content is relevant to learners' everyday lives and how the content links with other areas that learners study need to be taken into considerations.

- Prompt 3: *<u>What else you might know about this idea (that you would not share with students yet)</u>*

  When selecting what to teach, a difficult decision has to be made regarding which content should be omitted.

- Prompt 4: *<u>Difficulties/ limitations associated with teaching this idea</u>*

  As part of important aspect of teachers' PCK, it is important to take into account teachers' insight into potential difficulties when teaching a particular topic to the class.

- Prompt 5: *<u>Knowledge about students thinking that influences my teaching of this idea</u>*

  This Prompt makes explicit the influence on their decision-making of teachers' experience in teaching the topic. Teachers draw on their knowledge about alternative conceptions that are held by learners about the topic when planning their lessons.

- Prompt 6: *<u>Other factors that influence my teaching of this idea</u>*

  Contextual knowledge about learners and general pedagogical knowledge that influence teaching approach are indicated in this Prompt.

- Prompt 7: *<u>Teaching procedure (and particular reasons for using these to engage with this idea)</u>*

  The purpose of teaching procedures from a constructivist perspective is to influence learners' thinking in ways that promote better understanding of science ideas.

- Prompt 8: *<u>Specific ways of ascertaining students understanding or confusion around this idea</u>*

> As teachers we need to constantly monitor the progress of learners' understanding in order to determine the effectiveness of their teaching of the topic and plan future lessons.

As indicated in Chapter 1 that I taught the chloralkali industry for the first time in 2008 and then realised that my content knowledge on the topic was poor, hence I decided to do a Self-study on it in 2009. This implies that I did not have a CoRe prepared during 2008 teaching. Prior to preparation for my 2009 teaching, I decided to construct a CoRe for 2008 lesson (See appendix 6). This was influenced by my teaching material (lesson plan), my teaching practice and my reflection on the lessons. This was the time 'Big Ideas' for 2008 CoRe started to emerge. I used mainly a 2008 lesson plan (see appendix 6) as a reflection of what I taught which later informed the answers to Prompts for the 2008 CoRe.

All this was done prior to the construction of the first concept map and 2009 CoRe, because I wanted to outline everything I knew about the topic then i.e. before starting with preparation for the 2009 teaching (see appendix 7). It is worth noting that my eventual 2009 CoRe was influenced by all my previous concept maps (1, 2 and 3), the experts' comments and insights developed from my visit to the chloralkali plant, the lesson plans as well as the actual teaching of the topic.

The CoRe for preparation of 2009 lessons was shown to a self study group in order to get their input. For example my first CoRe's Big Idea states: redox reactions involve electrolysis of sodium chloride. The Self-Study group pointed out that I should rephrase the Big Idea as follows: "electrolysis of sodium chloride involves redox reactions". My first Big Idea implied that redox reactions must be driven by electrolytic processes. This was incorrect because redox reactions can occur without electrolysis. Therefore the Self-Study group input on the Big Idea made sense because electrolysis of sodium chloride would not be able to take place without redox reactions. But, redox reactions may occur without electrolysis. The Self-Study group's input thus helped me refine my CoRe Big Idea outlined in Table 5.1.

The other aspect of CoRe that I learnt from the Self-Study group was how to answer Prompt 5 in Table 5.1: "what knowledge can I share about students thinking that influences my teaching of this idea?" All my previous answers only referred to learners' prior knowledge. Other factors tabled in part of my journal below were only taken into account only after the input from the Self-Study-Study group.

> "I have learnt that knowledge about 'student' thinking which is part of the CoRe-does not relate only to learners' prior knowledge as I always mention but also their misconceptions, interests, background context etc."

The idea of including learners' interest and background context as indicated in my journal excerpt above allowed me to know more and has given me flexibility in thinking about Prompt 5 in the Table of CoRe for 2009. This can be seen from the difference between my answers to Prompt 5 in my Table 5.1.

The reason I decided to hold on to the same Big Ideas in the 2009 lesson is that I believed that when teaching about chloralkali process, the first main idea is that learners understand how the electrolysis, which involves redox reactions occurs on a laboratory scale. It was expected that this understanding would then help learners to understand better how the electrolysis process takes place at an industrial scale and its impact on human lives. Besides the similarity in the Big Ideas of the 2008-2009, there were other similarities in the response to Prompts as they appear in Table 5.1. My main goal was to undertake a detailed investigation of the differences in the responses to identify changes in my teaching of the topic. Firstly, I investigated the Big Idea "electrolysis of sodium chloride involves redox reactions". Secondly I investigated the second Big Idea "the chloralkali industry plant has impact on the societal, economic and environmental issues".

This approach was different from Loughran *et al*.'s (2004) who constructed the CoRes with the help of experienced teachers. Below I have compared my two CoRes (2008 & 2009) to depict possible changes in my approach to teaching the same topic. Table 5.1 outlines 2008 and 2009 CoRes respectively.

Table 5.1: 2008 & 2009 CoRes

Big Ideas	Electrolysis of sodium chloride involves a redox reaction.		The chloralkali industry plant has impact on the societal, economic and environmental issues.	
Prompts	**2008**	**2009**	**2008**	**2009**
1. What do I intend students to learn about this idea?	*Redox reactions are responsible for electrolysis.	*Redox reactions are responsible for electrolysis. *Electrolytic cell uses electrical energy– to drive a non-spontaneous reaction. *Electrical energy comes from an external power supply-battery.	*The choralkali industry uses three different types of cells in order to produce hydrogen, chlorine and caustic soda that human beings depend on.	*The choralkali industry is responsible for production of hydrogen, chlorine and caustic soda that human beings depend on.
2. Why is it important for students to know this?	*Because it explains to the learners what products and how they are formed are formed during the electrolysis of NaCℓ.	*Because it explains to the learners what products and how they are formed during the electrolysis of NaCℓ. *Because it helps to explain to learners that energy is absorbed in order to drive a non-spontaneous redox reaction.	*To know the uses of the products mentioned above. *To know health problems associated with the operation of the plant.	*To know the uses of the products mentioned above (the benefits- production of soap, plastic (PVC), food and the risks to human kind. *To think of sustainability in terms of economic development, society, and environment and possibly in the future. *To give constructive criticisms as to whether the plant should exist or not, looking at technology improvements
3. What else do I know about this idea that would not share with students yet?	*The chloralkali plant's impact on human lives.	*Uses of products of industrial process of NaCℓ. *The chloralkali plant's impact on human lives.	*Chlorine is responsible for organic chlorine compounds- through the process of chlorination there will a manufacturing of organochlorine insecticides known as Dichlorodiphenyl trichoroethane (DDT).	**Preparation of students for content at much higher levels of chemical industry in the future**. *How to calculate production of a chloralkali industry plant- hence its performance. *How to evaluate its power consumption.
4. What are the difficulties/ limitations associated with teaching this idea?	*Distinguish between electrodes- which one is the anode and cathode in both electrolytic and galvanic (voltaic) cells.	*Distinguish between electrodes-which one is anode and cathode in both electrolytic and galvanic (voltaic) cells. *Distinguish between electrodes and electrolytes.	—	**Limitation** *Students had never been to the chloralkali industry plant. They might assume that the diagrams or representations of electrolysis they see in textbooks, is exactly what is in

Big Ideas	Electrolysis of sodium chloride involves a redox reaction.		The chloralkali industry plant has impact on the societal, economic and environmental issues.	
Prompts	**2008**	**2009**	**2008**	**2009**
				the industry.
5. What knowledge can I share about students thinking that influences my teaching of this idea?	*Since it was the first group of learners to do NCS grade 12, I expected them to show much more interest in the new topic.	*Students always engage in basic chemistry concepts but do not get to take chemistry out of classroom in order to taste a bit of the real action. Often they are not aware or not sure that the chemistry they do in class also applies in everyday-life in industries etc.	*Learners are familiar with soaps, detergents, plastics, bleach, PVC, but do not know that all these start through industrial electrolysis of brine.	
6. Are there any other factors that influence my teaching of this idea?	*Knowledge of national curriculum *Knowledge of learners' context. *Linkage with previous work done (prior knowledge for conceptual progression. -Knowledge of chlorine, -Oxidation numbers, difference between oxidation and reduction, writing chemical formulae, writing and balancing chemical equations, the understanding of charges on ions and galvanic cells	*Knowledge of national curriculum and exam requirements *Knowledge of learners' context. *Linkage with previous work done (prior knowledge for conceptual progression. **-Knowledge of salt** **-Representing chemical change**-writing and balancing chemical equations. **-Electrochemical reactions**- Distinguish between electrodes and electrolytes, oxidation numbers, redox reactions, the understanding of charges on ions comparing (strengths) redox potentials, electrolytic and galvanic. *Students' interests.	*Knowledge of national curriculum *Knowledge of learners' context.	*Knowledge of learners' context. *Knowledge of national curriculum and exam requirements. *Linkage with previous work done (prior knowledge for conceptual progression **-Organic molecules** -systematic naming & formulae, substitution, addition and elimination reactions **-Organic macromolecules-** plastics & polymers
7. What teaching procedure would I use?	* **Probes** of learners alternative conceptions about chlorine. (learners are asked to write as many facts about chlorine) and followed by practical Activity on microscale electrolysis of brine	***Probes** of learners alternative conceptions about salt (e.g. To do an Activity of spotting the salt and to read about the history of salt so that they learn something knew). ***Practical Activity on microscale electrolysis of brine** - in order for learners to explains and describes what happens during the electrolysis.	*Lecture method of teaching explaining the health problems associated with operating the cells.	***Translation Activity**-learners are to interpret the flow diagram and translate it by making a story about products of brine electrolysis. This would help a teacher to facilitate their understanding on functions of the product in society. ***Table of comparison of 3 cell processes-** power point is to be used to show diagrams so that learners would be in a position to differentiate the cells and know their

Big Ideas	**Electrolysis of sodium chloride involves a redox reaction.**		**The chloralkali industry plant has impact on the societal, economic and environmental issues.**	
Prompts	**2008**	**2009**	**2008**	**2009**
				advantages and disadvantages in operating them. ***Debate**- learners would be able to engage in this debate as groups in a view of understanding the impact of the plant in societies and to also be encouraged to act responsibly.
8. What strategies could I use to ascertain learners' conceptions/ misconceptions of this idea?	*Ask questions at the end of the lesson in order to assess learners understanding. *Allow learners to also ask the questions.	*Ask questions at the end of the lesson in order to assess learners understanding. *Allow learners to also ask the questions. *Give learner class Activity that relates to the lesson taught to do individually and to be marked. This will help me to see the part of the lesson learners did not fully understand.	*Allow learners to also ask the questions.	*Ask questions at the end of the lesson in order to assess learners understanding. *Allow learners to also ask the questions. *Class Activity- in an attempt to find out what learners understood about the lessons taught.

5.3 Discussion of the CoRes

The CoRes represented in Table 5.1 have two Big Ideas that are similar which are:

- Electrolysis of sodium chloride involves a redox reaction
- The chloralkali industry plant has impact on the societal, economic and environmental issues.

5.3.1 Construction of Big Idea 1

In the first Prompt, I intended learners to know about the Big Idea “electrolysis involves redox reactions”. In the 2008 CoRe, my intention was for learners to understand and identify redox reactions only. As I was preparing the content for teaching the 2009 lessons using concept maps; I realised that it was important for learners to also understand that electrolytic cells require electrical energy in order to work. This knowledge can help learners calculate cell potential from their work on electrolysis and understand why it has a negative value. Learners can therefore explain that a non-spontaneous redox reaction requires energy input hence the negative cell potential value. Another important aspect that I intended learners to know about this idea was that the electrolytic cell functions with an external power supply (a battery which produces electrical energy). In the 2008 CoRe, I did not make this explicit. This is because the diagram to illustrate the electrolytic cell in industrial electrolysis I used did not show a power source connected to it. The reason I believe that the power source should be made explicit is that; this will help learners understand more clearly why the positive electrode is in the anode compartment whereas negative electrode is in the cathode compartment, which differs completely from the electrochemical cells.

A most important aspect is Prompt 6 of the CoRe. The Prompt interrogated factors that influenced my teaching of the idea. There were some similarities between 2008 and 2009 CoRes such as knowledge of curriculum and examination requirements, knowledge of learners’ context, representation of chemical change and some of the electrochemical reactions including oxidation numbers.

However, there were some important differences in the CoRes. For example in the 2008 CoRe, I considered learners' knowledge about chlorine to be the main prior knowledge for conceptual progression. The reason I intended learners to know about chlorine is that I believed since most of its by-products like PVC are used in medicine and the building industry as well as water purification are in demand. Therefore industry is more concerned about chlorine demand. Another reason was that of the name of the industry 'Chlor' which only emphasises chlorine. However, as I began to understand the content of the chloralkali industry better for preparation of my teaching in 2009, I visited the plant and reflected deeper on the process occurring. I thus realised that feasibility of the reaction is based on the availability of sodium chloride. Thus I included in my CoRe for 2009 the knowledge of salt, the main prior knowledge instead of knowledge of chlorine. I believed that chlorine is only one of the products of the process. Like sodium hydroxide and hydrogen depends on the availability of salt.

The other prior knowledge of electrochemical reactions is learners' knowledge of comparing strengths of reduction potentials. I did not make use of the table of reduction potential in the 2008 CoRe for the lesson as the manner in which my lesson plan was prepared showed the half reactions that were already given to learners as well as the anode and cathode. The CoRe for 2009 emphasised the need for learners to interpret and understand the reduction potential because they had to explain which substance was reduced and which was oxidised.

Some of the aspects that changed from 2008 to 2009 in the CoRes are the teaching procedures. This can be seen in Prompt 7 from Table 5.1. Here the practical Activity on microscale electrolysis of brine was highlighted as a teaching procedure for both CoRes. This Activity was meant for learners to explain and describes what happens during the electrolysis of brine. However, there was a distinction between how this practical Activity was used in 2008 and the way it was used in 2009 teaching. In 2008, learners were told about the products of the chloralkali industry and their uses before doing the practical Activity of sodium chloride electrolysis. In 2009 I did the same practical Activity first before explaining anything about the products formed. I wanted learners to explore this Activity, inform me about what they had observed and I would then use the results they got to inform the rest of my lesson.

Teachers need to have strategies that they can use to ascertain learners' conceptions or misconceptions when teaching. This was highlighted in Prompt 9 in Table 5.1. In the 2009 CoRe, I gave learners a class Activity that they would perform individually, which I would be able to mark and give feedback before continuing with the next lesson. I intended to see which part of the lesson the learners did not fully understand. I did not make use of this strategy in 2008 because most of the time learners were working in groups. I therefore assumed (perhaps wrongly) that answers given were correct.

Another reason for giving learners a written class Activity was that I needed to understand the kind of difficulties learners had with the topic. This could substantiate my assumption in Prompt 4 for 2009 (shown in Table 5.1). In the 2009 CoRe, I assumed that learners would have difficulties distinguishing between the electrodes (anode and cathode) in electrolytic and galvanic cells. This has indeed turned to be a problem to learners. I also found it hard to give an in-depth explanation to the learners because all I knew was that, in an electrolytic cell anode is labeled a positive electrode and cathode is labeled a negative electrodes which is the opposite of the situation in electrochemical cells. This has shown me clearly that my pure content knowledge and knowledge for teaching this topic still need improvement. I have thus considered that as a difficulty associated with teaching this Big Idea for the learners.

5.3.2 Construction of Big Idea 2

My second Big Idea concerned the impact of the choralkali plant on society. A comparison of the CoRes showed that what I intended learners to know about the idea was that human beings depend indirectly on the products that are produced in this plant. To Prompt 2, in the 2008 CoRe, I answered that learners would be able to know the uses of the product and the health related problems associated with operating the plant (See Table 5.1 for 2008). However, when preparing the CoRe to teach the topic in 2009, I found in the curriculum guideline (see Appendix 13) that learners were not supposed to know only the health risks. They were also expected to elaborate on whether the plant should exist or not. I thus incorporated this idea in my CoRe for 2009.

Prompt 3 was concerned with what I knew as a teacher that I did not want to share with learners yet; in my 2008 CoRe (see Table 5.1) all I could think of was that organic chlorine compounds made from chlorine could at the end manufacture organochlorine insecticides that can be used to kill mosquitoes. It is worth noting that after my visit to the industry this year, I also learnt new things such as to calculate chloralkali plant's power consumption and production capacity performance. These uses are beyond the scope of curriculum of the South African grade 12 learners.

In terms of difficulties or limitations associated with teaching this idea, I had nothing to enter on the table in 2008 (see Table 5.1). The reason for this was that I did not have any experience in teaching this topic and could not think of anything at that time because it was new in the South African curriculum and being taught for the first time in 2008. However, after teaching the topic in 2008 and the influence of my visit to the industry in 2009; I felt that there is a need for learners to visit the industry. This could help learners to visualise the process at industry scale in addition to textbooks' representation.

My teaching of Big Idea in my 2008 CoRe was influenced by my knowledge of national curriculum and exam requirements as well as learner's context. My 2009 CoRe was influenced by the knowledge of organic molecules and organic macromolecules as depicted in Table 5.1 for 2009. Learners need to know systematic naming and formulae as well as substitution, elimination and addition reactions. This can help them understand formation of soap, margarine, PVC, etc. Another important aspect that had changed in the 2009 CoRe is the teaching procedure for the Big Idea. I only made use of lecture method and group work in my previous year's CoRe and teaching for this idea. Flow diagrams, a table of comparison of three cells as well as a debate were used when teaching for 2008 CoRe. I used a flow diagram to help learners understand the manufacturing of soap, PVC, fats and oils; this helped learners identify the benefits of the whole process to human. The table of comparison was introduced to help learners to understand the environmental risks associated with various electrolytic cells as this is an important issue in a globalised world.

5.4 Conclusion on CoRes

In the next paragraphs, I outline some fundamental differences and/or similarities between the CoRes in Table 5.1 (starting with Big Ideas respectively). These differences and similarities could have contributed to the development of my PCK in terms of the teacher knowledge obtained from Geddis & Wood (1997) and Rollnick *et al.* (2008). My 2009 CoRe differed substantially from 2008 as can be seen from Table 5.1. I followed Loughran *et al*. (2004) Geddis &Wood (1997) and Rollnick *et al*. (2008), who consider in their analytical approach:

- Learner's prior knowledge.
- Instructional strategies and curriculum materials.
- Knowledge of students and knowledge of context.

For Big Idea 1 in Table 5.1, Prompt 6 intended to get teacher knowledge of all alternative conceptions and misconceptions. The answer to the Prompt 6 for my 2008 CoRe was limited. However, there was some development in the answer to this Prompt in the 2009 CoRe. For example, in 2009, I included under the prior knowledge of electrochemical cells the idea that learners should be able to compare the strength of the redox potential. Example 2, I added the consideration of the knowledge of examination requirements. The examination requirement was considered because it was not all the sections of the topic that are examinable.

Big Idea 2 also showed some development in Prompt 6. What accounted for this was that in the 2008 CoRe, I only had knowledge of national curriculum and learners' context as factors influencing my teaching. Learners' previous knowledge on organic molecules and macromolecules has been considered in the 2009 CoRe.

Instructional strategies and curriculum materials, which were addressed by Prompt 7 to 9 in the CoRes, had developed. Big Ideas 1 and 2, in the 2009 CoRe added a class Activity as a strategy to ascertain learners' conceptions, which I did not include in the 2008 CoRe. For instructional strategies, I have included debate and translation task which were not applied in the 2008 CoRe.

Knowledge of context and knowledge of learners, which I assumed were referred to in Prompt 4 and 5 seemed to have been reconstructed. This could have been influenced by my teaching of the topic in 2008. As far as Prompt 4 is concerned, I could not think of knowledge of context of curriculum in terms of limitations or difficulties learners could have had about the topic. However, in the 2009 CoRe I then thought of the availibity of resources for Big Idea 2 to be a limitation. I then suggested that a visit to the plant would expose and help learners develop the feel of industrial process.

For knowledge of learners (which is linked to Prompt 5), in the 2008 CoRe I thought as the topic was new to them, they would be excited about it. This was not the case at all and for this reason I decided in the 2009 CoRe to include under Big Idea 1 that learners should be made aware of the place of the chemistry they learn in class in their everyday life. The core idea behind that was, once learners start understanding and appreciating the meaning of the chemistry they do in schools they would endeavor getting answers to Prompt 5 under Big Idea 2.

I assumed that all the development of my knowledge of instructional strategies, curriculum materials, knowledge of students and knowledge of context, which were linked to the CoRes (Table 5.1), have attempted to unpack how I transformed my 'raw' content knowledge into ways accessible to learners. I therefore assumed that, due to the development shown in my knowledge between CoRes, my PCK could have improved.

5.5 Construction of PaP-eRs

The PaP-eRs could be in the form of a narrative or stories. They are about teaching the content in particular context and help illustrate aspects of PCK. The PaP-eR thus illuminates the CoRe (Loughran *et al*., 2004). PaP-eRs have different formats and the data were collected by means of a video recorder. In my study, the comments also emerged from my journal entries. These comments were used to document my approaches and ideas in order to review my own learning as well as analysis of learners' work (Loughran *et al*. 2004).

The PaP-eR illustrated in the next paragraph below was linked to my first Big Idea of the CoRe (see Table 4). The first Big Idea states that electrolysis of sodium chloride involves redox reactions. I have unpacked the aspects of my PCK on this Big Idea by making use of activities 1 to 3 of my lesson plan for teaching (See appendix 7). It was indicated in Chapter 3 that learners were repeating matric and were on a special upgrading project, so it should not be assumed that they were completely ignorant about the topic. However, it was important for me to first assess how much they knew about this topic. In most instances I have used the strategy where learners first work on a particular Activity in groups and then they have constructed answers. I was thus able to identify gaps in their understanding of the content when they responded and that helped me to adjust my methodology and then give instruction that was intended to remediate their misconceptions.

5.6 PaP-eR for the chloralkali industry

Before I could allow my grade 12 learners to engage in a practical investigation on the microscale electrolysis of brine, which was Activity 3, I gave them two activities that could help me to see what prior knowledge they had about salt. Learners were allocated to groups of four to six to facilitate discussion. After each part of the Activity, I gave remedial instruction where misconceptions arose. Part 3 of the lesson was based on the practical Activity on microscale electrolysis of brine, as mentioned above. For this Activity, I requested learners to write down what they observed guided by the questions that followed after the practical Activity. Part 4 of the lesson was about a comparison of the three cells. Parts 1-4 of the lesson were taught consecutively in one day and over two different classes since there are two groups available. Therefore I have drawn data from both groups.

Part 1: Spot the salt

I began this part of the lesson by informing learners that they will be learning about the chloralkali industry. I further told them that the industry which forms part of grade 12 chemical systems. Learners were advised to turn to the Activity entitled ‘spot the salt’. I then read through the instruction and elaborated on how I wanted them to respond to the Activity. I encouraged learners to work in groups when completing the table so that they could be able to share their ideas (See appendix 7). The aim was to help them assess how much they knew about salt. Figure 5.1 shows the figure that students used to identify salt or products from salt:

Figure 5.1: sample picture from part 1of the lesson

The Activity helped me to find out about both learners' prior knowledge. It also helped improve learners understanding of context of the topic. When I say context, I imply the things that learners see in everyday life like sea, chairs, umbrella etc. This is what I had anticipated before the lessons as shown in my journal excerpts below. This was written before the actual teaching when I was planning the lesson plans.

> "Most of the questions are open enough and give learners an opportunity to share what they know. In this way, I would be able to know what are learners' prior knowledge as well as their misconceptions."

Learners showed interest in the Activity. As soon as I finished explaining how I wanted them to undertake the Activity, discussion in groups followed immediately. I allocated 15 minutes for the Activity. Therefore I asked each group to give a reported where subsequent groups added what earlier groups had not mention. Different answers were given like: "sea contains salt in solution", "sweat contains salt in solution", "bread contains salt in solids", "sand contains salt in solid", etc. The answers indicated earlier in the report back were common and indentified by most groups, except the following that came from a learner from one group:

Ms P: Tell us Kato.

Kato: Another thing is we can just leave the dry ice out…. (Other learners chuckle)

Ms P: Yes, and talk about things that we can really see in the picture.

Kato: And talk about the cooler box.

Ms P: Oh cooler box, lovely.

Kato: We (*group)* thought that the cooler box is made up of PVC.

Ms P: PVC that is true, but is it only the cooler box? Is it the only plastic in the picture? (Some learners said yes and others said no) What else Fana?

Fana: Mam, the camp chairs

Ms P: Yes camp chairs, there is plastic on it. What else?

Learners: umbrella (chorusing)

Ms P: umbrella. What else?

Some learners: Sun glasses (chorusing)

Ms P: Sun glasses, even the radio.

One of the five groups of learners knew that polyvinylchloride (PVC) was plastic made from products of sodium chloride electrolysis as can be seen from the excerpt. The learner (Kato) who believed that salt or product from salt can be spotted in the cooler box because it is made from PVC showed some understanding of organic macromolecules and/or the uses of chlorine therein. I therefore presumed that there was a possibility that the chloralkali process was never taught in schools or some of the learners, who were repeating grade 12, might have not understood appropriately and that could partly justify their failing matric. I thus understood the need for careful and correct explanation. During my teaching of this topic I made a mental note that more time is needed on explaining how sodium chloride was involved in the whole process and other applications including the making of PVC.

Part 2: What do you already know about salt?

This part of the lesson intended learners to learn about some information on a particular salt and its history (see appendix 7). I first tasked learners to read individually some information about salt, write them down and then reflect trough discussions in pairs. In Part 1 when learners were about to start with Part 1 of the lesson of 'spot the salt' above, one learner asked me the question that appears in the excerpt below:

Thabo: Mam, by salt you mean sodium chloride?

Ms P: Salt as like salt in general. You are going to discuss that in your group. Err.. Thabo when we look at the Activity. If you come up with any of the question that you are asking me now..ah. But when you talk about salt which salt do you know? When we say salt. Spot the salt. When they say spot the salt.

Which salt do you know for example Thabo? You have just asked me a question earlier. What came to your mind?

Thabo: Salt from the kitchen.

Ms P: Salt from the kitchen. What else Thabo?

Thabo: Salt from...er sweat.

The excerpt clearly shows that Thabo did know types of salt but, wanted me to specifically tell which forms of salt has to be spotted in the picture given. I was not yet ready to inform learners yet. I knew that since these learners were in grade 12, they indeed should have known that there were many other salts like sodium chloride e.g. potassium chloride, calcium chloride etc in nature. His showed that the first type of salt he could think of was sodium chloride. My response used to his question was not clear as I only said salt in general and pushed him to elaborate on other salts he would be thinking about. Eventually, I asked learners to think of salts in general. The reason for this was that I did not want to specify which type of salt they would be referring to in this module as I already knew that Part 2 of the lesson would definitely narrow their thinking on the types of salts. Part of the passage can be seen below:

"Did you know that salt is a compound of two elements which are poisonous to us (Sodium and Chlorine) but our bodies cannot do without salt!! Harder - Salt is a clear, brittle mineral that contains the elements of sodium and chlorine. Its chemical formula is $NaC\ell$; its mineral name is halite."

I therefore found that giving learners this Activity helped them to realise that the type of salt they would be focusing on was sodium chloride and thus helped them in answering the question asked by Thabo. This Activity was followed by my feedback to them. The question to pairs was about new things that they might have found in the information on salt. Different pairs have reported new different things. One pair then asked the following question:

Ms P: Lerato do you want to ask something?

Lerato: I just want to know. What is brine?

Ms P: Brine (the rest of the learners said yes). Brine is when you mix salt and water the solution. The salt water solution is called brine in the industry.

Looking at the question asked by Lerato, one can see that this lesson also served as a way of exposing learners' prior knowledge and content knowledge gaps. When Lerato asked about brine, most of the learners did not seem to know what it was. Taking into account that the chloralkali industry uses brine solution in the whole process, I assumed that there was a possibility that most learners might not have been exposed to this topic in the past. I found that the question of brine came up at the right time because the next lesson in part 3 involved electrolysis of brine and then the learners knew what brine was.

Part 3: Microscale electrolysis of brine solution

As learners were having their 10 minute break before starting with part 3 of the lesson, I distributed apparatus and chemicals needed for practical investigation to all the groups (appendix 7). Here, I needed them to observe something real and not only to know the theory behind the process. I asked learners to first read the procedures individually and later within the groups while I was setting up the practical investigation. Learners became visibly excited as they were about to do the investigation. I have also had to remind them that there were questions that needed to be answered once they finished the investigation so that their excitement should not make them forget to get to the end of the task. Figure 5.2 illustrates a discussion among learners in a certain group:

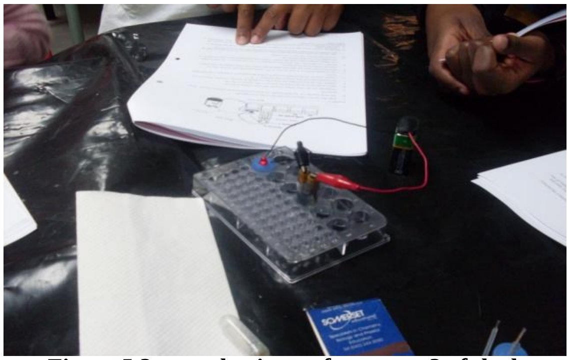


Figure 5.2: sample picture from part 3 of the lesson

Ms P: Do you have a reaction already?

Lesedi: We are just looking at what is happening…. (inaudible)

Ms P: Okay, what is happening?

Lesedi: We can see the colour change from the two electrodes straw.

Ms P: What?

Learners: (chorusing) Colour change.

Lesedi: The other one has more gas liberated than the other one.

Through this practical Activity learners were able to see how industrial electrolysis occurs and also make use of what they have observed to answer the questions in their worksheet. For example learners had to write down the overall reaction involved. They needed to first know which reactions were taking place at the two electrodes. Understanding of redox reaction was essential because it would help them to identify which substance was oxidised and which was reduced during electrolysis. Learners answered all the questions based on the practical Activity and feedback given to them. Thereafter, I showed learners how I used what they had observed during the electrolysis practical to drive the rest of other parts of my lessons. However, due to time constraints I am only going to show in Part 4 of my lesson below how the membrane and diaphragm cells operate to yield the products.

Part 4: Different types of cells

This part of my lesson intended for learners to study how the different type of cells operate. Before planning the lesson, I was not sure whether I should include all the types of cells in my teaching as the curriculum guideline for grade 12 only covers membrane. I discussed my intention with the Self- Study group as I indicated in my journal excerpts presented below:

"I started to feel comfortable around my fellow group members and decided to ask them whether I should cover all the 3 cell process in my chloralkali process lessons. I was advised not to, but to have a short answer ready in case learners asked me anything about other cell process. I found that this was a good question that I have been asking myself all the time about the cells or not. I then decided I will talk briefly about the three cells and see what would happen."

However, my focus in this PaP-eR is on the membrane and diaphragm cells as they look similar to the mercury cell. Initially as I was preparing to teach, I struggled to depict the major differences between these two cells. This was due to my inadequate content knowledge, and Prompted me to investigate different materials that could help me understand the functioning of the cells better. Finally, I found a document showing diagrams of the cells that were appealing to me. After I understood conceptually the functioning of the cells, I included them in my lessons. I prepared the slides with each cell on and went through each slide after teaching part 3 of my lesson. Figures 5.2 represent the membrane cell and Figure 5.3 shows a diagram of the diaphragm cell that I used during my teaching.

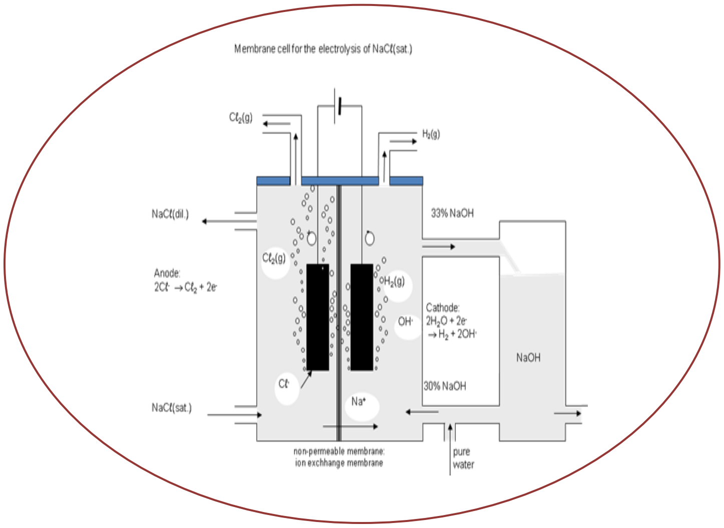


Figure 5.3: Membrane cell

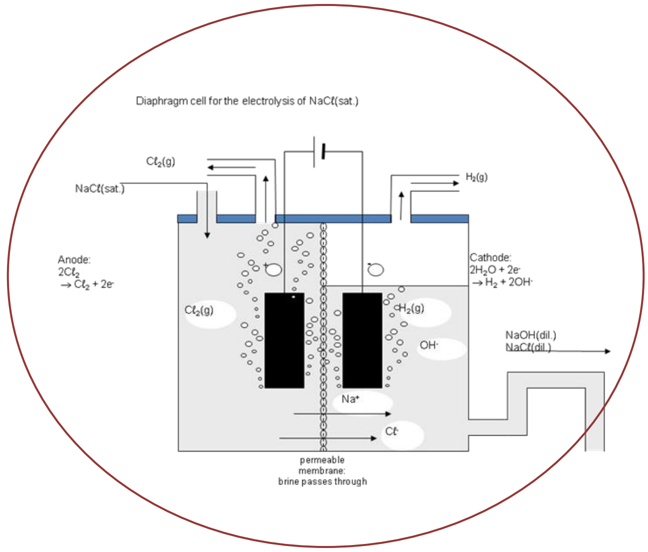


Figure 5.4: Diaphragm cell

Both figures helped me better understand the electrolysis of sodium chloride as I was preparing to teach. My improved content knowledge enhanced my new found flexibility in teaching this topic. My expectation was that learners would understand the advantages and disadvantages of the two cells. In my lesson I explained learners that, in the two cells above, saturated sodium chloride was fed into the anode compartment where chloride ions were oxidised in the anode compartment and water molecules were reduced, resulting in chlorine gas produced in the anode compartment and hydrogen gas produced in the cathode compartment. I made explicit to learners that in Figure 5.2, a non-permeable ion exchange membrane was used which allows only the sodium ions to pass through to the cathode compartment and thus the hydroxyl ions formed from the reduced water react with sodium ions to form sodium hydroxide only.

In a diaphragm cell, a permeable membrane allows the brine (both the sodium ions and chloride ions) to pass through to the cathode compartment. Thus, some of the hydroxyl ions react with both sodium ions or chloride ions to form sodium hydroxide or sodium chloride. After explaining the operation of all the cells and before moving on to the next part of the lesson, I solicited questions from learners. One learner asked the following question about the diaphragm cell:

Tshidi: Eh…Mam, the production of sodium chloride ($NaC\ell$) as one of the product in the diaphragm cell, does it have impact on the amount of sodium hydroxide ($NaOH$) produced?

Teacher: Yes it does. Tell us Tshidi, what do you think the effect will be?

Tshidi: I think maybe it will affect sodium hydroxide produced as it might not be pure.

The excerpt showed clearly that Tshidi was able to use the new ideas she had learnt about the diaphragm cell operation to draw a conclusion about its effect on the production of sodium hydroxide. I have found that the use of my subject matter knowledge, which in this case was diagrams of the cells helped me transform my pure content knowledge into the content knowledge for teaching (PCK). I assumed that Tshidi got a better understanding of the industrial electrolysis of brine in different cells because she made a correct assumption on her own about the effect on purity and /or strength of caustic soda produced through the diaphragm cell.

As I was waiting for other learners' questions, Tebogo put his hand up and ask the following questions:

Tebogo: How do you differentiate between the electrochemical cells and electrolytic cells?

Teacher: (Repeated the question for the learners who did hear Tebogo because his voice was not clear).

Teacher: (Teacher did not answer right away but instead probe further and asked). What do you know about electrochemical cells?

Tebogo: I think the negative is the anode.

Teacher: Now, that is a galvanic cell there is a difference. In electrolysis, in electrolytic cells... are you listening?

Learners: Yes

Teacher: Err…the one that is oxidised is what, is the anode is connected to the positive terminal (pointing the battery). But with galvanic is the other way round which is what you are asking me.

I had anticipated this type of question as I was planning my lessons. This can be seen from the CoRe where I identified the difficulties associated with teaching the topic for both 2008 and 2009 CoRes. With the answer that I gave learners, I was more convinced that it was correct. After teaching I then reflected on my lessons. I found that my answer about electrolytic cells was partially correct and that about electrochemical cells was incorrect. I felt like maybe there could be more information behind the reason I had given the learners that the anode was the positive electrode because it was connected to the positive terminal of the battery and the cathode was the negative electrode hence it was connected to the negative terminal of the battery in electrolytic cells. My answer: "But with galvanic is the other way round…" implied that even electrochemical cells require a power supply which is a battery. This was a serious misconception that was transmitted to the learners because in voltaic or galvanic cells energy is released from redox reaction and it is the system that does the work on the surroundings. For this reason no battery is used.

I then decided to talk more about my reflection on the question with the experts. What I actually needed was to find out a way of making the concept of electrode signs in both electrolytic and electrochemical cells more understandable to learners. I thus attempted to the pedagogical content knowledge (PCK) for explaining this during my teaching.

5.7 Conclusions on PaP-eRs

During the teaching of the lesson, learners' showed great excitement about the topic. They were encouraged to share ideas amongst themselves. With the given PaP-eR, one can see that different aspects of teacher knowledge, for example, the teacher knowledge of learners' prior knowledge, representations and the curriculum materials (curriculum guidelines) were utilized to make the tacit knowledge clearer.

Part 4 of lesson is a good example showing that teachers do not just improve their PCK overnight and neither is the journey of improving the framework linear as also indicated by Geddis & Wood (1997). There are many other factors in teaching that needed refinement. The most important element is content knowledge which, from my study's perspective still needs to be refined poor explanation of concept to learners in part 4.

CHAPTER 6

DEVELOPMENT OF MY PEDAGOGICAL CONTENT KNOWLEDGE MANIFESTATION FROM MY KNOLWEDGE DOMAINS

6.1 Introduction

In this chapter, I discuss how I integrated different knowledge domains while developing my PCK.

6.2 Data source

The data used in this chapter emerged mostly from the video of my lessons and my journal. Some data from my concept maps and CoRes were also included. The topic was taught over two days to different groups. My analysis builds upon the Rollnick's *et al.* (2008) tailored model for PCK depicted in Figure 6.1.

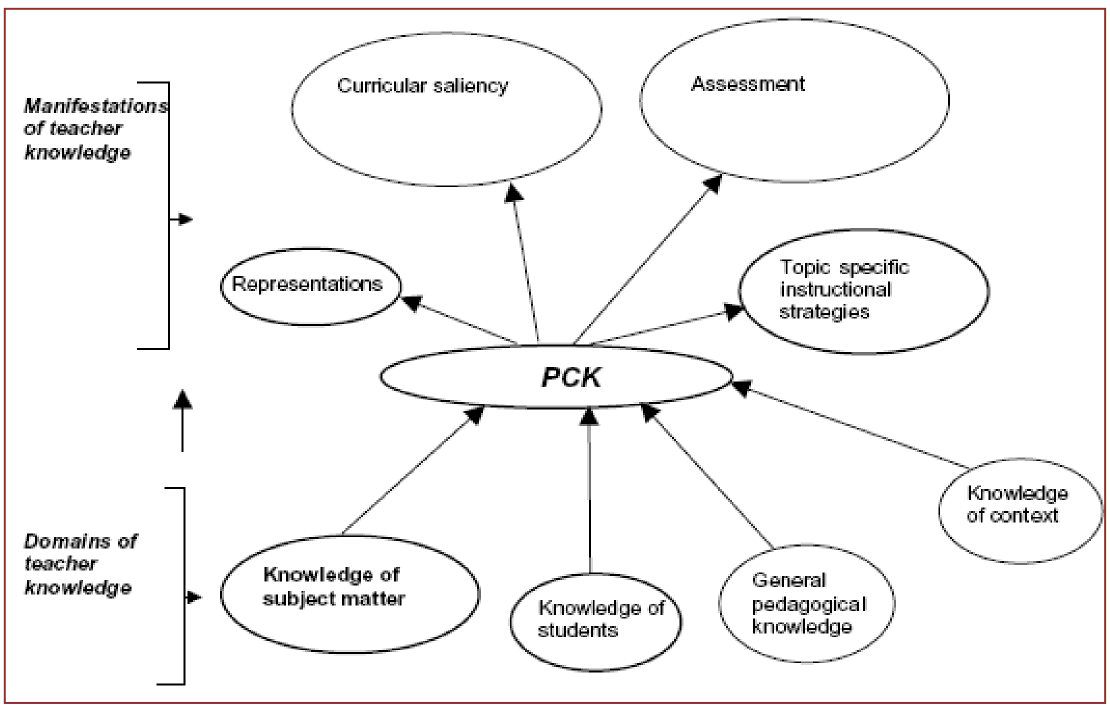


Figure 6.1: Tailored model for PCK (refer to Rollnick *et al*. 2008)

The Rollnick *et al.* (2008) model consists of two broad teacher knowledge namely: manifestations and domains. In the present Self-Study, the manifestation of teacher knowledge refers to the observable knowledge emerging during my teaching; these could also be visible to other observers. These teacher knowledge manifestations are produced by the integration of all the domains. The manifestations include representations, curricular saliency, topic specific instructional strategies, assessment and the domains includes knowledge of subject matter, knowledge of students, general pedagogical knowledge and knowledge of context. The domains of my knowledge mostly emerged from my journal.

In the following sections I discuss how the domains inform manifestations. It is worth noting that all the categories were explained in detail earlier in chapter 2. Here, I first briefly describe each domain before I get into the in-depth discussion.

- Knowledge of subject matter refers to my pure subject matter knowledge (SMK).
- General Pedagogical Knowledge (GPK) is a domain that helps teachers understand what counts as good teaching taking into account the best teaching approaches in a particular given context.
- Knowledge of context includes all the contextual factors influencing the teaching situation.
- Knowledge of student takes into account learners prior knowledge and how they learn. (Rollnick et al., 2008)

6.3 Data analysis.

I transcribed and analysed some of the relevant data from the video of my teaching lessons. I also drew upon some part of my journal. Learners written assessment (see Appendix 9) Activity was analysed in detailed.

6.4 Manifestations of my knowledge.

A brief description of each manifestation is given prior to the in-depth discussion.

6.4.1 Representations

Representations refer to analogies, illustrations, examples, explanations and demonstration that contribute to the transformation of SMK (Shulman, 1986). Rollnick *et al.* (2008) argue that subject matter representations form part of the manifestation of teacher knowledge.

After doing the practical Activity on electrolysis of brine, I decided to link what learners observed from the practical Activity to the diagrams of membrane cells in order to explain further about the process. It is important to note that in the case of this analysis, I referred to the representation of redox reactions which can be seen in Figure 6.2 and Figure 6.3 below.

The excerpt below shows how my teaching about electrolysis of brine in a membrane cell, illustrates a representation of the redox reactions that happen:

Teacher: (pointing on the white board) saturated sodium chloride is fed into the anode compartment. Can you see that this is the anode compartment?

Learners: Yes

Teacher: And what happens is the chloride ions gets oxidised in the anode? Are you with me?

Learners: Yes.

Teacher: If the chloride gets reduced, then chlorine gas is being produced. (A teacher pointing at the images of half reactions at anode in Figure 6.2 and later in the images of half reactions at the cathode in Figure 6.3).

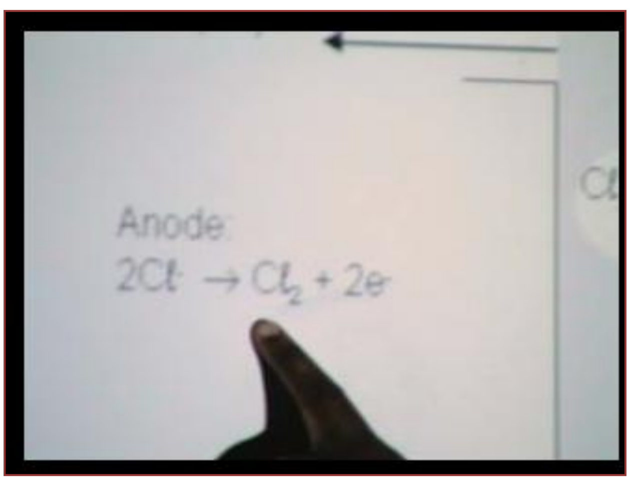


Figure 6.2: Explanation of oxidation

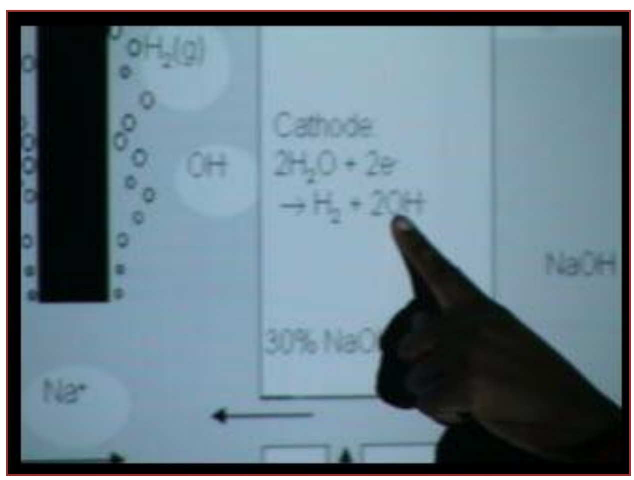


Figure 6.3: Explanation of reduction

Figure 6.2 and Figure 6.3 shows the representations I used when teaching learners about the redox reactions taking place in the anode and cathode compartment. I appeared confident and flexible during my teaching.

Although it is of great importance to represent the knowledge through representations in order to make it accessible to learners, it is clear in my explanation from the excerpt, that I did not engage learners in constructing some of the ideas. Some learners might thus have learnt these ideas through memorisation of facts given to them, which might have lead to rote learning. For example, instead of informing learners that chloride ions were oxidised, better Questions or statements should include:

1. Between sodium ions and chloride ions which one will undergo oxidation and why?
2. Work out oxidation numbers and show how this is a redox reaction.
3. Write down the oxidation and reduction reactions.
4. Balance the following chemical equations.

I believe that this kind of Questions would have made learners explore and use the table of oxidation-reduction potentials and allow them contribute to knowledge construction. This clearly showed that there were other ideas in the CoRes, for example like comparing strengths of redox potentials, which did not emerge from my teaching.

6.4.1.1 How were my representations informed by the domains?

In order to explain to learners about electrolysis of brine in a membrane cell in the representations shown in Figure 6.2 and Figure 6.3, I needed a better understanding of my SMK.

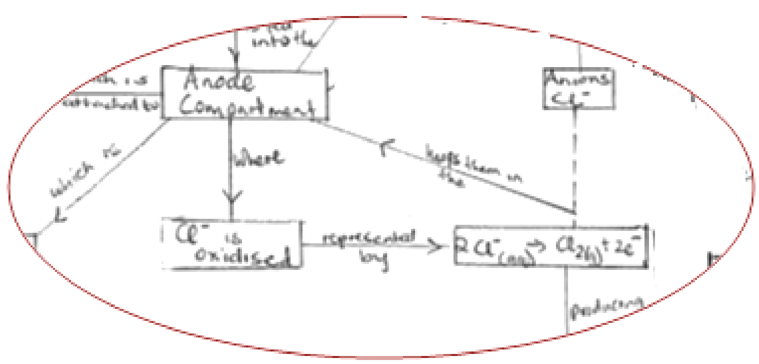


Figure 6.4: sample from concept map 3 about the anode compartment

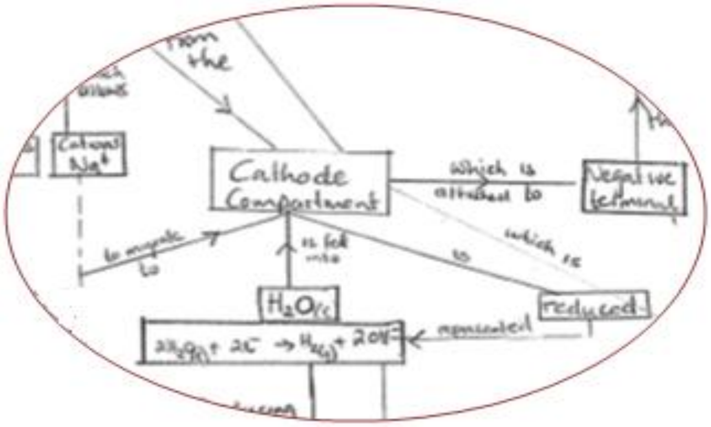


Figure 6.5: sample from concept map 3 about the cathode compartment

My concept maps played a role in developing my SMK on the electrolysis of brine in a membrane cell process. Figure 6.2 focuses on an important part of Figure 6.4 as it was explaining to learners about the oxidation at the anode electrode. Figure 6.3 focuses on an important part of Figure 6.5 as it was explaining to learners about the reduction at the cathode electrode. They should be able to:

In my CoRe, I acknowledged that the following learners' prior knowledge of representing chemical change and electrochemical reactions were important for conceptual progression.

- Write chemical formulae and balance the equations
- Show oxidation numbers
- Show the difference between oxidation and reduction reactions
- Compare (strengths) of redox potentials.
- Distinguish between electrodes and electrolytes.

However, as can be seen in the use of my representation, I did not attempt to find out what it is that learners know of the prior knowledge indicated in the CoRe. Some of these ideas emerged only during the teaching of the industrial process. For example, after explaining to learners the difference in the operations of the three cell types, a learner asked the following Question:

Koko: "It was said that those black things are electrodes, right?

Teacher: Yes

Koko: I want to know, what is electrode". I just hear a word electrode, electrode

Teacher: What is electrode? (Asking the whole class and eventually no learner answered).

The excerpt showed that a learner [Koko], did not know what an electrode was. I anticipated this as a factor that influenced my teaching and also as a difficulty in my CoRe. It turned out that even the rest of the learners could not tell what an electrode was. I would assume that, most of the learners found it difficult to define it but knew what it does. I wrote in my journal after teaching this lesson the following:

"I felt like I did not explain clearly to the learners the most important thing about the electrodes that, they are the conductors".

This would have made sense to learners since they are aware that electrons come in or out of the electrodes. Most learners might have not understood the cell processes because of lack of understanding of what an electrode is. This suggests I should have thus have considered all the factors that influence my teaching of the topic prior to the lessons. This would have helped in cases where, these ideas became misconceptions; and remediated during the teaching process.

Knowledge of context, which includes the contextual factors influencing the teaching, informed my representations. The planning, teaching and assessment Activity were completed within the time frame as can be noticed from part of my journal shown below:

"I think this lesson went fine but I was worried that they might not finish the assessment Activity because of the more time spent on the diagrams illustration."

General pedagogical knowledge (GPK) had also influenced the representations used in my teaching. I planned my lesson, selected better diagrams for representations, set up data projector and laptop for digital demonstration of diagrams before teaching. After analysing and reflecting on my 2008 teaching, I noticed that a battery (power supply) in my diagram was omitted then I included it in my detailed diagrams for my 2009 teaching. This could be justified by the excerpt from part of my journal below:

"I decided to put slides showing all the 3 processes used in the plant as part of my teaching material."

The reason I decided to represent the diagrams as slides using a data projector was that, I needed to control what learners had to view. For example, if I wanted to show learners the diagram on the membrane cell, their focus would be on that particular diagram. I assumed that from using this strategy, I would then have their attention when explaining. I avoided handing hard copies of the diagrams over to learner prior or while teaching to avert possible distractions usually associated with that practice.

6.4.2 Topic specific instructional strategies.

Example 1- Topic specific instructional strategy

Topic specific instructional strategy refers to the teaching methods (Rollnick *et al.*, 2008). I used in my teaching such as practical investigations and flow diagram strategies.

After completing the first two activities about salt, which were intended to elicit learners' prior knowledge, I proceeded with the practical Activity on the electrolysis of brine. The aim here was that learners investigate and get a feel of electrolysis of brine using microscale equipment as pointed out in part of my journal shown below.

"In conducting this experiment, I assume that my learners have something concrete to observe and hopefully with remain in their mind and will give valuable input to the entire teaching on this lesson."

While learners were investigating and discussing the process in groups, I observed them and captured some of the ideas outlined in the following excerpt:

Nkena 1: (pointing at the cell (as shown in Figure 6.6)"look at that, look at that?

Figure 6.6: Learner observing in practical investigation

Other members of the group: (observing) are the bubbles.

Kgadi: From, which one is it? This is electrode 1?

Other members of the group: No, 2

Nkena: *E red eke ya 1*, wow! [The red one if for electrode 1]

In the above excerpt, a learner [Nkena] was inquiring about what was happening at electrode two. Others responded by saying ‘bubbles’. This showed that indeed the strategy used facilitated the learning process. The learner [Kgadi] needs to understand clearly in which electrode the reactions took place suggested that she was trying to make sense of what was happening on the electrode and link that to the aim of the Activity.

Learners in group 3 were able to see that a reaction took place at a particular electrode. In general, learners seemed excited about this experiment probably because it was their first exposure to either this experiment or laboratory work in general as can be noticed in the following excerpt:

Mpumi :(trying to conncect a battery but struggling) (see Figure 6.7)

Figure 6.7: Learner struggling to connect a battery

Teacher: Do you connect that way?

Mpumi: How do we do this by the way?

Some learners: The other way round.

Mpumi: D*ilo tse di ya ka tlwaelo* [You can only do this if you are familiar with them]

The excerpt suggests that, Mpumi did not have a clear idea of how to connect a battery appropriately. Instead, she tried to fit in the wrong way.

Through this practical investigation, learners were able to identify correctly the hydrogen and chlorine gases collected in each straw (used to collect the gas) and thus link what they learned in theory through previous classes to something real. The idea of testing the gases was good as most of them would justify what they were told theoretically in their previous school. Hence some of them knew the theory behind this idea. Figure 6.8 and Figure 6.9 show the learners testing the two different gases.

Figure 6.8: Learner testing hydrogen gas

Figure 6.9: Learner testing for chlorine in the presence of NaI

6.4.2.1 How was my topic specific instructional strategy (practical Activity) informed by the domains?

My SMK influenced my practical Activity strategy, and my teaching as I needed a better understanding of the content of electrolysis of brine to interpret the results found by learners.

GPK also informed the strategy used. Before I could teach this lesson, I had to organise all the apparatus and chemicals needed. Most importantly, I had to test if the practical Activity would work as illustrated in the following passage from my journal:

"I decided to trial the experiment that will be done by students and I could not get the correct observation. (No hydrogen gas is observed).This had helped me to come up with other means before it is given to the learners. I decided to seek help from an expert. She told me to cut the straw to the same size as the electrode so the hydrogen gas could fill up in the straw. I did exactly that and it worked".

It was important and fair for me to test the experiment myself, to understand under which operating conditions best results could be obtained, before engaging with learners.

To facilitate an effective teaching process, I organised 24 learners into four groups of six, and provided one complete set of equipment and chemicals to each group, as can be noticed in Figure 6.10. The equipment included a battery, comboplate; LED, straws, graphite electrodes, microburner and the chemicals included brine, tap water, universal indicator and sodium iodide solution. Because I used micro scale equipment, negligible amounts of chemicals were needed. Therefore it was safe to generate the small amount of chlorine gas in the lab.

Figure 6.10: Apparatus and chemicals

The knowledge of contexts which include socio-economic background of the learners informed my strategy of practical Activity. I was aware that every year this South African programme accommodates learners who come from poor backgrounds. Most learners were never exposed to practical work (experiments) before thus; I gave them a guided practical Activity of electrolysis using a low-cost equipment; the RADMASTE micro science kit affordable to even poor schools. As they were familiar with some of the RADMASTE micro science kit, I explained all various components of the kit prior to a practical Activity.

The knowledge of learners also informed my practical Activity strategy as suggested in Figure 6.9 and Figure 6.10 showing learners testing gases and discussing the process. One learner of group 4 (Figure 6.9) took a longer time to expose the straw to the flame to observe and make sense of what was happening. This suggested that learners had the knowledge of what to expect when testing different gases e.g. hydrogen, chlorine as can be noticed in the following excerpts from my journal:

"During the Activity, one group of learners decided to smell the paper towel having sodium iodide and the gas from electrode 2 and they found that it smelled like bleach and because of that they were able to tell that there is chlorine gas"

"One group of learners was saying that they only knew the theoretical part of electrolysis of brine and were happy to see the practical side of it".

Learners manifested unprecedented excitement, which suggest their interest in the practical Activity. Rollnick *et al.* (2008) argue that knowledge of interest and aspirations forms part of knowledge of students.

Example 2- Topic specific instructional strategy

Another strategy used in my teaching was the use of a flow diagram. This strategy intended to introduce my Big Idea 2, which was the impact of the choralkali plant on living beings and of the use of products produced from electrolysis of brine in daily life, and write them to construct the ideas that would form the lesson. The strategy was a learner-centered as learners' output served as the building block for the lesson.

For Activity 5 on the flow diagram (Appendix 7), learners were expected to work in groups and make up a story about one part of the diagram. The diagram consisted of three parts namely: sodium hydroxide, hydrogen and chlorine. The excerpt given below shows how I elaborated on what learners had to do in this Activity shortly of the flow diagram (see appendix 7) shortly after reading through the instruction from their workbook:

Teacher: "The flow diagram is there to guide you. Write the story or relate the information like as if you writing for someone who does not even understand know.
Teacher: "So what part is sodium hydroxide (pointing on a certain group), your part is the chlorine part (pointing on a certain group)……

In order to illustrate learners understanding, I will show how a certain group (see Figure 6.11 and 6.12) that was focusing on sodium hydroxide interpreted the flow diagram and how I used learners' output to teach the lesson.

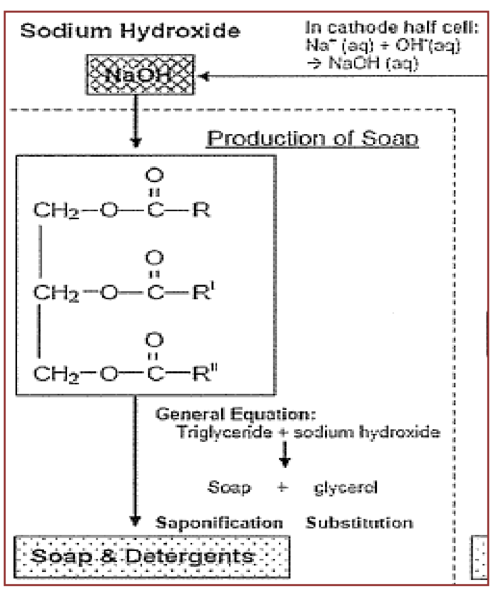


Figure 6.11: sample of part of NaOH

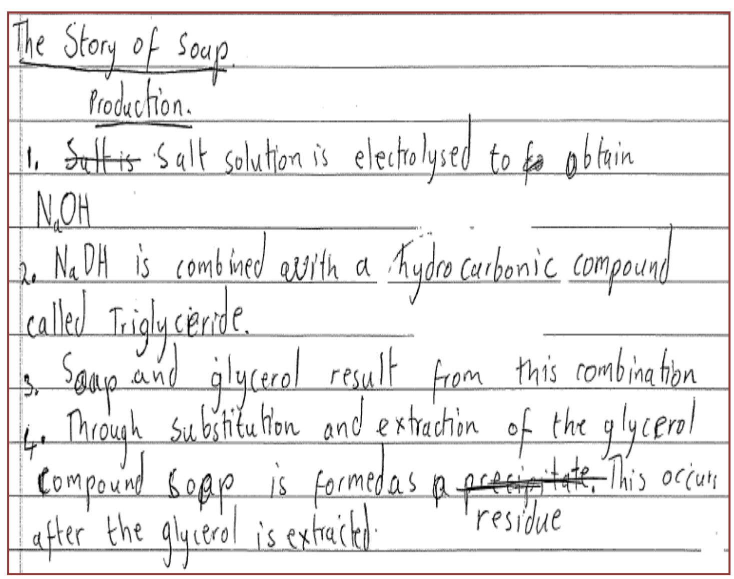


Figure 6.12: A story of NaOH

Figure 6.12 shows that the group had an idea of how sodium chloride was used for production of soap. Based on what they had represented in Figure 6.12, I was able to assess what was omitted as well as the wrong concepts showed by the learners. When learners were reporting back, I decided to write on the board things that I thought were incorrect and in need of elaboration.

From point 2 in Figure 6.12, I realised that this group did not know what hydrocarbon compounds are. For example, I used this as a strong point for my teaching. I assumed that learners overlooked the structure of the triglyceride. The structure does not only consist of hydrogen and carbon, but it also contains oxygen atoms in its ester group. Another aspect that I thought needed some elaboration was how the substitution reactions occurred. All the groups that worked with NaOH did not write down the equation. My strategy to solve this problem was to write down the chemical equation displayed below on the board, as a strategy showing that the OH group from NaOH is being substituted by RCOO group.

$$\underset{\text{Fat/ vegetable oil/Triglyceride}}{\underset{\downarrow}{RCOOCH_2\text{-}CH\ (OOCR)\text{-}CH_2OOCR}} + \underset{\text{Caustic}}{\underset{\downarrow}{\mathbf{3Na\underline{OH}}}} \rightarrow \underset{\text{Soap}}{\underset{\downarrow}{\mathbf{3\underline{RCOO}Na}}} + \underset{\text{glycerol}}{\underset{\downarrow}{HOCH_2\text{-}CH\ (OH)\text{-}CH_2OH}}$$

6.4.2.2 How was the topic specific instructional strategy (flow diagram) informed by the domains?

The flow diagram approach was influenced by the knowledge of my subject matter. That I was able to spot learners' content gaps shows that I had brought improved SMK to bear on this teaching method.

From the learners' stories about each product, I realised that most of the learners showed their understanding of prior knowledge of organic molecules (systematic naming & formulae, substitution, addition and elimination reactions) and organic macromolecules (polymers and PVC). One learner in a certain group was able to inform me that the formula for PVC monomer was wrong. In the Activity it was written as $C\ell H_2C= CHC\ell$ instead of $H_2C= CHC\ell$. Below is what I have written in my journal about my perception of learners' knowledge:

"Learners brought in their prior knowledge of macromolecules and organic chemistry. Hence they were even able to pick up that PVC formula has one chlorine atom and not as indicated on the flow diagram".

I used and followed extensively examination guidelines (DoE, 2009) for preparation of my lessons. According to Rollnick *et al.* (2008), knowledge of context includes all the contextual factors such curriculum. It is indicated in the examination guidelines that there is a need for identification of benefits to human kind associated with operating types of cells. The flow diagram in my lesson plan was intended to point out to learners the benefits of the product to society.

Instructions given to the learners on how to do the Activity and allocating each group a part of the story to present, presumably accounted for my GPK. The preparation and selection of the materials (flow diagram) to be used also constituted my GPK.

6.4.3 Curricular saliency

Curricular saliency is viewed differently by researchers. According to Rollnick *et al*. (2008) curricular saliency is evidence of understanding what comes before and after the topic in hand as is thus a factor that influences my subject matter transformation. Furthermore, curricular saliency can also be powerfully illustrated by what is omitted from the teaching (Rollnick *et al.*, 2008 and Geddis & Wood, 1997)

An analysis of my 2009 CoRe, my lesson (see appendix 7) and my teaching (video) showed that I taught the electrolysis of brine before analysing the benefits and risks associated with the operation of the plant. This was influenced by my reflections on the 2008 teaching. Learners were confused as I taught the lesson by explaining about the formation of soap which intended learners to learn the benefit of the plant. I realised that the sequencing of my activities did not make enough sense to them.

My content knowledge and knowledge of context were poor probably as this was only my second teaching experience about the topic. I then felt that, if I started teaching by explaining all the processes involved in producing products, it would make more sense to learner and facilitate their conceptual progression.

The South African National Curriculum Statement (DoE, 2006) and Examination Guidelines (DoE, 2009), emphasise only the use of a membrane cell in the teaching of the industrial chloralkali process. I included and explained in my teaching all types of cells that were just listed and not emphasised. For example, in my lesson, after explaining types of cells from the slides, I then solicited Questions from learners. One learner asked the following Question:

Kgabo: Mam what is the membrane made of?

Teacher: a polymer, certain polymers that is able to accept cations to pass through. So it only rejects the anions. It is mainly made up of polymers. I could even show you the picture of the membrane. The problem is that, I did not copy it in your work booklet

The Question: “what is the membrane made up of”, came up from the two different groups in my teaching. When analysing my content knowledge I did not know what to say to the learner in the first group who happened to asked me a similar Question to the one above, as indicated in Chapter 4. However, for the second group, I was able to elaborate in case learners asked in the next group.

As I was preparing to teach, I had spent time engaging in ideas I received from the discussion I had while visiting the plant. The ideas helped me explain deeper the structure of membrane. However, I did not take this part seriously into consideration as the curriculum does not provide enough details in for example the schematic view of membranes. This made me expose my poor content knowledge to learners as can be seen from my response from the excerpt above. Indeed polymers can be found in a membranes, however further details about the structure of a membrane could have been pointed out to enrich learners’ knowledge.

Figure 6.13 below, shows the schematic view of membrane. I was convinced that not including a schematic view of membrane (Figure 6.13) was the right way to go. I believed that the depth of the syllabus was covered as far my view of the curricular saliency was concerned but realised that my assumptions (though relevant to learners’ needs) were beyond the scope of the topic in grade 12. This can be seen from the foregoing excerpt in which I even said that, “I should have included the structure of membrane in learners’ workbook”. The path of my curricular saliency was a conscious decision based on the current curriculum.

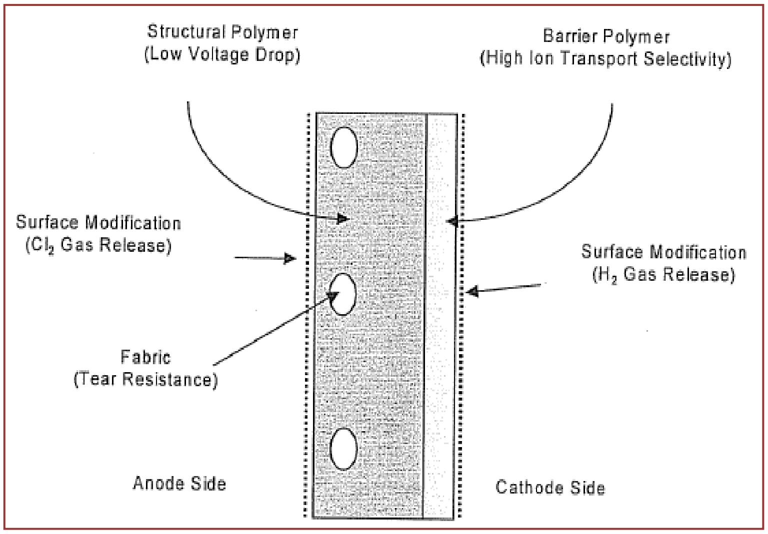


Figure 6.13: Structure of membrane (Developed from the Chlorchem plant)

In the next paragraphs, I am going to discuss how curricular saliency was informed by the domains.

6.4.3.1 How was curricular saliency informed by the domains?

My decision to omit the structure of the membrane illustrated my understanding of curricular saliency. However, I found myself in a position where learners needed to know more about the membrane. This implied that my SMK was essential in attempting to explain this point to learners. My SMK was insufficient as I could not say much about the structure of the membrane. I had to spend time during lunch break reflecting on the Question. Below is some of my thinking documented in part of my journal about the reflection on my lesson:

"I felt like there was a lot that I still have to learn deeper. After showing slides of 3 types of cells to the first class, one leaner asked me "what is the membrane made of"? I could not answer the learner correctly even though I had come across the information in one of the materials I got from the plant This was simply because I did not engage deeper with the idea it because I told myself that the curriculum does not involve it".

I tried during the development of my lesson plan to know more than learners in order to answer Questions. I indicated the following comment in the part of my journal shown below:

"I wanted to know more or beyond what the Questions want. I did this in case learners asked me more difficult Questions. The more I was doing that, the more content knowledge I had to include".

The knowledge of learners informed my curricular saliency. Kgabo asked me a Question about the polymer in membranes and I had anticipated that kind of Question from this class since. This indicates that I already had the knowledge about how learners learn. However, in many other cases I found that my knowledge of learners was lacking. This could have been influenced by the fact that the topic was new and I was unable to make the necessary connections.

The knowledge of context that emerged as curricular saliency is mostly about the curriculum. The reason I included all the three types of cells in my teaching is mainly because according to the curriculum documents, learners are expected to make a comparison. I omitted the structure of the membrane because it is not required in the curriculum and hence is beyond the scope of grade 12. GPK also played a role in my curricular saliency in that, I had to prepare and organise the materials to be used by learners.

6.4.4 Assessment

Assessment refers to formative or summative tasks given to learners for consolidation of what was learnt during the teaching (Rollnick *et al*., 2008). In my study, an Activity about the chloralkali manufacturing process was given to learners. This Activity was meant to consolidate what was learnt during my teaching. Rollnick *et al*. (2008) argue that, SMK would play an important role in producing suitable assessment tasks. In the next paragraphs, I analyse and discuss:

- learners' answers
- reasons behind their answerers
- learners' misconceptions and how I remediate them
- how the assessment informed the rest of my lessons.

Learners' answers

To illustrate this point, I focus on learners' responses to the following Questions relating to Figure 6.14.

Study the figure below:

1. Write down the equation for the half-reaction taking place at the electrode M
2. Which gas is chlorine gas? A or B.

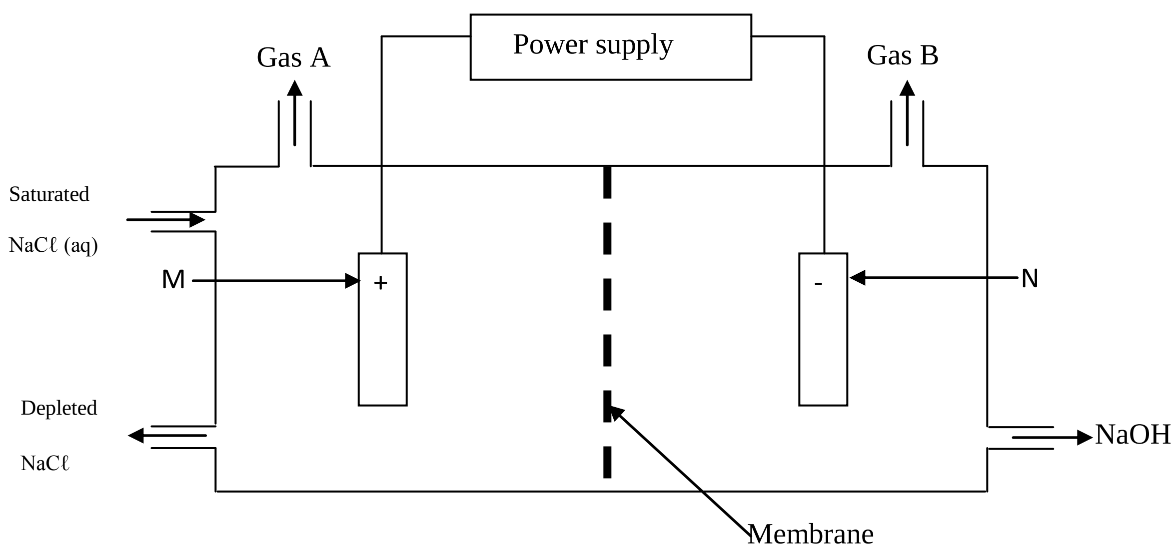


Figure 6.14: membrane cell process

I will analyse Question 1 and then Question 2.

For Question 1, out of 43 learners, 8 got completely correct answers, 3 learners did not respond to the Question, 1 learner's response was incorrect and I marked remaining learners' responses as incorrect. The Question asked about the reaction at electrode M, which is the site of oxidation. This implied that the right answer for Question 1 is:

$$2C\ell^{-}{}_{(aq)} \rightarrow C\ell_{2\ (g)} + 2e^{-}$$

For incorrect responses, different learners had given different responses. For example in Figure 6.15:

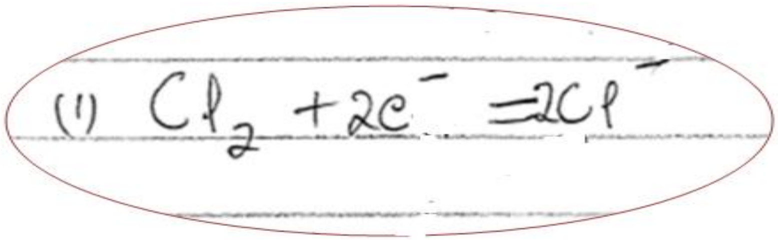


Figure 6.15: Temba's response to Question 1

The response shown in Figure 6.15 indicates that some learners did not know what type of reaction was taking place at electrode M. It seemed that this learner thought that chlorine gas was reduced instead of the chloride being oxidised, which led to production of $C\ell^-$ ions, which was incorrect. I assumed that poor understanding of the whole electrolysis process and redox reaction equations and conventions could have contributed to this learners' response. Better understanding of redox reaction (oxidation is loss of electrons and reduction is gain of electrons) could have helped those learners to interpret Figure 6.14, which clearly point out that $C\ell^-$ ions are consumed and there is loss of electrons. The Question would be: how could $C\ell^-$ ions be produced when they are already available in brine and how would we get chlorine?

Another example of an incorrect response follows:

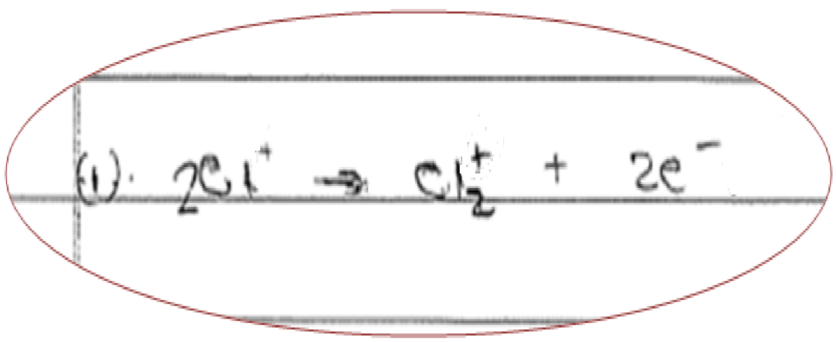


Figure 6.16: Thabo's response to Question 1

Figure 6.16 illustrates that this learner knew that chlorine ions lose electrons, hence an oxidation reaction occurs and chlorine gas is formed. I assumed that this learner might have understood the process of industrial electrolysis of brine including redox reactions. However, what became evident in this answer was that, this learner did not have an understanding of charges on ions. This can be seen from Figure 6.16, where he or she put the wrong charge sign (+) on both the $C\ell$ and also put a charge sign on $C\ell_2$ which is a gas and has no charge. I did not anticipate this kind of wrong concept from learners who are repeating grade 12. This is the reason I classified knowledge of understanding of charges on ions as the prior knowledge for conceptual progression in my CoRes for chapter 5. This implied that, I expected learners to have that knowledge.

Another example of a learners' response to Question 1 is illustrated in Figure 6.17 below:

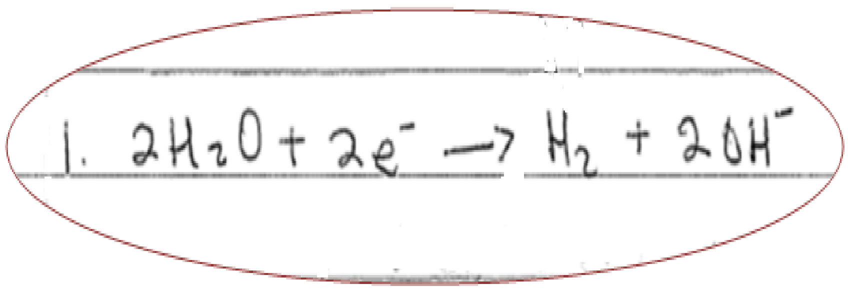


Figure 6.17: Lebo's response to Question 1

While the equation presented in Figure 6.17 is correct, it is an incorrect response to Question 1. It is incorrect because the reaction that takes place in electrode M is oxidised. I assumed that this learner might have had a better understanding of redox reactions. However, what could have contributed to this answer was that, he or she must have assumed that this is an electrochemical cell process. In electrolysis, the cathode is a positive electrode where reduction occurs whilst the anode is a negative electrode where oxidation occurs. This made perfect sense of why some learners gave the answer in Figure 6.17.

Of the 27 learners who got Question 1 correct, only 8 of them showed chlorine gas with a state or a form for example $C\ell_2$ (g) and the remaining learners did not indicate gaseous phase (g). Other learners did not balance the equation on the answers obtained. However, none of the learners put aqueous (aq) next to $2C\ell^-$. I did not mark them wrong since the standard reduction potentials table they use did not show itSee examples Figures illustrated below.

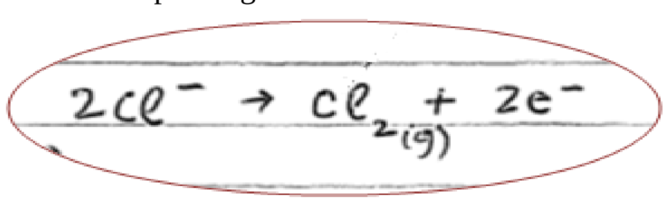


Figure 6.18: Musa's response to Question 1

Figure 6.18 showed the correct answer for Question 1. There were about 8 learners with this correct answer. The learners knew that oxidation reaction takes place at the positive electrode in an electrolytic cell and also knew how to represent it in a balanced half reaction equation with the correct charge on ions and the correct form of chlorine in gaseous phase. In Figure 6.19, the phase of chlorine was omitted however; the learners showed the full understanding of the concept required to answer the Question.

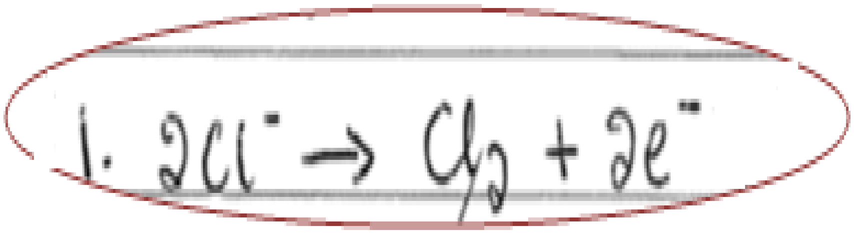


Figure 6.19: Dika's response to Question 1

In Figure 6.20 shows a completely wrong response to Question 1, indicating that the learner had no understanding of the concepts dealt with in the question.

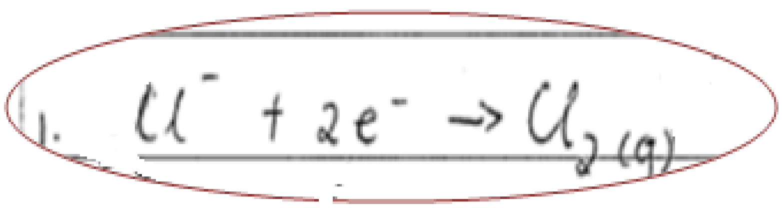


Figure 6.20 Papi's response to Question 1

Even though many of these learners could not answer Question 1 correctly, their answers to Question 2 were correct except for those who answered as in Figure 6.21 whom I believed were confused, assuming that this is electrochemical cell. (See an example in Figure 6.21)

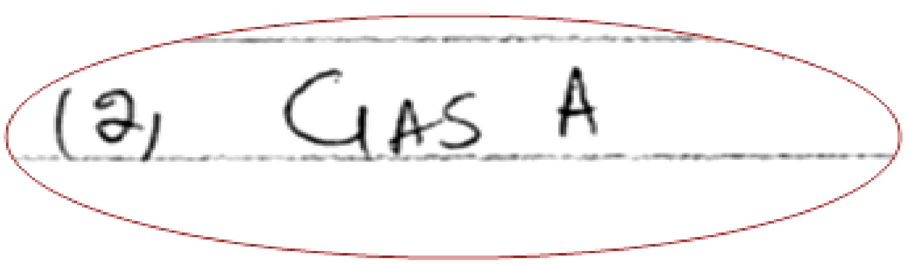


Figure 6.21: Majority of learners' response to Question 2

This response confirmed my assumption indicated in 6.2.5 under subject matter representations that I believed that most learners may have learnt through rote learning during the explanation of the three types of cells. Learners were not engaged deeply. And this had led to knowledge being transmitted to learners rather than being constructed. I therefore assumed that conceptual learning had not taken place in this kind of learning.

However, it is worth noting that during my deeper analyses of learners' Activity, I then realised that some of these incorrect responses are intelligible. I therefore decided to categorise them as partially correct. Table 6.1 (p104) gives more detail on the reasons into why I categorised them as partially correct.

I put more time into remediating misconceptions that arose from Question 1 and 2. This gave me direction in the second session. By this, I implied that after reflecting on learners' assessment Activity had actually informed my teaching. This was done prior to continuation of the lesson which took place the following day. I first gave learners their marked assessment scripts and asked them to reflect. Before I tackled the assessment Activity in detail for corrections, I decided to ask each group to discuss Question one first and report the answer they agreed on. To illustrate this point, see the excerpt from my teaching below:

Teacher: (talking to the whole class)....Looking at the marked Activity of the chloralkali process. Let's look at Question 1 that you did for Activity on the industry. (Teacher reading out Question 1 to the class). What is the half reaction taking place at electrode M? What is the half reaction for that? (Teacher walking towards the chalkboard and getting ready to write learners' response. Can you tell me what the half reaction for that electrode is?

Learners (chorusing): $2C\ell^-$

Teacher; (start writing learners' response on the chalkboard). See figure 6.22

As the learner was reporting, I decided to capture what he was saying by writing the information on the board (see below).

Figure 6.22: Corrections of learners' assessment

This gave me the opportunity to make learners part of this lesson, by appreciating their ideas. I was able to see the misconceptions that learners had about the assessment Activity in their reporting of the answers. I used extensively the chalkboard where I was writing different modeled answers given by each group for the same Question.

As far as Question 1 is concerned, I am partly to blame for learners' wrong concepts and omissions that has emerged. In my teaching of the types of cell process, I did not emphasise the use of reduction potential which could have helped the learners to better understand redox reactions. I also did not emphasise the need for the half reactions to be balanced as well as the state of chlorine. This can be seen from Figures 6.2 and 6.3 (p78) that the representation that I used during teaching of three types of cells did not also have the phase on the half equations reactions. I would assume that this is what had let to learners fail to notice the importance of balancing half reaction equations and to include the phase in the produced gas.

6.4.4.1 How was assessment informed by the domains?

My SMK influenced learners' assessment in that, to be able to effectively critique learners' written work, I needed better understanding of the content knowledge is needed. I had to know why did learners answered the way they did. This implied that, I had to find the root of the problem.

GPK was portrayed in the assessment. I had to come up with the best teaching approach that would make learners part of the consolidation process. Instead of giving them solutions to the assessment Question, I decided it would be best if they would compare how they answered in their respective groups. I assumed this strategy gave them an opportunity to share their ideas and reconstruct some ideas. Another example of my GPK is illustrated below from part of my journal:

"When I was marking their Activity, I kept on writing on the side what I was finding it to be their main difficulties. This was emerging from their work. However, I must mention that I was also noting the good things too. This was communicated to the learners on their scripts".

I believe that the above comment from my journal displayed the approach that I when marking the learners' Activity.

Knowledge of learners and contexts had also informed assessment. Learners were expected to show their understanding of different concepts. For example, redox reactions, balancing of chemical equations etc. shown below are the comments from my journal indicating my thinking about learners' assessment.

"I was able to see that some students did not know the oxidation and reduction reactions and because of that they were unable to write the half reaction on each cell.
Some of them did not know the ion charge. Some of them put + charge for chlorine which is wrong.
The difference between half reactions and overall reactions was a problem to some students. Some of them also neglected to balance the chemical equations."

Knowledge of context, which in this case is the availability of the resources, influenced assessment. I employed the use of a white board to capture information reported by different groups. This can be seen in Figure 6.22.

6.5 My subject matter knowledge

Subject Matter Knowledge (SMK) refers to a pure content or 'content per se'. Although it is part of the general knowledge domains, rather than manifestations, I decided to show how it has emerged during my teaching of this topic. As indicated in chapter 4, my aim was to develop my SMK through the construction and use of the concept maps, with experts' input, a visit to the plant, reflection on my first teaching lessons and further research using different materials.

I found in my study that my SMK was the most dominant domain of my knowledge that informed all the manifestations. In the next paragraphs, I consider some concrete examples on how my SMK on the one hand influenced my teaching and on the other, how my SMK was influenced by my teaching.

Example 1

In the process of improving my SMK of the topic through the construction and use of concept maps, wrong concepts in my first concept map emerged. I was convinced that Na^+ and OH^- ions in solution react to form solid NaOH. One expert gave the following comment about this incorrect entry in concept map one:

"Na^+ and OH^- are shown forming NaOH. In aqueous solution they do not! They remain as ions. Only on evaporation of some of the water does crystallization of the NaOH (s) begin, and it is then we may say the ions form NaOH".

This comment helped me improve my SMK which then influenced my teaching. I now understand that it is important to emphasise in my teaching that, when substances which are in aqueous solution react, they do not form solid unless the water is evaporated.

The excerpt from my teaching of the lesson below highlights how I then applied this improvement in my teaching:

Teacher: (pointing on the diagram of the cell membrane) pure water that is fed into this, cathode compartment, can you see pure water? (Pointing at the sign written pure water)

Lerato: (Chorusing) Yes

Teacher: And then what happens is water gets reduced. You can see the cathode, the reduction reaction there. If it gets reduced, hydrogen is produced; hence you can see H_2 there. What happens is even the hydrogen ions are formed. Now this hydroxide ions together with sodium ions when they combine, they react and water get evaporated because since there are ions it means water is involved isn't it?

Learners: (Chorusing) Yes

Teacher: then they (water from the two) evaporate the two until they form the crystal NaOH

Example 2

The second example emerged from another expert's comments about my second concept map. He indicated that, I did not make explicit the idea that electrolytic cells are non-spontaneous in nature. His comment was as follows:

"To me the essence of the process is its non-spontaneous nature, i.e. the need for an external source of energy…."

This comment challenged me to learn further about the electrolytic cell process. I found that the important thing about electrolytic cells is that they require energy input to function as opposed to electrochemical cells, which produce electrical energy which is released to the surrounding. I then included this important idea in my teaching. The following excerpt from my lesson, illustrate this point:

Teacher: (after explaining the electrolytic process for diaphragm cell). "Another thing is it is a non-spontaneous reaction, it uses what, and it uses electrical energy. Hence you will see that there is energy supplied (pointing a battery on the diagram). It is a non-spontaneous reaction.

It can be seen from the excerpt above that I incorporated in my teaching, the idea learnt from the expert. I explained to learners about the nature of the reaction in the diaphragm cell only. However, I forgot to explain the idea when discussing the membrane cell process as I started with it first.

I believed that most of the learners might not have understood well the idea of non-spontaneous reactions. I realised that the connection of the battery in the diagrams used was not enough to convince learners about the non-spontaneous nature of the reaction. If I could teach the topic again, in addition to using the battery in the diagram, I would ask learners to compare and calculate the values of half cell potential from the table of reduction potentials. This would help learners see that the negative value of the E^{θ} cell is an indication that more energy is required for the process to take place, and that this energy is provided by the battery. These show that my SMK influenced my teaching in a positive way.

My visit to the chloralkali plant also played a role in enhancing my SMK for teaching, which also influenced my teaching. Activity 6 (see appendix 7) in which learners had to compare the three types of cells and deduce their advantages, illustrates the enhancement of SMK. Most high school science textbooks differentiate the advantages and disadvantages of cells based on the following parameters:

- Cell voltage
- NaOH concentration
- Energy used
- Steam consumption
- Poisonous products, wastes etc

My visit to the plant informed me about other parameters that can be used to differentiate the advantages and disadvantages listed below:

- Membrane cell- is a safe procedure compared to the other two cell type (advantage); however the cost of membrane is very high because it is imported from Japan and America.
- Diaphragm cell- is sensitive to pressure variations (disadvantage)
- Mercury cell- is expensive to operation; hazardous and occupies large floor space.

I incorporated the foregoing parameters in my teaching, as illustrated in the excerpt below:

Learners: So graphite also can be improved?

Teacher: I am not sure whether they improve it. But all he *(tour guide)* has told us is that, after some time they service all their equipment, but they (I meant some equipments) got life span. They can go and on especially the membrane. He said you can actually replace anode electrode after so many years. Once you allow the ions to pass through in a membrane cell [to anode], it can actually affect the lifespan of the anode.

It can be seen from the excerpt above that I shared with my learners the knowledge gained from visit to the plant. I was attempting to answer the questions asked about the cell process. This type of question could not be answered using the information provided in most of the high school textbooks. I attempted to explain that the anode has a life span, which implies that it can last a limited time. However, in my explanation as the excerpt shows, I only mentioned “many years” and was not specific. This question was partially answered because the anode could last for a period of 6 to 8 years. I also attempted to indicate what could affect the life span of the anode. My response was as follows:

"Once you allow the ions to pass through in a membrane cell [to anode], it can actually affect the life span of the anode".

When I reflected on this excerpt after my teaching I thought that the answer (of ions passing through the membrane) given to learners was incorrect. I was convinced that this response was incorrect because I was informed during my visit to the plant that caustic soda passes through the membrane to the anode compartment, it would attack the coating of the anode thus, reducing its lifespan. This is the reason why, in both membrane and diaphragm cell process, caustic soda is collected in the cathode compartment and not in the anode compartment.

However, I informed one expert about this comment received from the plant visit. The expert's critiqued this comment by saying that ions could be involved too, because caustic soda is still in solution. This implied that there are ions available. When reflecting deeper on the expert comment, I realised that she might be correct thus my answer to the learners might be correct. In my understanding, I thought that, this could have contributed by the fact that some engineers in the plant do not have a deeper understanding of the process at molecular level. Unlike chemists, I believe that engineers are mostly interested in the yields or products.

I found that analysing the learners' assessment Activity, informed me about both my SMK and PCK. In Table 6.1, I present a detailed analysis of learners' responses to Question 1.

Table 6.1: Learners' category/codes, answers and respondents percentage to Question 1

Category/Codes	Answers	No of respondents (%)
1. Learners with completely correct answers	$2C\ell^- \rightarrow C\ell_{2\,(g)} + 2e^-$	8 (19%)
2. Learners with partially correct answers i.e. balanced chemical equations, but no phase shown.	$2C\ell^- \rightarrow C\ell_2 + 2e^-$	17(40%)
3. Learners with partially correct answer but the chemical equation is not balanced and no phase shown.	$C\ell^- \rightarrow C\ell_2 + 2e^-$	2(5%)
4. Learner with partially correct answer -chlorine molecule is displayed with a charge on it, the chemical equation is not balanced and no phase shown. Charges are not balanced.	$C\ell^+ \rightarrow C\ell_2^+ + 2e^-$	3(7%)
5. Learner with partially correct answer -chlorine molecule is oxidised not $C\ell^-$ ions, the chemical equation is not balanced and no phase shown.	$C\ell_2 \rightarrow C\ell^- + 2e^-$	4(9%)
6. Learner with completely incorrect answer –$C\ell^-$ ions are reduced not oxidised, the chemical equation is not balanced.	$C\ell^- + 2e^- \rightarrow C\ell_{2(g)}$	5(11%)
7. Learner with completely incorrect answer – reduction not oxidation and no phase shown.	$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$	1(2%)
8. No responses	-	3(7%)
Total number of learners		**43 (100%)**

Based on the low percentage of respondents, 19% for Category 1 responses, I would presume that careful attention on particular concepts was needed. This implies that, my SMK and SMK for teaching needs some refinement.

I assumed that, the most important analysis that would inform my SMK and SMK for teaching was learners' response in categories 4 to 6, followed by categories 1, 2, 3 and 7. I would analyse in detail learners' answers and justify why I categorized them as partially correct and Category 7 as incorrect.

I presumed that learners' response in Category 4 in Table 6.1 was partially correct. The part that was correct was 1) the concept of electron transfer subsequent to oxidation and was well understood and 2) the direction of the reaction was also correct. However, what made this response to be incorrect was that, 1) learners displayed chloride ion with a wrong charge and 2) chlorine molecules produced was placed on the right side, but given a charge.

Learners' response in Category 5 was partially correct. Learners showed a better understanding because e^- was on the right i.e. the concept of electron transfer in oxidation was well understood. However, it appeared that, these learners did not understand the definition of oxidation as the increase in oxidation number. From their response, there was a decrease in oxidation number (from 0 to -1), which implied reduction.

Learners' response in Category 6 was also partially correct. Learners' seemed to have a better understanding of definition of oxidation number. The answers showed an increase in oxidation number (from -1 to 0) but, the concept of electron transfer was incorrect.

The responses from categories 4 to 6 have informed my PCK. I found these responses to have made me develop my teaching strategy. If I had to deliver this topic in future, I would start teaching learners in detail the concept of oxidation number, which incorporates the understanding of charges on ions. I would also emphasise that, oxidation half reactions involves electron transfer and reduction half reactions involve gaining of electrons. This implied that, where there is electron transfer, there would be increase in oxidation number on atoms involved.

About 40% of the learners displayed Category 2 responses, i.e. partially correct answers. Answers were considered partially correct because learners gave the correct balanced chemical equation but omitted the phase in chlorine molecule. Categories 3 to 6 responses displayed answers that were also partially correct. Category 7 responses were also incorrect answers (reduction half reaction was given instead of oxidation reaction) with unbalanced chemical equations and without a phase. This implied that, 34% of learners did not see the importance of balancing the chemical equation. In total, 74% of learners did not see the importance of displaying the phase of chlorine gas. Based on these findings, in future I would make it explicit to learners that, half reactions should be balanced and phases should also be displayed.

6.6 Conclusion

My findings showed that all the domains that were integrated and its subsequent manifestations played a role in the development of my PCK.

It appeared that my knowledge of subject matter carried the highest weight of all the manifestations (representations, curricular saliency, topic specific instructional strategy or assessment) relative to others (GPK, knowledge of learners and knowledge of context). In fact, I needed a better understanding of SMK in order to decide and formulate proper Questions and make fair assessments. My analysis also revealed that careful integration of the domains greatly impact learners' understanding of the topic.

SMK also informed my curricular saliency which guided me on what to cover, what to include and omit in my teaching. To be able to know which part of the teaching comes first, I needed a better understanding of the whole topic. My curricular saliency was mostly influenced by the curriculum. As a result, I found myself frustrated when learners asked me some of the things I did not know. The large improvement in my SMK was influenced by my visit to the plant, construction and use of the concept maps, input from the specialists and all have been incorporated in my teaching.

The domain of knowledge of learners, displayed in all the manifestations, was important in my teaching. The need to know learners prior knowledge before attempting to teach the lesson, prompted me to use different teaching procedures in my teaching. Learners worked in groups, whole class teaching was used and part of individual working was involved when writing the assessment Activity. I assumed these teaching strategies accommodated most the learners who normally learn differently. I extensively encouraged learners to ask Questions at the end of the lesson and this proved to be an effective teaching strategy. Thereafter, a learner-centred approach was followed.

I discovered that, in most cases learners appreciated the fact that I was using their ideas and they provided more. This affected my teaching of some of the concepts, for example redox reactions, balancing of chemical equations, which I presumed learners knew. Fortunately, remediation of those wrong concepts was done during the teaching.

General pedagogical knowledge (GPK) emerged in all the manifestations. Amongst others my GPK was observed in the manifestations in the following:

- Giving instructions to learners during my teaching;
- Preparation and planning of the materials for the lesson;
- Preparation of the equipment (apparatus and chemicals);
- Allocating learners to groups;
- Managing time during my teaching.

All the domains in my teaching were integrated to form my PCK. As Rollnick *et al.* (2008) indicated that this teacher knowledge constitutes the development of one's PCK. I found my improved SMK helped improve my flexibility while teaching, which resulted in a stronger PCK. Since this topic was new, I found it difficult to understand how learners learnt, suggesting that my knowledge of learners was lacking, and should have been improved for further development of my PCK. However, I also acknowledge that the development of SMK is an endless process. When associated with reflection, the teaching of the same topic is very likely to result in refinement, and improvement in SMK, therefore PCK.

CHAPTER 7

CONCLUSIONS AND REFLECTIONS

7.1 Introduction

In this chapter, I give the overall conclusions of the study. This comprises a summary of my research methods, findings and followed by the reflections, recommendations and limitations of my study.

7.2 Summary of my research methods

This study intended to find out how I transformed and developed my subject matter knowledge (SMK) on the chloralkali industry when teaching grade 12 learners. Three concepts maps were constructed and used for that end. I captured my Content Representations (CoRes) and illuminated those using Pedagogical Presentation and Professional repertoires (PaP-eRs) as a way of expressing my PCK. An analysis of my teaching using the Rollnick *et al*. (2008) tailored model for PCK, showed how the manifestations of my PCK emerged from my knowledge domains.

7.3 Critical reflection of the study

The use of concept maps allowed me to elaborate what I knew about the chloralkali industry. It is important to mention that I did not have problems with how to develop concept maps as I was engaged once before in the construction of concept maps for my honours project. However, in the beginning I experienced difficulties when developing my first concept map particularly when attempting to link concepts because of my poor content knowledge at the time.

I found myself with scattered ideas about the topic, which needed coordination to make meaning. I realised that it was extremely difficult to link concepts if I did not understand the topic well enough. I presumed that this was the reason experts were able to spot more incorrect links that reflected my misconceptions in my first concept map. During the development of my second concept map, I began to find it easier to link concepts and finding linking words was not problematic. This was influenced by the fact that I had better understanding and flexibility of content knowledge. The more I exposed my understanding in concept maps to experts, the more they were able to read my understanding on this topic and supply me with more input and comments. I thus believe that concepts maps played an important role in this study in terms of my content knowledge development.

Having to keep a journal for documentation of all my reflections was very important. I realised that what I was thinking played an important role especially in accessing the domains of my knowledge in chapter 6. However, I must emphasise that I found it really difficult to document all my thinking processes. I only realised this when analysing my teaching. There were other things that I felt I might have overlooked when writing my journal, which I believe could have been documented.

This study adapted Loughran's *et al.* (2004) method of capturing and documenting my PCK through the use of CoRes and PaP-eRs. With CoRes, I was obliged to put myself in a teaching position. The prompts on the CoRe template helped me document my PCK as I was responding to them. With the use of the CoRes at different stages, I was able to compare how my PCK had improved from 2008 to 2009. The PaP-eRs brought the CoRes to life through teaching. They portrayed my actual classroom teaching in the form of a narrative where different forms of teacher knowledge were utilised in order to make the tacit explicit.

Capturing my teaching through videotaping was helpful hence I was able to re-play it as many times as I can. The process of videotaping was successful but certain parts were not captured due to shortage of space on the memory card. In the absence of video recording, I used audio recording so that I could access the information needed.

The learners' assessment was written and completed within the time frame allocated. The assessment activity was marked and feedback was given to learners prior to continuation of the remaining lesson. All learners' assessment scripts were then collected back from learners after corrections were made for analysis of data.

My knowledge of subject matter was a great concern in this study. I needed to acquire a better understanding of the topic prior to my teaching. The construction and use of concept maps was very useful. The positive aspect about the use of concept maps was that I was able to expose to experts what I knew about the topic. Through these concept maps, they were able to spot gaps in my content knowledge which I couldn't easily identify and close on my own. I needed to reflect, integrate and make sense on expert's comments. This made easier the development of my correct conceptualisation about the topic.

The framework I used for analysing my concepts maps was also very useful. It required me to assess what was correct and incorrect about my maps. By engaging with the element of correctness, I was able to see what was wrong before and how I changed those particular wrong concepts. Another aspect that made me realise how much I grew in content, was the construct of connectedness. I was able to show more of correct links and cross links implied that I was engaging in integrative reconciliation of concepts, an idea by (Novak and Gowin, 1984).

The third construct I used from the framework was complexity. Although I analysed the complexity of my concept maps, I did not see how it benefited the development of my content knowledge. The reason I am saying this is that it took into account all the links including the incorrect ones. I realised that the complexity of the map does not automatically imply that the content is known well enough. Therefore, I felt that the complexity did not indicate much about my content knowledge development.

One expert commented on my first concept map (see appendix 2):

"This is not a concept map of the chloralkali industry, but rather of the industrial electrolysis of $NaC\ell$ (aq)"

This expert realised that I attempted to cover both the industrial electrolysis and downstream products & applications in one map. He felt that I should have drawn two concept maps, one on each Big idea ("electrolysis of sodium chloride involves a redox reaction" and "the chloralkali industry plant has an impact on the societal, economic and environmental issues") on this topic. I reflected on his comment and decided to construct my second concept map (see appendix 3) based on the chemical side of the topic (industrial electrolysis of brine). I found that my decision to do that was in line with my first Big idea in the CoRes which looked into the electrolysis aspect of the chloralkali industry. I must make it clear that I do not regret taking the expert's advice because I believe that there was so much I learnt from concentrating on this particular idea for my construction of concept maps.

As far as concept maps are concerned, there were experts' comments that left me confused. For example, I wrote in my first concept map that, "cathode is known as a plus pole". One expert advised me to use the word 'terminal' instead of pole. The other expert said he preferred the word 'positive' instead of 'plus'. This was an example of some of the unanswered questions in my study. I would assume that this comment had a lot to do with chemistry language. This is clear from my findings that different chemists prefer different words.

As I was reflecting on the teaching of my lesson, I realised that not much was said (in both textbooks and my own teaching) about why an anode is positive and a cathode is negative in an electrolytic cell. This was just mentioned with no proper explanation in the resources I used. I consulted different chemistry experts who had different opinions. I needed to know and understand this conceptually. Ogude and Bradley (1996) argue that teachers should avoid terminology like negative and positive electrodes when teaching as they are not crucial when interpreting the electrolytic and electrochemical processes. I just felt that since I was engaged in a Self-Study, there was need for me as a teacher to explore and go as far as knowing more than learners and more than what the curriculum demands. This included using textbooks hence they are being used for examination purpose.

My third concept map was an indication that my content knowledge grew. As I got to understand the topic better, I needed to know more. For example, I never thought of interrogating the sign on the cathode and anode in electrolytic cells in my previous teaching. Because restructuring of content knowledge improved my teaching, this implied that my PCK also developed.

The use of CoRes and PaP-eRs in my study greatly influenced the development of my PCK. As I indicated in chapter 5, the use of CoRes in my study was different from Loughran *et al*.'s (2004). They constructed the CoRes with the help of a group of experienced teachers. In my study, I worked on my own prior to seeking comments on CoRe from the Self-Study group. I realised that my CoRe for 2009 showed better development in my PCK relative to 2008 CoRe. This is an indication that the CoRes improved my PCK. The PaP-eRs illuminate some aspects of the CoRes such as learners' prior knowledge, strategies, difficulties.

The teaching of my lessons went well. When reflecting on my teaching, I realised that the content's deepness of my lessons differed. I did best when teaching about Big idea one, which involved the electrolysis of brine. I was confident when explaining the preparation of brine industrially for three types of different cell. This was influenced by the fact that I spent time constructing concept maps on Big idea one. Although I learnt about Big idea two ("the chloralkali industry plant has an impact on the societal, economic and environmental issues"). I found that my visit to the plant played a role in my teaching process. I was excited to share with learners what I learnt from the plant. This emerged mainly from my teaching where the processes of the three cells were compared. However, I did not find myself comfortable and flexible when teaching this idea.

The tailored model for PCK by Rollnick *et al.* (2008) helped me analyse my PCK on this topic. The findings from using this model, made me appreciate more the importance of content knowledge. The reason is that for each manifestation, the visibility of my content knowledge emerged more than any other domain. Although I had only taught the topic once, it was not easy to find much about knowledge of how learners learn. However, in most cases I considered knowledge of learners as learners' prior knowledge, rather than teacher's knowledge of what learners know, how learners learn, learning styles and preferences, as well as difficulties they experience.

The reason I decided to do a self-study in the first place was, to see how my topic unfolds in a view of developing my PCK. Senese & Austin (2007) argue that self study is challenging as it requires one to put his or her beliefs, assumptions and ideology about teaching practice under scrutiny. This is in line with what I experienced. I had to expose my ideas of teaching the industrial electrolysis of brine to experts for criticism. I found this difficult to do at first. This was influenced by the fact that, throughout my teaching career, I never exposed my weaknesses to other teachers or experts. I used to do my own teaching in my class and ended there.

According Senese & Austin (2007), teachers should not be content to work in isolation. This is exactly what I did the minute I decided to engage myself in a self study project. Having to talk to my colleagues who are experts, made me feel proud of myself in the field of teaching. I also learnt that the more I collaborated, the more I felt that I grew, taking even more responsibility in my teaching.

Senese & Austin (2007) also indicate that teacher researchers are observers, questioners and learners. I have been a learner throughout the process. I was a learner to my colleagues, tour guides in the plant and finally to my own learners. I kept on asking my colleagues things that I did not understand in the whole process. I would even analyse both of their response in particular questions as some of them were pure chemists and others were chemistry teachers. I was also a questioner in the process because I questioned myself when making decisions as to whether they were correct or incorrect. My thinking which also involved questioning was documented in a journal (see appendix 5). I feel very confident and proud when talking about my research. This is an indication that I have grown professionally.

7.4 Discussions of the findings

Teaching a new topic is not easy. I needed a better understanding of the content knowledge of the chloralkali industry in order to transform it into accessible forms. I found that the concept maps helped me facilitate my content growth. The construction and use of concept maps informed me about the state of my prior knowledge on the chloralkali process.

The large increase in correctness between concept maps 2 and 2 done, suggests a great improvement in both the quality and accuracy of my content knowledge. This improvement was influenced by experts' input and comments. My findings are in line with those of Kinchin and Hay (2000) who argue that constructing concept maps can promote one's understanding. The observed large increase in connectedness in concept map 3 after teaching suggests more connections in links and cross-links occurred which resulted in a net structure map. Kinchin and Hay (2000) argue that a net structure map allows one to use various routes in a map and in that way more connections occur. This implied that the accuracy of the links influenced the observed connectedness. In effect, I needed a better understanding of the topic first, in order to make these connections; the process that Novak and Gowin (1984) termed integrative reconciliation of concepts.

This improved content and better understanding of the topic helped me to develop as Big ideas. The Big idea 1, namely "electrolysis of sodium chloride involves a redox reaction" was informed by the electrolytic processes I learnt during construction the concept maps. For example, it is clearly shown from concept maps that electrolysis of brine result in a redox reaction taking place. I then incorporated this idea in my teaching (as representation manifestation) when explaining to learners how oxidation and reductions occurs in electrolytic cells.

From these two 'Big ideas', I developed two CoRes to represent my PCK and its development from 2008 (first time I taught this topic) to the 2009, after my teaching. The comparison was based upon variations in answers given to key prompts related to "Big ideas". The analysis focused on both "Big ideas:" namely "electrolysis of sodium chloride involves a redox reaction" and "the chloralkali industry plant has impact on the societal, economic and environmental issues". I found the use and construction of concept maps which helped improve my content knowledge, to have influenced how I intended to teach this topic. Hence the answers to the key prompts for the 2009 CoRe improved in such a way that other teacher may be in a position to learn from them.

Prompts one, two and three in Table 5.1 of "Big ideas" intended to find out about my curricular saliency. For me to give responses to these prompts, I needed to know what comes before and after in this topic. This emerged in my teaching as I started teaching about the redox reactions in electrolysis prior to the impact of the chloralkali plant. The content knowledge I developed through the concept maps also played a role in answering these prompts. For example, I needed to understand the topic well enough so that I could decide on what comes before or after.

There were some differences in answers given to prompts in the 2008 and the 2009 CoRes. The answer to prompt one of Big idea one for the 2008 CoRe was limited as compared to the 2009 CoRe. In the 2008 CoRe, I had only one point that I intended students to learn about this idea. In the 2009 CoRe had about 4 points. Prompt two and three of the two Big ideas also show increase in the number of points. This implies that my curricular saliency which was influenced by my improved content knowledge on Big idea one on the topic for the 2009 has grown and developed as compared to the 2008.

The development of my PCK could greatly be ascribed to a constructivist approach. In Table 5.1 of CoRes, prompt six aimed at finding out about factors that influence my teaching of the idea which relates to learners' prior knowledge. I used learners' prior knowledge extensively in both Big ideas to introduce the lessons in an attempt to facilitate the learning of electrolysis. The reason I employed the approach was to explore learners' possible misconceptions and then devises possible remediation approach. This is in line with Hewson *et al*. (1998) who believe that in many abstract topics, learners tend to manifest alternative conceptions or misconceptions which are extremely resistant to remediate. However, there were some developments in both Big ideas for 2009. For Big idea one in 2009 CoRe, I included knowledge of salt and electrochemical reactions for conceptual progression. I also included the knowledge of examination requirements for both Big ideas. Big idea two for 2009 CoRe also showed more development because organic molecules and organic macromolecules were included for conceptual progression. I believe that the development shown in both Big ideas for prompt six implies that there was a deeper understanding of the content in 2009 CoRe relative to the 2008.

My teaching procedure in 2009 CoRe for both Big ideas had changed and improved. This can be seen from prompt seven in Table 5.1. In the 2008 CoRe for Big idea one, I taught the lesson first and then followed it by a practical activity on electrolysis. This is different from the 2009 CoRe where I first allowed learners to perform the practical activity on electrolysis so that it could inform the rest of my lesson. This activity has effectively helped transform my SMK because it allowed learners to conceptualise the chemical process in the industrial chloralkali. In both Big ideas for the 2009 CoRe, I was able to include different teaching procedures such as the use of power point showing cell diagrams, translation activities of flow diagram and table of comparison of types of cells.

These teaching procedures informed the different representation and strategies used during the actual teaching of the topic. For example the use of practical activity and flow diagram were strategies used in my teaching. These strategies were informed by all four knowledge domains (knowledge of subject matter, knowledge of students, GPK and knowledge of context) which were integrated. In using both strategies, I found that adequate SMK was essential. In order for me to interpret the practical activity to learners, better understanding of electrolysis of brine is needed. In terms of flow diagrams strategy, I needed to assess learners' response on how they translated it so that I would be in position to spot the learners' knowledge gaps. The domain of knowledge of learners emerged during the practical experiment where learners showed their understanding on how to test for gases like hydrogen and chlorine, which I then took into account when teaching. It is worth mentioning that I did not think of this prior knowledge before, hence it was not mentioned in my CoRes. It was also integrated during the manifestation of strategies. However, I anticipated learners' prior knowledge such as organic molecules and organic macromolecules as part of knowledge of learners in my CoRes. This knowledge became evident during the use of flow diagram strategy.

The use of appropriate teaching strategies helped transform my SMK. There was some development on the strategies used in 2009 CoRe for both Big ideas. Varieties of strategies like, asking learners' questions at the end of the lesson and allowing them to ask questions were identified in the 2008 CoRe. However, in the 2009 CoRe there was an inclusion of learners written class activity to be marked. Learners' written activity allowed me to assess the learners better. I needed better understanding of SMK in order to come up with questions that would promote learners' conceptual understanding. For learners to perform the assessment activity, prior knowledge was necessary. They had to employ understanding of different concepts such as redox reactions, balancing of equations. This strategy did not only inform me about what learners did or did not understand about the lesson taught but also informed me about the development of my PCK. I was able to think critically about why learners answered the way they did. In doing so, I was able to see part of the lesson where learners did not understand.

A better understanding of SMK helped and gave me confidence when explaining to learners about the process of electrolysis of brine. The use of representation also highlighted the importance of depicting learners' prior knowledge first. Through the use of representation, I was able to see that some learners did not know what electrodes are. This made me realise that in future, I should not take for granted learners' prior knowledge when teaching. The domain of GPK which included selection of activities and planning of the lesson also informed the representation.

Integrating carefully the domains had great impact learners' understanding of the topic, which improved my SMK for teaching.

7.5 Summary of the findings

The aim of the study was to map my PCK while teaching about the chloralkali industry to grade 12 learners. Below, I sum up my findings, focusing particularly on how they address the research questions set out in chapter 1.

7.5.1 **Research question 1**:

How do my ideas on chloralkali industry develop as I prepare to teach?

My ideas on Chloralkali industry have greatly developed through the construction and use of concept maps. My content knowledge about the topic has improved. Through comments and input I received from the experts, I learnt new concepts that led to my knowledge growth. For example, in the 2008 teaching, I did not give much attention the idea that electrolytic cells use electrical energy to drive non-spontaneous reactions. This was suggested by one of the experts and I also came to realise the importance of this idea as I was preparing to teach. Hence I incorporated this idea in the 2009 CoRes under prompt one which states "what do I intend students to learn about this idea". It is important to mention that I did not include the idea of non-spontaneous reaction only but, I was able to give a reason why in prompt two that states "why is it important for student to learn this idea". I realised that in order for me to give the reason for prompt one, showed an improved SMK of the topic.

The other important aspect that contributed to my knowledge growth is that of learning about the difference between current and electrical energy. I noticed that initially I was using these two concepts interchangeably. I could also say that throughout my entire teaching career I did not know the difference between the two which implied that I fed my learners this misconception. One expert picked up this wrong concept and I was able to engage further to find out the difference between the two. In so doing, I believe that my content knowledge grew hence I can now confidently differentiate them when teaching.

In remediating all these wrong concepts in response to feedback I got from the experts, my concept map's correctness had a large increase suggesting a great improvement in both the accuracy and quality of my SMK. There were also more connections in links and cross-links which resulted in the observed large increase in connectedness. In effect the existence of these connections showed a better understanding of the topic.

7.5.2 **Research question 2**:

How do I document and portray my PCK about chloralkali industry?

I used Loughran *et al*. (2004)'s model of CoRes and PaP-eRs. Firstly, I developed two CoRes with two 'Big ideas' in order to represent my PCK and to also see how it developed from 2008 to 2009. There were fundamental differences between the CoRes. This implied that there were different knowledge (aspects) that I considered when preparing and representing the topic for 2009 teaching which I did not know for the 2008 teaching. For example, in Big idea one for 2008 CoRe, I had only one idea that I intended learners to learn about. However, for 2009 CoRe, there were about three ideas. Although there was one idea in prompt one for both 2008 and 2009 CoRe for Big idea two, reasons given in prompt two of the CoRe in that particular Big idea showed a large improvement in my content knowledge for 2009 CoRe.

Through the help of the construction of concept maps, lesson plans and my teaching of the lessons, I was able to see more developments in prompt six (about factors influencing my teaching of the ideas) of the CoRe for 2009. The new developments in this question showed that I had deeper understanding of the topic. For example, in Big idea two of the CoRe, I had answers such as organic macromolecules and organic molecules which I did not have in the 2008 CoRe. This was influenced by the type of lesson activities I intended to give learners (see appendix 7). The use of various teaching procedures and strategies were employed in the 2009 CoRe as compared to 2008. I was more confident about my SMK and therefore able to explore my teaching in different ways. All the development in the 2009 CoRe indicated a stronger PCK.

Secondly, I narrated the ideas from the CoRe in the form of the PaP-eRs and put them into classroom practice. I found that PaP-eRs integrated the ideas in order to make the tacit clearer. For example, I indicated in the 2009 CoRe for prompt four that one of the difficulties associated with teaching Big idea one would be to distinguish between electrolytic and galvanic cells. Indeed, I spotted this difficulty during my teaching and decided to narrate in my PaP-eRs. This shows that PaP-eRs bring CoRes to life. I assumed that my PaP-eRs also informed me that my PCK had improved. However, as my SMK was further refined, my PCK was also affected. This suggested that the development of PCK also improved.

7.5.3 **Research question 3:**

How does my subject matter knowledge on the chloralkali industry transform into teachable knowledge?

For each manifestation to occur, careful integration of all the domains took place and helped in the development of my PCK.

The representations (cell diagrams) employed in my teaching that originated from prompt seven of the teaching procedure in the 2009 CoRe, showed integration of all my knowledge domains. I displayed a sound SMK during my teaching which was informed by concept maps, visit to the plant etc. However, through the use of representations, I realised that the knowledge of learners was partially displayed. The reason is that, I did not attempt to find out about all the learners prior knowledge indentified in the 2009 CoRe. I only noticed this when learners started to ask me about concepts that I assumed they knew.

I analysed two topic specific instructional strategies (practical activity and flow diagram) used in my teaching. Both strategies were informed by the domains. There was a need for me to understand the content knowledge better in order to interpret the practical activity to learners. In terms of the diagram, I had to know beyond what learners knew so that I could spot learners' misconceptions. The importance of learners' prior knowledge emerged as knowledge of learners. GPK also emerged especially in doing practical work where organisation of learners, chemicals and equipments was essential. Since learners were doing practical work, it was easier for me to depict knowledge of context. As I indicated earlier that most of them may not have been previously exposed to practical work.

For curricular saliency, I needed to understand the content well enough in order to know what comes before or after and/or what to omit or include in my teaching. Knowledge of context surfaced because I followed the curriculum guidelines in order to know what came first. This was accounted for in my lesson plan (see appendix 7) which was informed by the 2009 CoRe under prompt three that states “what else do I know about this idea that would not share with students yet”. In the first part of the lesson I dealt with electrolysis of brine before attempting the impact of the chloralkali plant. GPK was employed as the preparation and organisation of materials to be used by learners were made.

I found my assessment style to be mostly influenced by SMK as I needed to give questions that prompted conceptual understanding and to also critique learners’ written work. Assessment also needed best teaching approach so that learners could be in a position to understand properly where they went wrong. In assessing learners, knowledge of learners is essential as they need to use all the ideas learnt when answering questions such as redox reactions, balancing of equations.

Although all the domains are essential in terms of informing manifestations, I still maintain that SMK plays a major role in developing one’s PCK. My improved SMK gave me a good level of flexibility and confidence in my teaching, which led to stronger PCK. This implied that one’s teaching experience plays an important role in developing his or her PCK.

7.6 Limitations of the study.

The time available and circumstances including the research designed allowed me to work with the small sample of two groups from one school. I was allowed to teach this case study within two days according to the school programme. I could not find time to teach learners the pre-requisite topics such as electrochemistry (as it did not fall within the scope of our contract) in an attempt to find out about their prior-knowledge. I had to put together the whole module for chloralkali industry in the time frame given which was too little. The time available did not allow me to give learners more assessment tasks in order to compare parts of the lesson that they understood better.

I indicated earlier that I focused more on the industrial electrolysis part than the chlorakali plant. It would have taken more than six months (time frame) to finish this study if I had to also construct concept maps on the applications and downstream (actual industrial processes) of the plant. This could have implied that six concept maps in total were going to be analysed. It had already taken me a long time to analyse some of ideas in the three concept maps.

7.7 Recommendations.

It came out throughout my findings i.e. in my concept maps, Co-Res & PaP-eRs, and teaching the need to understand my content knowledge better in order to develop better PCK. I would recommend that, more proper in-service training be done by well qualified tutors to be available for teachers as this would help improve their content knowledge. I would also encourage teachers to visit the plant factories when teaching industrial chemistry. Although most of the teachers believe that it is difficult to be admitted to the plant, they might opt to go on their own and share some of the experiences with their learners.

I have seen in my study the importance of finding out about learners' prior knowledge. Giving learners' assessment activity helped me realise that there were many concepts that learners did not know that I presumed they knew. I noticed that, these wrong concepts were the ones that could not allow them to understand the correct concepts. Therefore, learners' prior knowledge forms a crucial part of their ability to transform SMK into accessible forms. I would then emphasise that it is crucial for teachers to spent time eliciting learners' prior knowledge prior to the teaching. These could be explored in case where they were misconceptions, could be remediated.

In some of the teachers' workshops I have delivered myself, I was told by the teachers that they do not engage learners in practical activities, especially in this knowledge area of chemical systems. This indicates that all they do is to teach the theory on the topic. I think that, it is important for teachers to start exposing the difficulties they encounter in class and share them with other teachers. In South African context, this could be done in 'cluster meetings' that are often held with curriculum advisors.

7.8 Directions for future research.

South Africa is producing very few university graduates in science education degree every year Science. I believe that, the content knowledge of these teachers needs great improvement for better performance in teaching, attracting learners into scientific fields and science education. Such teachers are particularly likely to make learners develop interest in teaching as a career.

Besides the intention of obtaining a degree, I think that more teachers should engage in Self-Study research in order to be experts in their field. For future study, I intend to look deeper into the chloralkali industry, particularly the mechanical and other technical aspects of the process in the plant, which I felt are not sufficiently taught or learnt in high schools since the introduction of the choralkali industry. This would include processes like precipitation, filtration, oxygen removal, compression, concentration, liquefaction among others.

Finally, I believe that the analysis and use of learners' assessment activity helped develop my PCK in this self-study. However, a deeper investigation of the effects of assessment activities on the development of PCK could be subject of future study, before generalization, which I think would be beneficial to other teachers.

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APPENDICES

Appendix 1- Rubric

Rubric for scoring concept maps (from Luft, J. Pers. Comm)

<u>Definitions</u>

Node – a word/concept linked to one or more other words/concepts

Link – a direct connection between two nodes on successive levels

Cross-link – a connection between two nodes on either the same level or other levels

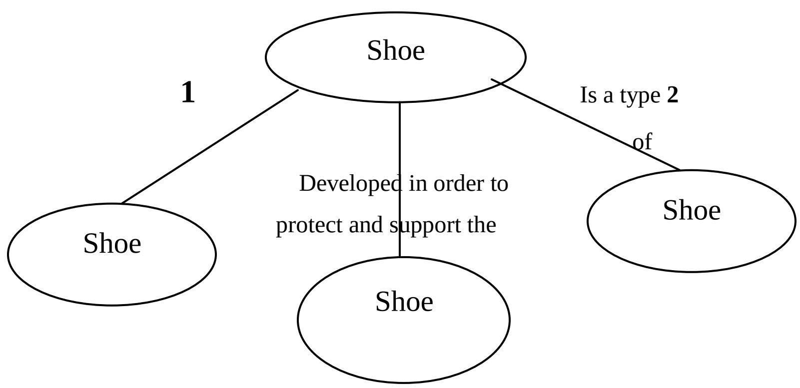
Successor – a linked word one level down from a node

Width – the greatest number of concepts at one particular level on the map

Depth – the length of the longest chain on the map

Chunk – a group of linked concepts for which the leading concept has at least two correct successors

In an example below ***shoe*** is a chunk because it has **3** successors with correct links.



<u>Analysis</u>

A. Correctness

1. All links are assessed for correctness (cross-links and links)
2. The following rating is provided for each link (Li):

   0 = the link is missing or incorrect

   1 = a link is present, but there are no words or propositions on the link

   2 = the link is represents a basic or superficial idea that while acceptable shows limited or "scientifically thin" knowledge.

   4= the link shows a detailed and sophisticated understanding that is "scientifically rich"

3. All of the scores are added for each link and cross-link, and the final score is divided by the number of nodes. This corrects for the fact that some teachers chose to add extra nodes. The formula is: (L1) + (L2)…)/total number of nodes x 100= Correctness

B. Connectedness

1. The correct chunks are determined and the number of correct links (do not include cross links in this count) for each chunk are counted (CNL). A chunk is a group of linked concepts for which the leading concept has at least two *correct* successors.
   Procedural note: in cases where links can be assigned to more than one node always select the link that creates a chunk if applicable
2. The correct cross-links are determined (CCL).
3. A score for the connectedness is:
   nCNL + nCCL= connectedness

C. Complexity

Procedural note: when redrawing the map in hierarchical form nodes are assigned to a hierarchical level based on their distance from the overarching concept.

1 The width of the concept map is assessed (W). This is the greatest number of concepts at one particular level on the map.

2 The depth of the concept map is assessed (D). This is the length of the longest chain on the map.

3 The numbers of cross-links are counted (CCL).

4 The formula: (W x D) x CCL =complexity

Detailed scoring

Correctness = <u>Total number of links</u> x 100

Total number of nodes

Concept map 1= 6+3+9+124/37 x 100

= 387

Concept map 2= 0+1+6+104/26 x 100

= 426

Concept map 3= 0+0+6+152/37 x100

= 427

Connectedness = nCCL + n CNL

Concept map 1 = 17 + 6 = 23

Concept map 2 = 18+7 = 25

Concept map 3 = 27 + 7 = 34

Complexity = (W x D) x CCL

Concept map 1= (8 x 9) x 6

= 432

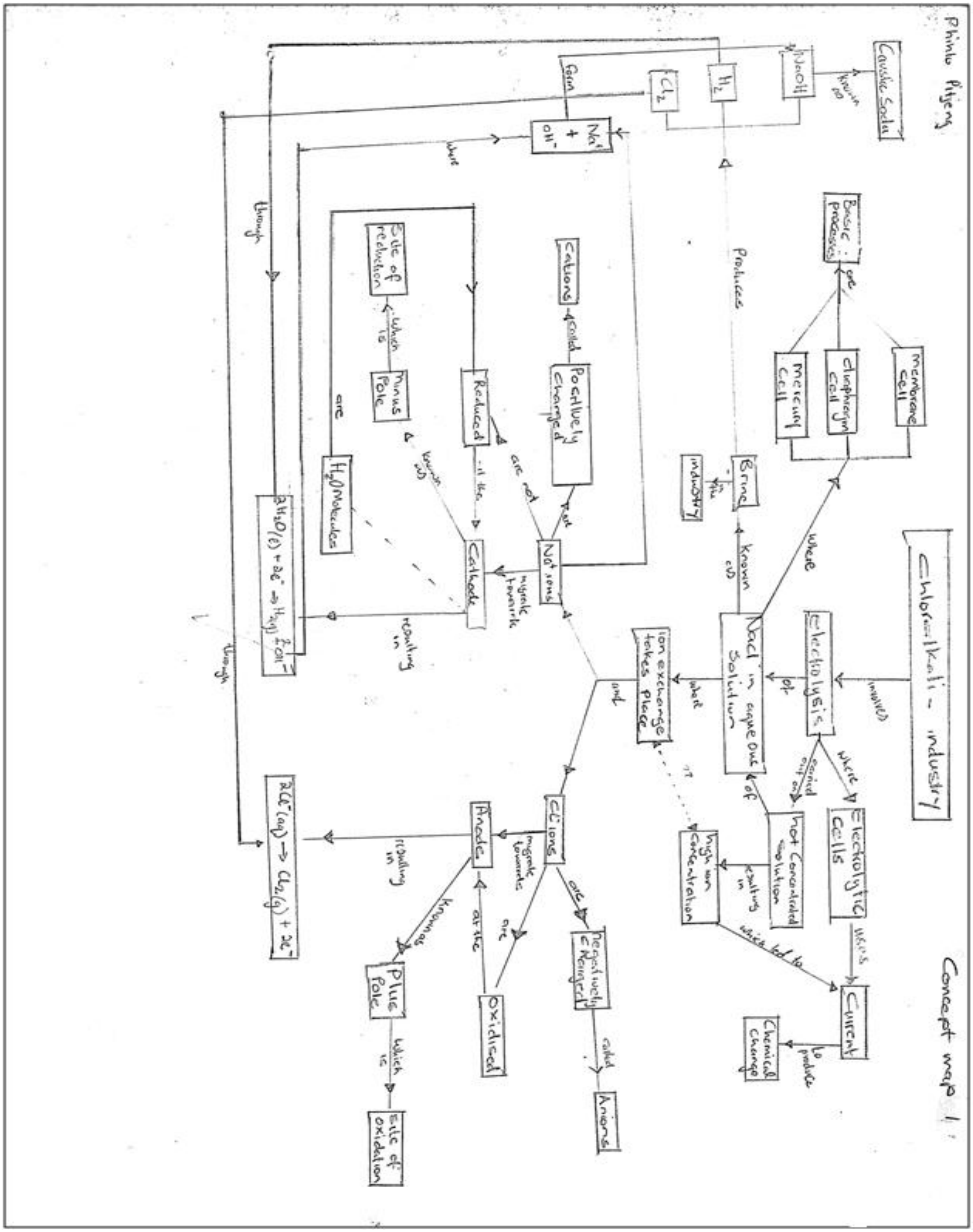
Concept map 2 = (5 x 13) x 5

= 325

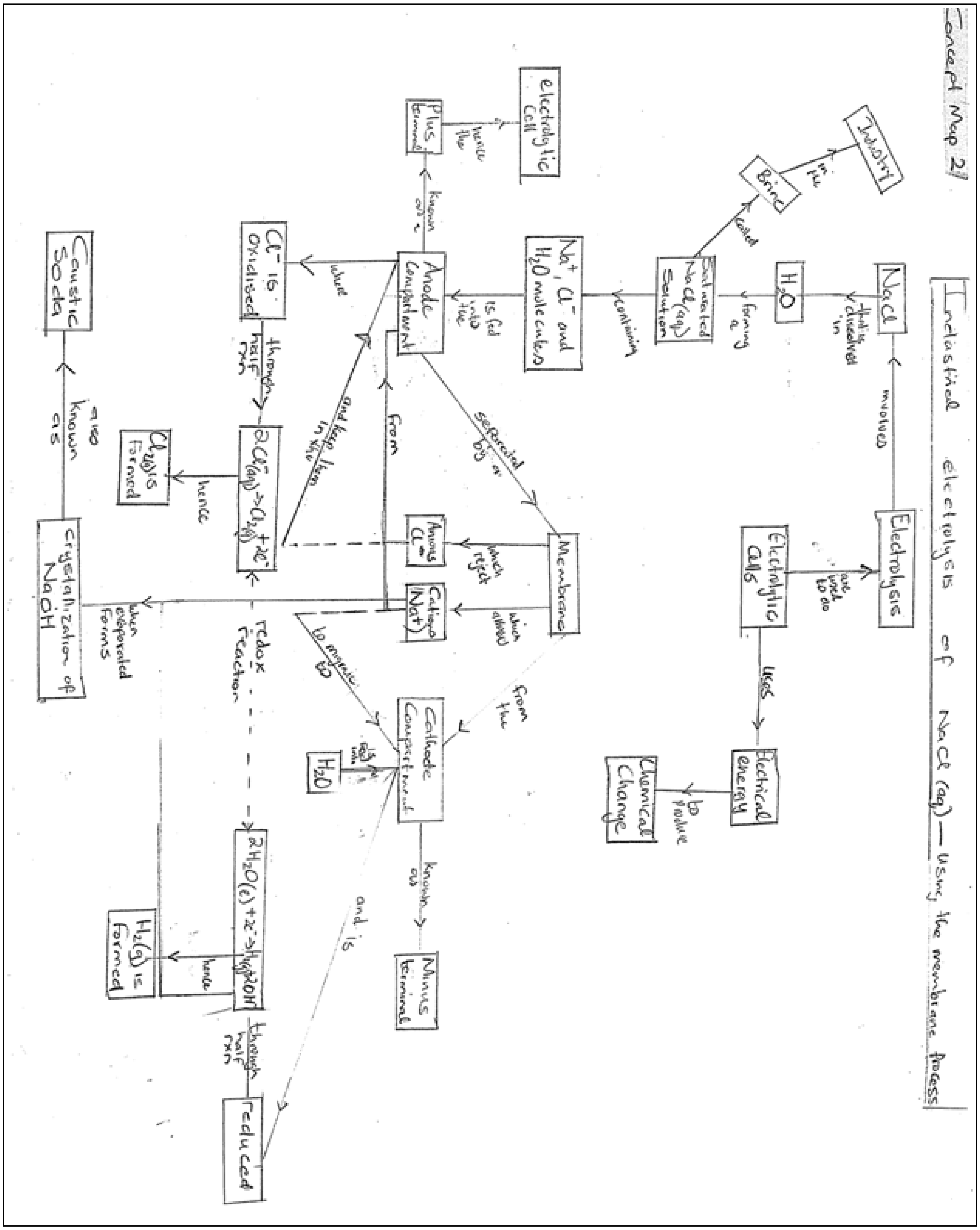
Concept map 3= (8 x 14) x 7

= 784

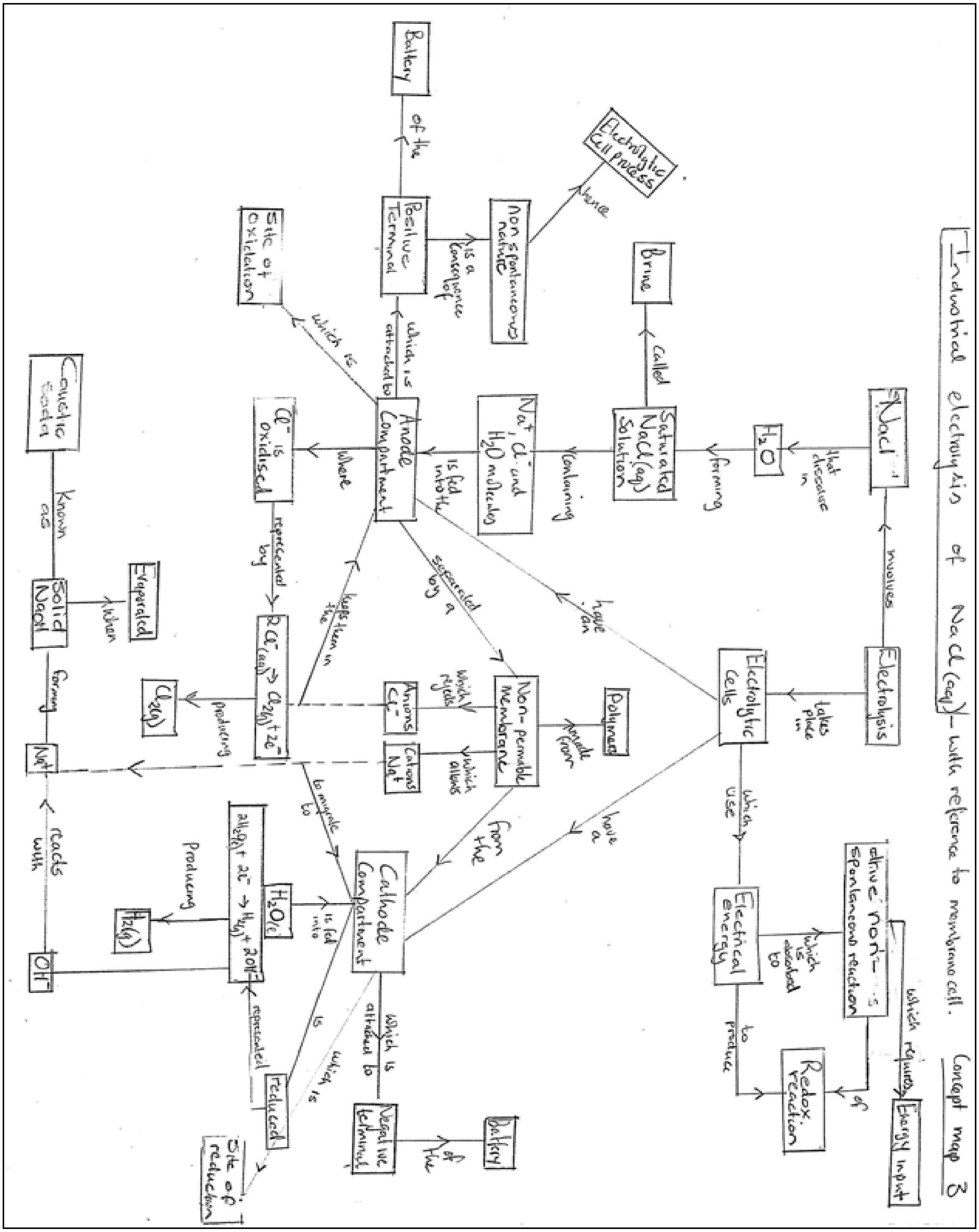
Appendix 2- Concept Map 1



Appendix 3- Concept Map 2



Appendix 4-Concept Map 3



Appendix 5-Journal

	What happened?	How do I feel about it?	What did I learn?
Teaching the chloralkali industry for the first time	As part of knowledge area in chemistry chemical systems grade 12, I was faced with the topic of the chloralkali industry for the first, which I had to teach-hence it forms part of the new curriculum. It was my first time to teach this topic.	I was very confused and scared and I could not get the sense of what I was actually doing. All I taught was the electrolysis of $NaC\ell$ which I never understood and nothing much was said about the chloralkali plant in detailed. The reason I felt this way was that I did not have enough content knowledge of the topic and this intend could not allow me the flexibility when teaching	The first thing I have learnt was that I could have done better only if I knew what I was doing. When teaching this topic. Learners should actually get that feeling of how chemical industry works which I think my lesson did not give them that. I actually never covered much on the main big idea of the risks associated with operating the plants (of different cells), which intend covers the LO3.
Creating the <u>first</u> concept map	From the little knowledge I have on the topic, I had to do the concept map that will cover all I know about it. This concept map will show things like misconceptions and knowledge gaps that I have on the content. Since this concept map served for diagnostic purposes, I have decided to put down everything that I knew about the topic before other things.	It was little bit difficult to put down what I know in a concept map form. This was because of the fact that I had to find a way to link all the concepts so that they make sense to the reader (since concept map is meant for formative purpose) and to me too. I was not too comfortable about showing other people my first concept map. This was mainly because I felt like they will somehow undermine me based on what they see (poor content knowledge maybe). But I had to remind myself about what self study is-sharing, collaborative work, making ones work public. After getting comments about on my concepts map, I really felt proud of myself. The fact that I was able to allow other people to critique my content knowledge irrespective how much of the negative outcomes I got.	I have learnt quite number of things: • The major reaction is redox reaction not really ion exchange. This is one misconception I had. • I always thought that it is correct to say electrolytic cells uses current to produce chemical change. However, that is not true. Instead electrical energy is the one that is produced. • I have also learnt that it is important to explain to learners that Na^+ an OH^- forms NaOH only after they have been evaporated and no longer ions. • I also learnt the

			difference between industrial electrolysis and the choralkali industry. Industrial electrolysis of sodium chloride involves basic chemical concepts while the choralkali industry takes in account the resources used and the downstream processes (products produced).
Visit to the chloralkali plant	Since I will be teaching this chemical industry case study, I decided to go to chlorchem in chloorkop where there is chloralkali plant here in South Africa. I arrived at 9h00 in the morning and until 12h00.	I very was happy about the fact that I will see the real industry and I could intend share this with my students. Due to the set up of the industry, I was a little bit lost I could not identify things like electrodes. I have also learnt most of the things that I could share with my students that I could not find in the textbooks.	The first thing that I learnt was that what you see from the industry is totally different from what is portrayed in learners' textbooks. Hence the size, long procedures they follow, production scale is somehow different. I have learnt that a membrane used during the electrolysis of brine is imported from Japan and America. Hence the membrane is costly. However, I was told that a membrane cell is most preferred because is inexpensive, can be shut down and further improvement can be expected. The industry did away with mercury and diaphragm cells because they both pose more

			health risks. One uses asbestos while the other one uses mercury. I have also learnt that anode coating have a lifespan of about 6-8 years and the salt that they use come from Namibia. Safety in the plant was their main priority.
Creating the <u>second</u> concept map	I developed the second concept map based on what I learnt form the plant site, experts' comments, as well as the reading that I have been doing lately.	I was very confident about my work and comfortable in showing people what I know and have done. I was also little bit clearer on how to start my concept map as compared to when I was doing the first one.	• I have learnt that it should be made clear that electrolysis involves energy input • My content knowledge was now much improved in the second map. Most of the comments were on the linking words.
Creating Co-Res and big ideas (13/08)	I have decided to do the first Co-Res and big idea since I have completed concept maps and also the fact that time for my data collection is approaching. The reason for doing these Co-Res is that, I wanted to get an idea of the how I will go about doing/ preparing the lesson plan. It was not easy to come up with 'big ideas' at first. This is because I had to have the <u>picture of the whole topic in my mind</u> and to also understand it and to make learners to understand it too. Finally I have to ask myself one question which helped me to start. **What is the main idea (concept) that this topic mostly depends on?**	Part of me struggled at some point. I felt like I should have a draft lesson plan existing on paper or at the back of my mind respectively with the Co-Res. This has to with the question on the Co-Res paper that says 'teaching procedure'. One should have an idea on how will go about teaching the topic and the type of activities to be given to the learners in order to answer this question. Knowing the chloralkali industry content scope and understanding it, helped me to find flexibility when creating the Co-Res. This also made me feel good about what I was doing.	I have realized that doing the concept maps helped me a lot in terms of understanding the content. When I was creating big ideas, I always looked at the concepts maps and the comments that come from people. Some of the comments like (non spontaneous nature of electrolysis) made part of my Co-Res explicitly now that they it make a lot of sense to me in terms of understanding this topic. The big ideas and Co-Res are not just there to put what you know and what

			you will be teaching. But most importantly is the <u>sequencing</u> around what you will be teaching to the learners. Ones teaching experience and expertise make part of the Co-Res preparation.
Self-study group meeting(13/08)	This meeting involved masters' students who are doing self study as well as our supervisor. However, only three students were present including me and two were not available. This group is meant to help others in terms of reflecting on their studies, sharing our experiences and the improving content knowledge. I have asked the group to give me their inputs and suggestions based on the Co-Res and big ideas that I have created. We also discussed the way forward in getting someone to video-tape my teaching lessons. One member of my group agreed to borrow me his video. Finally, we proposed the date for the next meeting of self study which will be on Monday the 24 August.	At first I could not believe that most of this important information could emerge from this meeting. I do not know maybe I might have undermined that fact that we were few in number. But I was proven to be wrong hence all what I have learnt was essential. I started to feel comfortable around my fellow group members and decided to ask them about as to whether I should cover all the 3 cell process in my chloralkali industry lessons. I was advised not to, but to have a short answer ready in case learners ask me anything about other cell process. I found that this have answered the question that I have been asking myself all time in terms of covering all the cells or not. I will say briefly about the three cells and see what happens This discussion went as far as taking about the mercury cell and just to get clarity on what is being reduced at the cathode, Na^+ or Hg amalgam. I could not wait to get a chance to work on my Co-Res again and use all the ideas and comments I have got from the self study group. I also very much ready to start with my lesson plans and hopefully to do my teaching.	There are so many things that I have learnt in these meeting. What I liked the most about this group is that <u>they were giving me suggestions and inputs based on the big ideas I have created</u> and helping me on how I could better improve them in order to be sensible. <u>Firstly,</u> the group helped me to rephrase the two big ideas I came up with. Through that I was able to learn two things as far as the creating big ideas is concerned: **1-big idea is suppose to be a statement, 2 -I have learnt that electrolysis involves redox reaction not the other way round because we can have redox without electrolysis.** <u>Secondly</u>, I have learnt that knowledge about 'student' thinking which is part of the CoRe-does not relate only to learners' prior knowledge as I always mention but also their misconceptions,

			interests, background context etc. <u>Thirdly</u>, my supervisor also clarified that the Co-Res that says-why is it important for students to know this always need one to think of its usefulness in everyday life or useful in future. <u>Finally</u>, I have learnt about how to reflect on self study hence this will come handy for me when I am analyzing my data-reflection chapter which is aimed at pulling out the main findings. It was of importance to me to learn that <u>1.</u> **When out reflects-makes a point and elaborate on it.** <u>2.</u> **I can add what is on Pap-eRs to my reflection chapter as long as I do not repeat the transcript.** <u>3.</u> **I should make the headings for reflection chapter.**<u>4</u>. **Reflection comes from the inside of you, not always from data.**
Planning of the Lesson plans	I have started with the planning of the lesson. The Co-Res and big ideas that I have developed guided me through the process of planning my lessons. I have also taken into consideration what physical sciences examination guidelines grade 12 for NCS need learners to achieve out of the chloralkali industry.	I am very excited about the lesson activities. Most of the questions are open enough and give learners an opportunity to share what they know. In this way, I would be able to know what are learners' prior knowledge as well as their misconceptions. I believe that every activity will be compensated by information from the teacher and in a way I will be able to see how my content knowledge grew.	I have learnt that it is important to know in depth what one will be teaching the students as well as experiments to be given to them. I decided to trial experiment that will be done by students and I could not get the correct observation. (no hydrogen gas is observed).This had helped me to come up with other

			means before it is given to the learners. I decided to seek help from an expert. She told me to cut the straw to the same size as the electrode so the hydrogen gas could fill up in the straw. I did exactly that and it worked. Again, developing the questions for activities that will promote conceptual learning to be done by students has not been easy. Lastly, I have realized that if one understands the content knowledge better, This gives flexibility when responding to what learners said.
Putting a memo together	I had to do a memo of the activities that I will give to the learners. This has helped me to even learn more and more. I decided to put slides showing all the 3 processes used in the plant as part of my teaching material. The reason was that I needed learners to know the differences between them. I am aware that a membrane one is being used and preferred in the plant now and even the NCS included it. However, I felt like it would benefit learners' interest and knowledge more if they could see how other cells worked too.	I was very curious about each and every question that I have answered. I wanted to know more or beyond what the questions wants. I did this in case learners asked me more difficult questions. The more I was doing that, the more content knowledge I had to include. I must say this is part where my visit to the industry played a big role. Hence I was able to relate all the cells to what I have learnt in the industry. This includes the advantages and disadvantages of each cell.	I have learnt that it is important to know more than the learners. I intend to show this during my teaching tomorrow. I also decided that it is useful to elaborate the question further. **For example there is a question that need to be answered by saying-sweat contains salt. As a teacher I decided to ask question like why is that. Answer-sweat burn salt from one's body.** <u>Activity 5-the flow diagram</u> This activity helped me to realize that in order for learners to understand how production of soap, plastic and hydrogenation

			occurs, knowledge on types of polymerization-macromolecules is essential. (Substitution, addition and elimination). This proves the point that I once mentioned when creating co-res that they are also influenced by the lesson plan. Hence knowledge on macromolecules-polymerization need to be included as the knowledge those learners bring.
Teaching lesson-day 1	This was my first lesson which covered almost first four activities of the module. It had taken 3 hours in each class to do these activities. The first two activities were intended to expose the knowledge that learners have about salt. This also included the history of salt. The third activity was about the experiment on the electrolysis of brine (microscale) and followed by classwork to be marked by the teacher which compensated the lesson taught. I think this lesson went fine but I was worried that they might not finish the assessment activity because of the more spent on the diagrams illustration.	As usual being captured on camera is never being easy for me. However, for the first few minutes of the lesson I was scared but later I said to myself: "this is research Phihlo and you are doing this to hopefully learn more and learn from your mistakes and be an expert in future. Whatever I have gathered till this point in time will benefit a lot to these students". I was very happy to also see that my students seemed to be enjoying the lesson. I must mention that they do not always get this kind of questions (the ones that are open and allow them to show how much they know) in their other module. I felt like I have made a difference to some of the learners. One group of learners was saying that they only knew the theoretical part of electrolysis of brine and were happy to see the practical side of it. Taking into consideration that most of these students come from the disadvantaged schools and were never being exposed to the microscale kits for experiments.	<u>Activity 1-spot the salt</u> I think learners helped me to realize that when one say 'salt', one can think of different type of salts that we have. I never really thought of any salt rather that NaCl, hence it is the one used in the chloralkali industry. This activity also helped me to see whether learners knew about production of plastic i.e. it is indirectly a product from salt. Only one learner in one group was able to talk about it. This definitely gave me an indication that I should emphasise this later. <u>Activity 2-what do you know about salt</u> This activity helped me to know that learners did not know what **brine is**, and that salt is used to in **making soap and glass.** From this I exactly knew where to start in my lesson. I did not expect

		"I also felt like there was a lot that I still have to learn deeper. After showing slides of 3 types of cells to the first class, one leaner asked me **"what is the membrane made of"?** I could not answer the learner correctly even though I had come across the information in one of the materials I got from the plant This was simply because I did not engage deeper with the idea it because I told myself that the curriculum does not involve it".	this at all from these learners because this is their second year in matric and one would indeed expect them to know all this. Activity 3- electrolysis of brine' In conducting this experiment, I assume that my learners have something concrete to observe and hopefully with remain in their mind and will give valuable input to the entire teaching on this lesson. During the experiment activity, one group of learners decided to smell the paper towel having sodium iodide and the gas from electrode 2 and they found that it smelled like bleach and because of that they were able to tell that there is chlorine gas. I have learnt a lot since I never thought of smelling the paper towel.
Marking learners' classwork activity	I have decided to give learners a classwork activity on the chloralkali manufacturing process to do individually that I will have to mark after school hours. This activity was intended to see how well they understood the lesson. This could be shown by the manner in which they answered the questions. I was also hoping to see where they have misconceptions. When I was marking their	What came to my mind after marking their scripts was that "I have to take what emerged from their activity to be part of my starting point in my next lesson tomorrow". There is one questions that I felt like almost all learners poorly answered it and I decided that tomorrow I have to unpack that question 5 and let learners discuss it in groups and on their own come up with alternative answers and I will then use their alternative answers	Firstly, I was able to see that some students did not know the oxidation and reduction reactions and because of that they were unable to write the half reaction on each cell. Secondly, some of them did not know the ion charge. Some of them put + charge for chlorine which is wrong. Thirdly- the difference between half reactions

	activity, I kept on writing on the side what I was finding it to be their main difficulties. This was emerging from their work. However, I must mention that I was also noting the good things too. This was communicated to the learners on their scripts.	given to me to them explain even more what the question need. I am hoping that by doing this, they will realize that they misunderstood the question and if so, they will try to see where the problem is originated.	and overall reactions was a problem to some students. Some of them also neglected to balance the chemical equations. Lastly I have realized that some learners find the "why" questions difficult to answer since these types of questions require them to show their conceptual understanding of the topic.
Teaching lesson-day 2	I started lesson by giving learners their scripts of yesterday's activity back and do corrections as a class. This was followed by the activities that look directly into the industry i.e. production of products-soap, food and plastic, comparisons of the cell process and debate on the building of the plant which links well to the LO3.	I was very much interested in seeing how learners will incorporate what they have learnt so far in order to make responsible decisions in their society hence debate activity which is influenced by activity 5 and 6 which looked at production of products caused by the plant as well as how these process are compared. I felt like it was a bit unfair to let learners to use Euro-Chlor pamphlet for debate. Hence one boy learner said to me why not SA chloralkali-plant pamphlet. I soon notice that the boy did not really feel comfortable and interested in a debate. I was aware that some learners were confused hence they could not relate this to the developed countries since they fall under the developing countries. Hence the issue of learners' context.	I have learnt that giving learners' activity that promotes conceptual learning is important. Hence I was able to pick up parts were they did not actually understand the lesson. Using learners' alternative ideas was also the best strategy that indeed worked for me because learners are forced to think. "Learners brought in their prior knowledge of macromolecules and organic chemistry. Hence they were even able to pick up that PVC formula has one chlorine atom and not as indicated on the flow diagram". Learners were able to relate to their everyday life how the chloralkali plant can affect their lives both positively and negatively.

Developing the <u>third</u> concept map	I had done the concept map for both industrial electrolysis and chloralkali industry after teaching. I had taken into consideration what had emerged from my teaching as well incorporating the comments I have got from the second concept map when developing the third one.	After the comments about non-spontaneous nature of the reaction, few things started to be clearer like movement of electrons and ions. I started to ask myself why are most textbooks not making the external source explicit when explain electrolysis of sodium chloride. I think it is important that teachers know more the learners. This will help in case learners ask questions like the one they asked me about the membrane. Some of the comments I got from the two experts involve clarity on linking words. I feel like understanding the content does play a role when linking the concepts.	There was a need to make explicit the non-spontaneous nature of the reaction in electrolysis. This was suggested by one of the experts when critiquing my second map. I have also learnt that it is important to link the fact that anode is positive in an electrolytic cell because it is connected to the positive terminal of the battery and not only that it is electrolytic cell not galvanic/voltaic cells. It had emerged from my teaching that one needs to know more about what is it that membrane is made of. This is the reason why I decided to put it in the concept map of electrolysis.
Developing the <u>third</u> Co-Res and big ideas	I have developed the big idea and Co-Res now. This was definitely influenced by my teaching of the topic. The influence comes from both the good and bad side of my teaching content.	I felt like I did not explain clearly to the learners the most important thing about the electrode that, they are the conductors. I also think that deeper explanation was essential when one learner asked the question why in galvanic cells anode is negative. I believe there is more to the fact that anode is connected to the negative terminal of the battery. I think I need to look deeper than that. I also believe that learners were able to use information learnt about the industries and incorporate it in their debate.	• I have learnt that some learners did not know what electrodes are and therefore I assumed that they did not know the difference between electrodes and electrolytes. • I also learnt that some learners did not know how to write half and overall reactions. • I have learnt that learners' knowledge of macromolecules and organic

			chemistry plays a very important role in understanding production of soap and PVC.

APPENDIX 6- Lesson plan 2008

CHEMISTRY COURSE 2008

CHEMICAL SYSTEMS-CHLOR-ALKALI PROCESS

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THE CHLORALKALI INDUSTRY

Chlorine was discovered by Carl Scheele (1742-1786) in 1774, but it was not known as an element. The main use of chlorine is the manufacture of polyvinylchloride (PVC). PVC is used in medicine (bags for transfusions, sterile tubing, catheters and prosthetics) and in the building industry (water pipes, floor covering, roller shutters, etc).

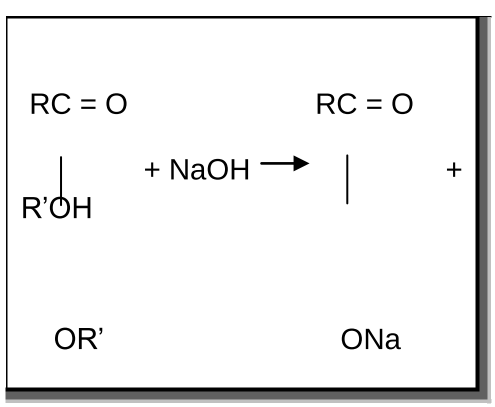
Other uses of chlorine include water purification (large and small scale) and bleaching.

Activity 1

Testing your memory: Write down as many facts about chlorine as you can in 60 seconds.

Keeping clean

This sector of the chemical industry is one with the longest history. In its early days one of the big needs that it met was for soap. Rapid industrialization in Europe more than a century ago, created a lot of health problems, some of which could be solved simply by keeping clean. Similar phenomena occur today in rapidly-developing countries, such as can be found in Africa. The chloralkali industry is relevant to this social development because one of its main products is sodium hydroxide, a strong base which is required in making soap from animal fats. Fat is a type of carboxylic ester and the reaction can be represented as follows:



R and R' are alkyl groups

This is a substitution reaction where the OH^- from the NaOH substitutes the OR' group of the carboxylic ester, RCOOR'. The products are an alcohol, R'OH and the sodium salt of a carboxylic acid, RCOONa. When the alkyl group, R is a long chain, e.g. $C_{12} – C_{20}$, the sodium salt acts as a soap. The reaction is more complicated when an animal fat is used. When animal fat is used, each molecule of fat yields one molecule of glycerol (1,2,3 propantriol) and three molecules of sodium carboxylate.

Electrolysis to the rescue

Strong bases, like sodium hydroxide, cannot occur in our natural environment. They are too reactive. For example, sodium hydroxide would react with the carbon dioxide in the atmosphere to form sodium carbonate. Being very reactive implies that a lot of energy is going to be needed to make NaOH. This energy can be electrical, and in this case it is the best option. The source of Na atoms is sodium chloride and the source of the OH is water: both of these resources are readily available at many locations. The electrolytic plant needs to have access to a cheap source of electricity. Chloorkop, close to Johannesburg and the industrial heartland of South Africa, is the important site for this today.

Electrolysis of sodium chloride is done in aqueous solution. This solution is called brine in the industry. The overall reaction that takes place is as shown below:

$$2NaC\ell aq) + 2H_2O(\ell) = 2NaOH(aq) + H_2(g) + C\ell_2(g)$$

Activity 2

2.1 Work out oxidation numbers and show that this is a redox reaction.

2.2 What atoms are oxidized and what atoms are reduced?

2.3 At which electrodes will these half reactions occur?

The equation shows that sodium hydroxide is one of three products which are useful and can be sold. This helps make the process cost-effective. The gaseous hydrogen forms at the cathode whilst the gaseous chlorine forms at the anode, so they can be collected separately. The sodium hydroxide forms in the aqueous solution. It may be sold as an aqueous solution or else the water must be evaporated from the solution to obtain the solid sodium hydroxide. It is cheaper to transport the solid (less weight), but evaporating the water costs money.

The electrolysis is carried out on a hot, concentrated solution of sodium chloride. The ion concentration is high and so there is good electrical conductivity and fast electrolysis. Chloride ions (the anions) move towards the anode, whilst the sodium ions (the cations) move towards the cathode. The chloride ions are oxidized at the anode but the sodium ions are not reduced at the cathode. Instead water molecules are. The half-reactions are:

Anode: $2C\ell^-(aq) \rightarrow C\ell_2(g) + 2e^-$

Cathode: $2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

The two half cells are separated by a selective polymer membrane that allows the sodium ions to pass into the cathodic compartment where they react with hydroxyl ions to form sodium hydroxide. The chloride ions pass through the membrane to the anodic compartment.

Activity 3

3.1 Look at the table of standard reduction potentials. Find the values for the cathode half-reaction and the reverse of the anode half-reaction (which is an oxidation). Calculate the cell potential.

3.2 What is the minimum applied potential difference at which electrolysis should occur?

3.3 Why does reduction of sodium ions not take place at the cathode?

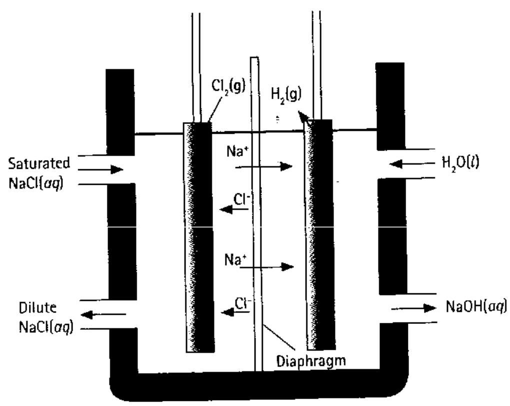


Figure 1: Diagram of the components of one electrolytic cell

Figure 2: A bank of cells in series for electrolysis of brine at NCP Chloorkop

The diagram above shows that in an industrial scale electrolysis, you need to provide for continuous (24 hr) production. Hence the electrolytic cell has a flow-through design. This means that the electrolysis is incomplete: as sodium chloride solution flows through, not all the sodium chloride is electrolysed. Hence the sodium hydroxide solution emerging from the cell contains some

Unchanged sodium chloride. This sodium chloride has to be removed. This is done by heating the solution to evaporate some of the water. The sodium chloride crystallizes out preferentially as it is less soluble in water than sodium hydroxide is. The sodium chloride is separated off and sent back to the electrolytic cell. The sodium hydroxide solution may then be sold as such. Alternatively it may be further heated to evaporate off all the water, and then sold as solid sodium hydroxide.

The hydrogen which is produced is used to manufacture ammonia or for the hydrogenation of sunflower oil (or other plant oils) to make margarine. For every tonne of chlorine produced,

1.1 tonnes of caustic soda (100% concentration) and 0, 03 tonnes of hydrogen are produced.

Side reactions that can occur in the membrane cell can include:

$$C\ell_2(g) + 2NaOH(aq) = NaOC\ell(aq) + NaC\ell(aq) + H_2O(\ell)$$

$$3NaOC\ell(aq) = NaC\ell O_3(aq) + 2NaC\ell(aq)$$

The world production capacity of chlorine reached 53 million tonnes in 2002 and is expected to increase to 65 million tonnes by the year 2015.

Generally-speaking the soap manufacturers are not in the same plant as the manufacturers of the sodium hydroxide and other products. They, and the users of the other products, are often referred to as “downstream” manufacturers. This means the products are being used within the industry rather than being sold directly to consumers like us.

Activity 4

Microscale Electrolysis of Brine

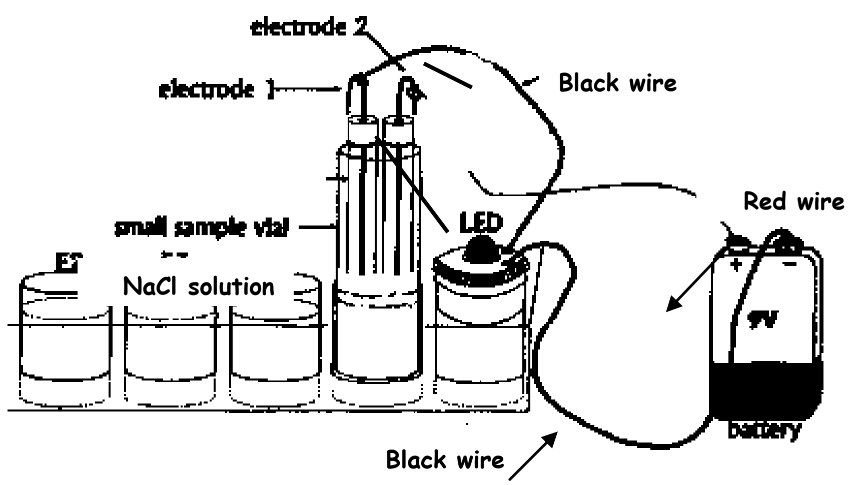
You will need:

Apparatus:

1 x 9V heavy duty battery (or two 1,5V cells); 1 comboplate®; 1 current indicator (LED) with wire connections; 2 x straw electrodes fitted with graphite electrodes; 1 x small sample vial; 1 x microburner; matches; 3 x thin stemmed propettes; paper towel.

Chemicals:

Saturated sodium chloride solution ($NaCl_{(aq)}$); tap water; universal indicator solution, sodium iodide solution.



Procedure:

1. Push the current indicator into well E6 of the Comboplate®

2. Fill three-quarters of the small sample vial with saturated sodium chloride solution, using a propette.
3. Completely fill the same sample vial with tap water, using a propette.
4. Add 2 drops of Universal Indicator solution to the solution in the vial.
5. Stopper the vial with a finger and invert the vial gently to mix the contents. Place the vial into well E3 and note the colour of the contents.
6. Connect each of the electrodes to a red or a black wire (DO NOT CONNECT THE BATTERY YET!)
7. Use an empty propette to suck up some of the sodium chloride solution from the vial.
8. Hold electrode 1 with the open end upwards and fill the electrode completely with sodium chloride solution from the propette.
9. Quickly turn electrode 1 the other way up and place it into the solution in the small sample vial. Repeat the procedure with electrode 2. Return any remaining sodium chloride solution in the propette to the small sample vial.
10. Connect the current indicator to the battery.

The current indicator will show whether there is current in the circuit. If it does not light up, but bubbles are forming at the electrodes, you can assume that the circuit is correct.

11. Periodically tap the electrodes with your finger to dislodge gas bubbles which may build up in localised areas.

12. Note any changes in the straw electrodes and in the solution at the bottom of the sample vial.

13. After about 10 minutes, or when electrode 1 has been filled with gas, disconnect the battery from the circuit.

14. Light the microburner. Carefully remove electrode 1 from the solution, sealing the open end with your finger when it is out of the water. Bring electrode 1 very close to the flame of the microburner. Do not burn yourself or the straw!

15. Remove your finger from the opening, allowing the gas in the straw electrode to escape and to react with the flame of the microburner. Note your observations.

16. Carefully remove electrode 2 from the solution, sealing the open end with your finger when it is out of the water. Test the contents of electrode 2 by bringing a piece of paper towel moistened in sodium iodide solution into contact with the solution in the straw electrode.

Rinse the sample vial and propette with tap water.

Questions

1. **What do you observe at the different electrodes once current is passing through the sodium chloride solution?**
2. **When you stop the reaction by disconnecting the battery, how do the volumes of the gases collected in electrodes 1 and 2 compare?**
3. **Write down the overall reaction taking place in the sample vial.**
4. **How should the volume of the gases compare, according to the overall reaction?**
5. **Explain the difference in the volumes of the gases collected during the experiment.**
6. **Describe what happens if the gas in electrode 1 is exposed to the flame.**

7. **Identify the gas you have collected in the straw of electrode 1.**
8. **Describe what happens if you test the solution in electrode 2 with sodium iodide.**
9. **Identify the gas you have collected in the straw of electrode 2.**
10. **Write down a fully balanced chemical equation to show the reaction between the gas in electrode 2 and the sodium iodide solution.**
11. **Describe the contents of the small sample vial once the electrodes have been removed. What is the composition of the solution remaining in the sample vial likely to be?**

APPENDIX 7- Lesson plan 2009

CHEMISTRY COURSE 2009

CHEMICAL SYSTEMS-CHLORALKALI INDUSTRY PROCESS

STUDENT NAME: ___________________________

RADMASTE Centre

UNIVERSITY of the WITWATERSRAND

JOHANNESBURG

Telephone: 011 717 6070

Fax: 011 339 1054

LEARNING OUTCOMES:

After completing this chapter you should be able to:

- Describe and explain what happens during the electrolysis of brine.
- Explain the process using the half reactions and the overall redox reaction taking place in the cells.
- Identify all the products and give a use of each.
- Make clear the meaning of the term electrolytic cell.
- Identify the cathode (reduction, H_2) and anode (oxidation, Cl_2).
- Describe the function of the cell membrane where applicable (ion exchange).
- Identify the benefits to human kind of the products of this process.
- Identify the risks associated with operating each of this cell.

Activity 1: Spot the salt!!!

Look carefully at the picture below and identify all the places in the picture where you can find salt or its products

Fill the following table

Where in the picture	Salt? or Product from salt?	In what form is it?

<u>Activity 2</u>: What do you already know about salt?

Here is some information about salt. Underline the things that are new to you and discuss with your neighbour

Easier - Salt is a common colorless or white substance that is found both in sea water and in deposits in the earth. Animals including humans need salt in their diets. Salt is used to season and preserve food. It is also used in making soap and glass.

Did you know that salt is a compound or two elements which are poisonous to us (Sodium and Chlorine) but our bodies cannot do without salt!!

Harder - Salt is a clear, brittle mineral that contains the elements of sodium and chlorine. Its chemical formula is $NaC\ell$; its mineral name is halite. Salt forms clear, cube-shaped crystals. Impurities can cause salt to appear white, grey, yellow, or red. Table salt also appears to be white.

All salt deposits began as salty water; brine from seas, oceans, and salt lakes. Even underground salt deposits were formed by the evaporation of sea water, a long time ago. In ancient times, salt was found mainly in the dry coastal areas like those surrounding the Mediterranean Sea.

Since ancient times, salt has been used to flavour and preserve food. Early trade routes and many of the first roads were established for transporting salt. Many ancient civilizations levied taxes on salt. Salt was considered so precious that it was traded for gold. In ancient China, coins were made of salt. In the Mediterranean regions, salt cakes were used as money. Ancient cities such as Genoa, Pisa, and Venice (in Italy) became salt market centers. By the fifteenth century, salt was obtained by boiling brine from salt springs, and many towns and cities in Europe located near such sources. During the eighteenth century, the efficiency of the boiling brine process was improved by using coal instead of wood as fuel. Because of its coal supply, England became the leading salt producer in the world. Early colonies in America were dependent on England for most of their salt.

By the early nineteenth century, equipment and technology was developed for the deep-drilling of wells, a process that improved the quality and increased the quantity of salt springs used for salt production. In the mid-1800s, underground mining of salt deposits began.

(Adapted from Morton Salt http://www.mortonsalt.com/)

Activity 3: Microscale Electrolysis of Brine

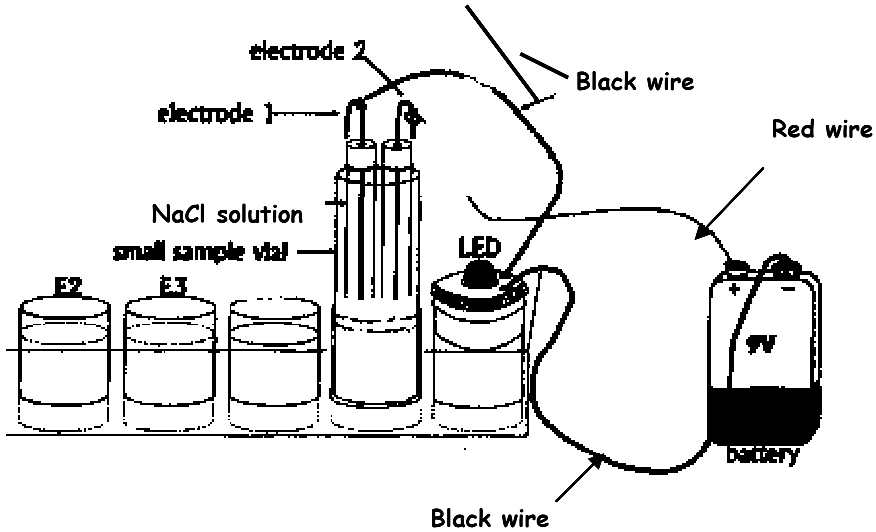
You will need:

Apparatus:

1 x 9V heavy duty battery (or two 1,5V cells); 1 comboplate®; 1 current indicator (LED) with wire connections; 2 x straw electrodes fitted with graphite electrodes; 1 x small sample vial; 1 x microburner; matches; 3 x thin stemmed propettes; paper towel.

Chemicals:

Saturated sodium chloride solution ($NaCl_{(aq)}$); tap water; universal indicator solution, sodium iodide solution.



Procedure:

11. Push the current indicator into well E6 of the Comboplate®
12. Fill three-quarters of the small sample vial with saturated sodium chloride solution, using a propette.
13. Completely fill the same sample vial with tap water, using a propette.
14. Add 2 drops of Universal Indicator solution to the solution in the vial.
15. Stopper the vial with a finger and invert the vial gently to mix the contents. Place the vial into well E3 and note the colour of the contents.
16. Connect each of the electrodes to a red or a black wire (DO NOT CONNECT THE BATTERY YET!)
17. Use an empty propette to suck up some of the sodium chloride solution from the vial.
18. Hold electrode 1 with the open end upwards and fill the electrode completely with sodium chloride solution from the propette.
19. Quickly turn electrode 1 the other way up and place it into the solution in the small sample vial. Repeat the procedure with electrode 2. Return any remaining sodium chloride solution in the propette to the small sample vial.
20. Connect the current indicator to the battery.

The current indicator will show whether there is current in the circuit. If it does not light up, but bubbles are forming at the electrodes, you can assume that the circuit is correct.

11. Periodically tap the electrodes with your finger to dislodge gas bubbles which may build up in localised areas.

12. Note any changes in the straw electrodes and in the solution at the bottom of the sample vial.

13. After about 10 minutes, or when electrode 1 has been filled with gas, disconnect the battery from the circuit.

14. Light the microburner. Carefully remove electrode 1 from the solution, sealing the open end with your finger when it is out of the water. Bring electrode 1 very close to the flame of the microburner. <u>Do not burn yourself or the straw!</u>

15. Remove your finger from the opening, allowing the gas in the straw electrode to escape and to react with the flame of the microburner. Note your observations.

16. Carefully remove electrode 2 from the solution, sealing the open end with your finger when it is out of the water. Test the contents of electrode 2 by bringing a piece of paper towel moistened in sodium iodide solution into contact with the solution in the straw electrode.

Rinse the sample vial and propette with tap water.

<u>Questions</u>

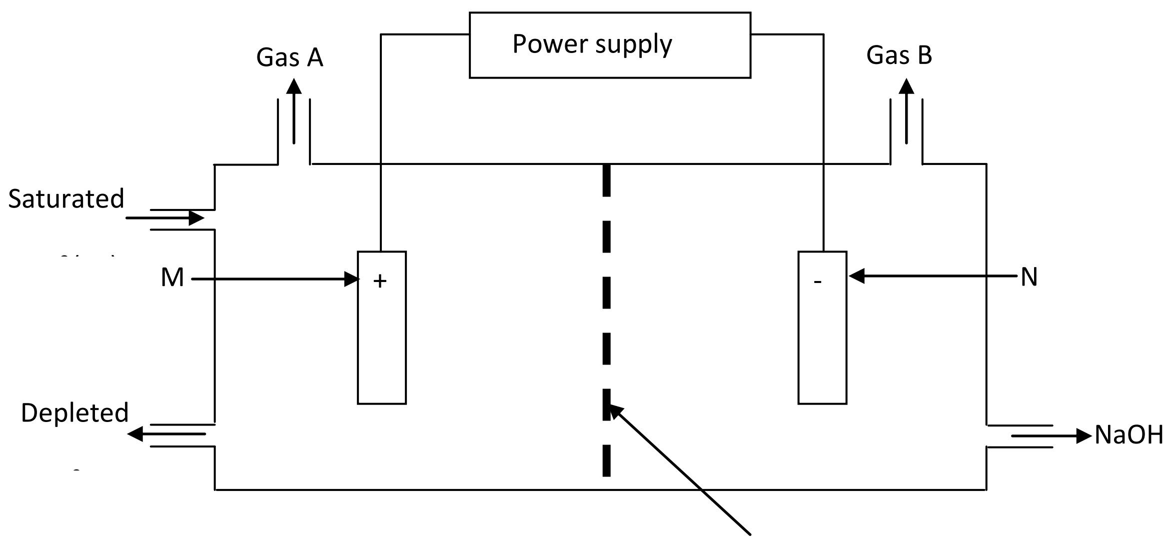
12. What do you observe at the different electrodes once current is passing through the sodium chloride solution?
13. When you stop the reaction by disconnecting the battery, how do the volumes of the gases collected in electrodes 1 and 2 compare?
14. Write down the overall reaction taking place in the sample vial.
15. How should the volume of the gases compare, according to the overall reaction?
16. Explain the difference in the volumes of the gases collected during the experiment.
17. Describe what happens if the gas in electrode 1 is exposed to the flame.

18. Identify the gas you have collected in the straw of electrode 1.
19. Describe what happens if you test the solution in electrode 2 with sodium iodide.
20. Identify the gas you have collected in the straw of electrode 2.
21. Write down a fully balanced chemical equation to show the reaction between the gas in electrode 2 and the sodium iodide solution.
22. Describe the contents of the small sample vial once the electrodes have been removed. What is the composition of the solution remaining in the sample vial likely to be?

The chloralkali industry is one of the largest electrochemical technologies in the world. Chlorine is produced using three types of electrolytic cells. Your teacher will discuss in detail the membrane cell for the electrolysis of brine and show how it differs from both diaphragm and mercury cells.

<u>Activity 4:</u> Chloralkali manufacturing process

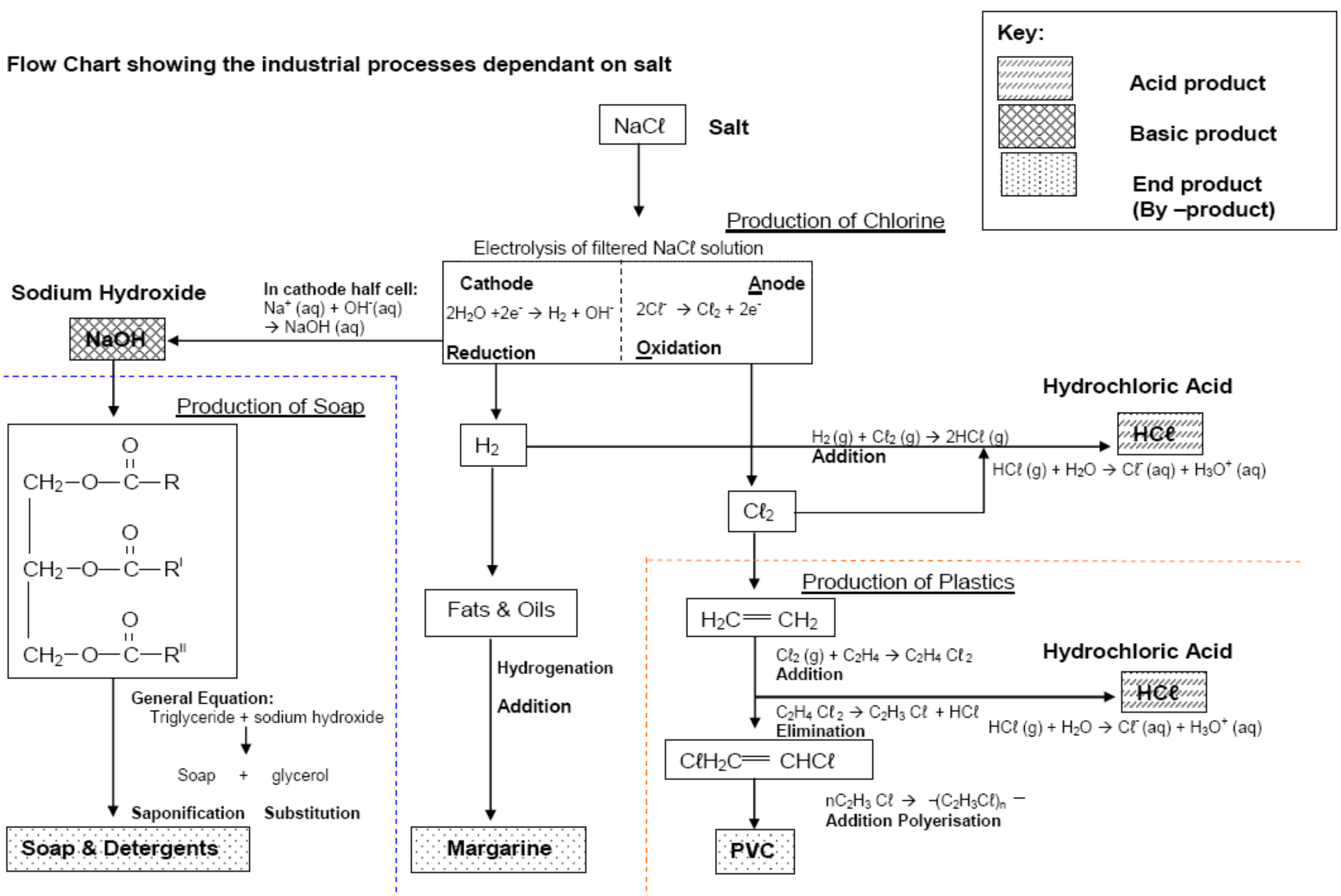
The simplified diagram below shows a membrane cell used in the chloralkali industry.



1. Write down the equation for the half-reaction taking place at electrode M.
2. Which gas is chlorine gas? Gas A or B.
3. Briefly explain how sodium hydroxide forms in this cell.
4. Why do you think it is advisable to use inert electrodes in this process?
5. Explain why this electrolytic process cannot be done in one large container without a membrane.
6. Give reason(s) why the membrane cell is the preferred cell for the preparation of chlorine.

Activity 5: The flow diagram

Today salt is even more important. It is the source of many chemicals. The flow chart supplied provides a summary of the chloralkali processes. Different portions of the chart can be allocated to groups to write about. For example the electrolysis process to produce, NaOH, H_2 and $C\ell_2$ can be cone portion. There are three other identifiable portions of the chart, all related to by



products – plastics, margarine and fats and soaps and detergents.

1. In your group, make a story about <u>one</u> of the parts of the diagram. Write down the story.

Developed by John Mc Bride and Marissa Rollnick

Activity 6: A comparison of 3 processes

You have learnt about the membrane cell in the previous work. There are in fact three processes that are used in industry – the mercury cell, the diaphragm cell and the membrane cell. Each one has advantages and disadvantages. The table below gives a comparison of the three types of cell.

Type of Cell	**Mercury Cell**	**Diaphragm Cell**	**Membrane Cell**
Cell Voltage (V)	3,9-4,2	2,9-3,5	3,0 - 3,6
NaOH strength (mass %)	50	12	33
Total energy used (kWh/ton $C\ell_2$)	3560	2970	2790
Steam consumption (kWh/ton CI_2 to increase concentration of NaOH to 50%)	0	610	180
Adjusted total energy used (kWh/t CI_2)	3560	3580	2970
Waste water (m^3 per ton of chlorine produced	Not available	1.6	0.1
Poisonous products and wastes	Mercury, Chlorine, NaOH	Asbestos, Chorine and NaOH	Chlorine and NaOH

(From Kelder, K. Govender, D & Govender, J (2007) Study & Master Physical Sciences Grade 12 Learner Book, Cambridge University Press, Cape Town.)

1. Decide with a partner which cell you would choose and why.
2. Write down the advantages and disadvantages of each cell.

Activity 7: Debate

The city council wishes to pass plans to build a chloralkali plant in your town. The Mayor has called for a debate in the town hall to discuss the issue. You have found the following pamphlet from the internet:

THE EUROPEAN CHLOR-ALKALI INDUSTRY

On the Move Towards Sustainable Development produced by Euro Chlor accessed at www.eurochlor.org

This is what they say about themselves:

Euro Chlor represents 85 industrial companies directly employing more than 40,000 people in the chlor-alkali sector across 21 countries. The federation is the voice of the European chlorine industry. It plays a key communications and representation role on behalf of its members, listening and responding to society's concerns about the sustainability of chlorine chemistry.

What you must do

Read the pamphlet. Your teacher will tell you whether to make an argument for or against the development, using points made in the pamphlet:

Guidelines:

Those arguing **for** the plant: The people writing this pamphlet are representing the industry so they are providing you with all the arguments you need to promote the factory. Look carefully at the disadvantages so you can argue against the people who don't want the factory

Those arguing **against** the plant: Remember that the people writing this pamphlet are in favour of the industry so if they make points about the disadvantages, these must be well known. Use these to try and create an argument against the points in favour of the factory.

Appendix 8- Comments from experts

Phihlo Pitjeng

From:	
Sent:	Monday, July 20, 2009 5:57 PM
To:	Phihlo Pitjeng
Subject:	concept map

Dear Phihlo,
I studied your concept map over the weekend and have the following comments:
1. This is a sound concept map with concepts linked with propositions and showing some hierarchy and cross-linking. Substantially all correct.
2. This is not a concept map of the chloralkali industry, but rather of the industrial electrolysis of NaCl (aq). A concept map for the industry would take into account the resources used and the downstream products (& applications).
3. Ion exchange leaves me puzzled. What is it and what is its place in the map? It would be better to just state the solution contains sodium and chloride ions and water molecules.
4. There is an attempt to cover industrial concepts as well as basic chemical concepts. It would perhaps be better to keep these two streams of thought separate rather than mixed up as they are now. Mixing up also prevents giving attention to some potentially important concepts such as the functioning of the diaphragm.
5. Electrolytic cells use electrical energy (rather than current) to produce chemical change.
6. The reduction half-equation should show 2 OH^- produced.
7. Na^+ and OH^- (in a box) are shown as forming NaOH. In aqueous solution they do not! They remain as ions. Only on evaporation of some of the water does crystallization of the NaOH (s) begin, and it is then they we may say the ions form NaOH!

I hope these remarks make sense and are helpful. If you would like to discuss them please do not hesitate to say so.
Best of luck,

COMMENTS ON CHLORALKALI CONCEPT MAP (ES)

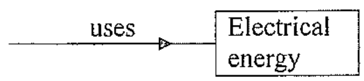
- The first impression is that there is too much information on the map.
- The hierarchical structure is also not very clear.
- The major reaction type is redox, not ion-exchange.
- The high concentration of ions in solution leads to good conductivity, not to current. The current is supplied by an external power source and that remains constant.
- The current process uses membrane technology. The reactions given apply only to the diaphragm and membrane process, not to the mercury cell.
- Although it is correct that oxidation takes place at the anode, the anode is only positive in the case of an electrolytic cell. In a galvanic cell, the anode is negative. Linking the name anode with a polarity, can lead to difficulties when electrolytic and galvanic cells are compared. The same applies to the cathode (only negative in the case of an electrolytic cell).
- The sodium ions do not participate in the redox reaction at all, and they should not be shown so prominently. The sodium ions migrate through the membrane to combine with the OH^- produced in the cathode compartment.
- The water in the solution is involved in reduction, and this is not shown clearly enough.
- The direction of the arrow between Cl_2 and the oxidation reaction is misleading, chlorine is a product.
- Use the word 'terminal' instead of the word 'pole'.

Concept Map of the Chlor-Alkali process with special reference to the membrane cell

Comments:

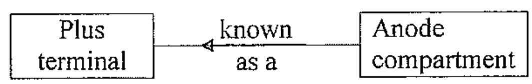
Firstly I am impressed with this concept map. I believe it shows the interconnectedness of the most important concepts very well. My comments are about how I might draw my own concept map and how it might differ from this one, i.e. give some alternate possibilities.

- I would refer to a positive and negative terminals not a plus and minus terminals.
- To me the essence of the process is its non-spontaneous nature, i.e. the need for an external source of energy in the form of an applied potential difference – of course this is implied by the term electrolysis and the bit



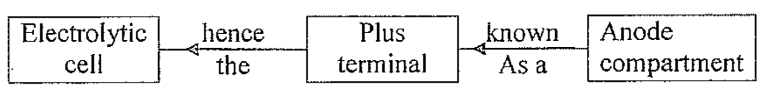
but I would make the non-spontaneous nature of the reaction more explicit

- The electrodes are attached to a potential difference and the electrode in the anode compartment has a positive sign as its label because it is attached to the source of higher potential. I therefore find

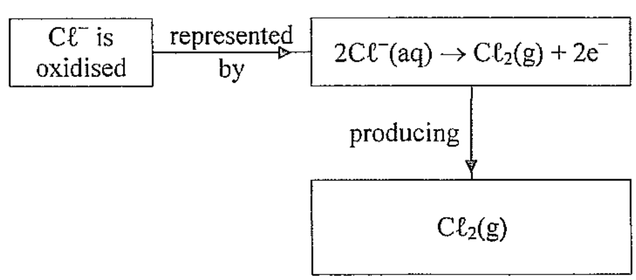


The linking words here strange

- For me the fact that the anode is positive (as opposed to negative in a voltaic cell) is a consequence of the non-spontaneous nature of the overall reaction and the reason why this is an electrolytic process. So I find the following sequence strange:



- I would perhaps start with the overall cell reaction and work this into the concept. I would link the reaction equation to its non-spontaneous nature, then link this to the need to supply energy to get this reaction to occur then link this to the need for electrolysis and then to the electrolytic cell
- I would link the reactive nature of the products of the reaction to the need to separate them and therefore the need for the electrodes to be separated and the need for the membrane.
- Alternate linking words?



Appendix 9-Learners written assessment

Chloro - Alkali Industry

Activity 4.

(1) ~~Cl + 2e- → Cl~~ $2Cl^- \to Cl_{2(g)} + 2e^-$

(2) Gas A

(3) (Na^+) Sodium ions reacts with (OH^-) Hydrodcide ions, OH^- formed from reduced water.

(4) Not reactive, meaning taking place in the whole process

not enough though

(5) The membrane allows the cell to be able to seperate the (Na^+) Sodium Ions, as it pass through.

(6) Yields a pure caustic, than the diaphgram cell. And it's not as expensive as the mercury cell. The membrane is also environmental clean compared to the other cells.

Appendix 10

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa

Tel: +27 11 717-3007 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website: www.wits.ac.za

STUDENT NUMBER: 0419042J
Protocol: 2009ECE85

15 October 2009

Ms. Phihlo Pitjeng

P O Box28571

KESINGTON

2101

Dear Ms. Pitjeng

Application for Ethics Clearance: Master of Science

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

Developing Pedagogical Content Knowledge through Self-Study: A Case of Teaching about 'Choralkali Industry'.

Recommendation:

<u>Ethics clearance is granted</u>

Yours sincerely

Matsie Mabeta

Wits School of Education

Cc Supervisor: Prof. M Rollnick (via email)

Appendix 11

Radmaste Centre

Research and development Officer: Pitjeng Phihlo (RJ)

Phone: 717 3483;

E-mail: phihlo.pitjeng@ wits.ac.za

Dear learners

I am interested in studying how my knowledge of the ‘chloralakli industry’ is transformed into teachable material. Please note that this will not interfere with your studies as the topic on chemical industries is part of the grade 12 knowledge area of chemical systems.

I am asking your permission to carry out video and audio recording for my research. Videotaping will involve placing one digital camera at the back of the classroom, which will run throughout the discussion period on each day of taping. The videotapes and audio recordings collected in these sessions will only be used for the purpose of teaching and research purposes.

Some video clips may be shown and shared with fellow researchers at seminars and conferences. Please note that the clips used during seminars and conferences will show only the researcher, not the learners. Also note that you have the right to review the video and the transcripts made of our conversations before these are used for analysis if you so choose. You can delete or amend any material or retract or revise any of my remarks. Everything you say will be kept confidential by the researcher. You will only be identified by a pseudonym in the transcript. In addition, any persons I refer to in the video will be kept confidential.

As part of research, please note that there will be a written class activity to be done by you which will be used only for research purposes and therefore will not be part of the assessment.The participation is voluntarily and I understand that you may withdraw from the study at any time.

Please read the attached consent form carefully and decide if you will be willing to allow video and audio taping in your classroom. Your consent would be greatly appreciated.

Thank you for considering this request.

Yours Sincerely,

Pitjeng Phihlo

(Msc student at the University of the Witwatersrand)

Consent Form

I,

Printed Name & Surname ------------------------------------

Institution --

consent to participate in this study conducted by Pitjeng Phihlo of the University of Witwatersrand (Radmaste centre). I realise that no harm will come to me as a result of participation in this study, and that the study is being conducted for purposes of improving the learning and teaching of science. I give permission for the material to be used for research or teaching only.

I further consent to being video and audio recorded as part of the study as outlined in the information sheet above.

I have no objection to being recognized/I wish my face to be obscured (Please delete the option not applicable).

Verbatim quotes from me may be used in the research report, but they will be reported so that my identity is anonymous.

Signature----------------------------------

Date---

Appendix : 12

Radmaste Centre

Research and development Officer: Pitjeng Phihlo(RJ)

Phone: 717 3483;

e-mail: phihlo.pitjeng@ wits.ac.za

Dear Principal/Manager

I am interested in studying how my content knowledge on 'chloralakli industry is transformed into teachable material. I intend to do year during my normal teaching time. Post matric learners will be requested to participate. I intend to involve both of my groups. This will involve video and audio recording of proceedings. Please note that this will not interfere with the programme as the case studies on the chemical industries form part of the grade 12 knowledge area of chemical systems.

I am asking your permission for both carrying out the recording and using the recordings for my research. Taping will involve one digital camera at the back of the classroom, which will run throughout the discussion period on each day of taping. The videotapes and audiotapes collected in these sessions will only be used for the purpose of teaching and research purposes.

Please read the attached consent form carefully and decide if you would be willing to allow me to be taping the post matric learners. Your consent would be greatly appreciated.

Thank you for considering this request.

Yours Sincerely,

Pitjeng Phihlo

(Msc student at the University of the Witwatersrand)

Consent For

I,

Printed Name & Surname ------------------------------------

Institution --

hereby grant permission for video and audio recording of lessons with post matric learners to be used for research purposes. I have read the above information and I understand its contents. I am also aware that the participation by post matrics is voluntary and they may choose to withdraw at anytime

Signature----------------------------------

Date---

Appendix 13- NCS Documents

CHEMICAL SYSTEMS	
Chemical industries	**Learners must be able to:**
Chloroalkali industry (soap, PVC, etc.)	• Given diagrams of the membrane cell used industrially to produce chlorine electrolytically: o Explain the process using half reactions and the overall redox reaction taking place in the cells o Identify all the products and give a use of each o Make clear the meaning of the term electrolytic cell o Identify the cathode (reduction, H_2) and anode (oxidation, $C\ell_2$) o Describe the function of the cell membrane where applicable (ion exchange) • Identify the benefits to humankind of the products of this process. • Identify risks associated with operating this cell. • Given a flow diagram of, for example, the membrane cell (or even an unknown process pertinent to the manufacture of these products), answer questions on aspects of the process. • For example identify the reactants and products of a particular step, or the purpose of a sequence of steps.
Fertiliser industry (N, P, K)	• List, for plants: o Three essential nutrients and their source; C, H and O (atmosphere (CO_2) and rain) o Three primary nutrients and their source N, P and K (the soil) • Explain the function of N, P and K in plants. • List for humans the four major elements, and their source, on which the body relies for form and function; C, H, O and N (atmosphere, water and food – animals and plants). • Match the parts of the human body that utilise particular chemical elements with those from a list of primary, secondary and micronutrients in plants (e.g. P, K, Fe, Ca …). • Give the form in which plants and animals absorb N, P and K (e.g. nitrates, phosphates, potassium salts … implies the need to fix nitration). • Give the source of N (guano), P (bone meal) and K (German mines) before and after the First World War). • Interpret the N:P:K fertilizer ratio • Describe and explain (rates, yields, neutralisation …), using chemical equations wherever appropriate, these aspects of the industrial manufacturing of fertilizers, given diagrams, flow charts and so on: o N_2 – fractional distillation of air o H_2 – at SASOL from coal and steam

	o NH_3 – Haber process o HNO_3 – the Ostwald process o H_2SO_4 – including the contact process • Give sources of potash (mined imported potassium salts like KNO_3, K_2SO_4, KNO_3 …) • Describe the term eutrophication and: o Its causes o Its consequences o Be able to identify circumstances that can lead to it from a supplied text o Suggest ways to prevent it o Suggest ways to solve the problems that arise from it • Evaluate the use of inorganic fertilizers on humans and the environment.
Batteries, torch, car, etc.	• Use the knowledge gained studying galvanic cells to provide, for an unknown cell: ○ The equation for the cell reaction given the half equations ○ The cell voltage if applied with the voltage of the half cells • Explain and use the concepts: ○ Energy stored in cells and batteries $W = Vq$ ○ Cell capacity and use the unit Amp-hour (Ah and mAh) and the equation $q = I \Delta t$ ○ Primary cells and secondary cells

<u>Chemical industry – resources, needs and the chemical connection:</u>	Learners must be able to
• SASOL, fuels, monomers and polymers, polymerisation;	•
• The chloroalkali industry (soap, PVC, etc);	• Given diagrams of any one of the three types of cell used industrially to produce chlorine electrolytically: explain the process using half reactions and the overall redox reaction taking place in the cells identify all the products and give a use of each make clear the meaning of the term electrolytic cell identify the cathode (reduction, H_2) and anode (oxidation, $C\ell_2$) describe the function of the cell membrane where applicable (ion exchange) • Identify the benefits to humankind of the products of this process • Identify risks associated with operating each of these cells • *Compare the three cell types provided with a table of data, for example Cell voltage (V) NaOH strength (wt%) Steam consumption (kWh/MT Cl_2) for concentration to 50% NaOH as to which cell is more efficient. • Given a flow diagram of, for example, the membrane cell (or even an unknown process pertinent to the manufacture of these products), be able to answer questions on aspects of the process. For example identify the reactants and products of a particular step, or the purpose of a sequence of steps. • Give an equation for the production of soap from animal fat and NaOH and describe how the structure of the soap molecule relates to its function • Describe how the structure of a detergent is different to that of soap and the consequent advantage of detergents over soaps • Evaluate the impact of the use of detergents on humankind and the environment.
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