UNDERSTANDING TEACHERS' USE OF COMPUTER-BASED SIMULATIONS IN TEACHING ELECTROLYSIS

by

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Submitted in partial fulfilment of the requirements for the degree

PHILOSOPHIAE DOCTOR

in the Faculty of Education

at the

UNIVERSITY OF PRETORIA

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MARCH 2019

DECLARATION

I declare that the thesis, which I hereby submit for the degree Philosophiae Doctor in science education at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any othe tertiary institution.

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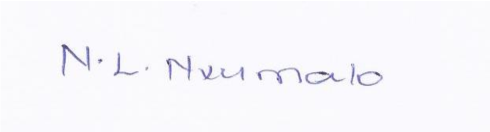

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DEGREE AND PROJECT	PhD Understanding teachers' use of computer based simulations in teaching electrolysis
INVESTIGATOR	Ms Nkhululeko Nxumalo-Dlamini
DEPARTMENT	Science, Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	23 February 2017
DATE OF CLEARANCE CERTIFICATE	20 July 2018

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ACKNOWLEDGEMENTS

I would like to thank God for giving me the wisdom, courage and good health while I was doing the study.

My sincere thanks also go to Professor E. Gaigher and Dr. T. Salagaram for their patience, guidance and the supervision up until the completion of this thesis.

I also wish to give thanks to the staff of William Pitcher College, especially the science department for the support they gave me while I was doing the study.

My gratitude goes to the teachers who took the time and agreed to participate in this study.

Finally, my thanks go to my husband, Dominic Nxumalo, for his support throughout the study.

ABSTRACT

Understanding teachers' use of computer-based simulations in teaching electrolysis

This study explored teachers' views on the use of computer-based simulations (CBS) in teaching and learning electrolysis and also how they integrate CBS into teaching electrolysis.

This was a qualitative case study the methodology of which was framed by the Consensus Model of PCK (2015). The model is divided into five sections, namely: teacher professional knowledge bases, the topic specific professional knowledge, teachers' beliefs and orientations (amplifiers and filters), classroom practice, the students' beliefs, prior knowledge, and behaviours (amplifier and filter). For this study, the student outcome in the consensus Model (2015) was omitted because learners were not part of the study.

Three teachers from three schools were observed while teaching electrolysis to Form 5 students. A sequence of three lessons was recorded and transcribed. These teachers were further interviewed before and after using CBS to teach electrolysis. Furthermore, two questionnaires were completed before and after the use of CBS by the same teachers. The documents were analysed using the themes that emerged from the data.

The findings of this study indicate that the teachers' understanding of the use of CBS influences their classroom practice, which includes whether they allow learners to only observe or manipulate. The findings also show that teachers are aware that CBS enhances learners' understanding of electrolysis, and even that of teachers. However, they were concerned that the shortage of equipment and large class size, as well as the socioeconomic background of learners may affect its effective use. Although these schools have computers, the departments work in isolation, which makes the computers inaccessible for use by the other departments except for the ICT department. It is recommended in this study that teachers be educated more on how CBS enhances learners' understanding of abstract topics so that they can use these appropriately when teaching, allowing learners to manipulate and combine them with other suitable teaching methods. It is also recommended that departments in schools review their policies so that computers are accessible to all of the departments.

Keywords: Computer-based simulations, electrolysis, computer access

EDITING CERTIFICATE

Exclamation Translations

To whom it may concern

The dissertation entitled, "Understanding teachers' use of computer-based simulations in teaching electrolysis" has been edited and proofread as of 02 November 2018.

As a language practitioner, I have a Basic degree in Languages, an Honours degree in French and a Master's degree in Assessment and Quality Assurance. I have been translating, editing, proofreading and technically formatting documents for the past seven years. Furthermore, I am a member of the South African Translators' Institute (SATI) and the Professional Editors' Guild (PEG).

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ABBREVIATIONS

CBS	Computer-Based Simulation
PCK	Pedagogical Content Knowledge
SMK	Subject Matter Knowledge
UNISWA	University of Swaziland
ECOS	Examination Council of Swaziland
Co-Res	Content Representation
TPCK	Technological Pedagogical Content Knowledge

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CHAPTER 1 INTRODUCTION

1.1 ORIENTATION

This study sought to explore the use of Computer-Based Simulations (CBS) as an instructional strategy in teaching electrolytic cells. The difficulties associated with the teaching and learning of science is an international problem and, as such, great efforts have been made internationally to address it (Hodkinson & Hodkinson, 2001). These efforts, among others, include the improvement of teaching strategies. CBS were used in this study because literature has shown that there some advantages in using CBS, which include that CBS have been found to enhance the teaching and learning process (Cox, Junkin, Christian, Belloni & Esquembre, 2010).

This chapter provides an introduction to the study on the use of CBS in teaching electrolytic cells. The sections of this chapter include: background information that gives a brief discussion of what the study is about; and a statement of the problem, which outlines the challenges that are experienced in the teaching and learning of electrolytic cells. This is what prompted me to do this study. The rationale and the purpose of the study are discussed next. The research questions are presented, together with the significance of the study, which details who will benefit from the results of this study and how they will benefit from it.

1.2 BACKGROUND

A CBS is a program that is run on a computer to explore the approximate behaviour of the real system (Krain & Shadle, 2006). Jaakkola and Nurmi (2008) suggest that computers can be used to enhance the teaching and learning process. For example, Easy Java has been found to enhance the teaching of physics (Cox *et al*., 2010). Studies have shown that computer simulations based on real-world examples can aid learners' understanding of abstract concepts in physics and chemistry (Cox *et al*., 2010). Therefore, CBS may enhance learners' understanding of certain abstract topics like electrolysis by enabling learners to visualise some of the abstract microscopic processes and concepts, which, in most cases, they fail to understand. CBS gives an enormous variety of possibilities of modelling concepts and processes. Because chemistry involves many abstract and complex concepts (Halim, Ali, Yahaya & Haruzuan, 2013), models are very important.Through them, observed phenomena are reconceptualised not only at the macroscopic level, but also in terms of the theoretical models of the structure of matter at the submicroscopic level (Dumon & MzoughKhadraoui, 2014; de Jong & Taber, 2014). Taking into account that “the basis of the correct comprehension of chemical concepts is an understanding of the structure of matter” (Devatak, Vogrinc & Glazar, 2009), indeed “one of the essential characteristics of Chemistry is the constant interplay between the macroscopic and microscopic levels of thought” (Sirhan, 2007). The use of a specific language is another characteristic of Chemistry. This symbolic language, used to describe relationships between macroscopic and microscopic levels contribute to increased complexity of Chemistry (Dumon & MzoughiKhadhraoui, 2014). Johnstone, (1991, 2000) mentioned that chemists view their subject at three different levels: descriptive and functional, representational and explanatory. Johnstone associated the above mentioned terms with macro, symbolic and submicroscopic worlds.

The literature has confirmed that CBS, especially in teaching science lessons, enhances learners’ understanding of scientific concepts. To a greater extent, CBS comprises abstract and computer simulations, therefore it helps to show concepts in the science laboratory, such as processes at molecular level, which learners can otherwise only imagine (Jaakkola & Nurmi, 2008).

However, learners’ understanding of abstract concepts is also influenced by the abilities of teachers to present the content in a comprehensible way. Teachers’ ability to teach in class has also been found to depend on Pedagogical Content Knowledge (PCK) (Shulman, 1986). This concept was introduced in 1986 by Shulman, who described PCK as the ability of the instructor to help learners understand by breaking the content down into sections. One can therefore expect that the efficient use of CBS will be related to teachers’ PCK.

1.3 CONTEXT IN SWAZILAND

To familiarise the reader with the context of the study, a synopsis of the Swazi education system is first presented. School education in Swaziland is divided into three levels: primary education (seven years), lower secondary education (three years) and upper secondary education (two years). Progression from one level to another is determined by the learners' performance in the external examination, which is administered by the Examinations Council of Swaziland (ECOS), a public institution. Learners are awarded certificates after successfully completing each of the levels. The Swaziland Primary Certificate (SPC) is awarded after successful completion of the first seven years. The Junior Certificate (JC) is awarded after the successful completion of Form 3 and the Swaziland General Certificate of Secondary Education (SGCSE) after the successful completion of Form 5. Information on the certification awarded at each level and the duration thereof is presented in Table 1.1 below.

Table1.1 Certification awarded at each level and duration taken (www.examscouncil.org.sz)

LEVEL OF EDUCATION	CLASSES AND DURATION	CERTIFICATION
Primary Education	Grade 1 through Grade 7 (seven years)	Swaziland Primary Certificate
Lower Secondary Education	Form 1 through Form 3 (three years)	Junior Certificate
Upper Secondary Education	Form 4 and Form 5 (two years)	Swaziland General Certificate of Secondary Education

The Examinations Council of Swaziland (ECOS) is responsible for developing the syllabuses and ensuring the quality of the local examinations. The National Curriculum Centre (NCC), another public institution, is responsible for developing the content for different syllabuses in the country.

The three types of schools in Swaziland are government schools, government aided schools, and private schools. Government and government aided schools are considered to be public schools, and they often follow the local SGCSE syllabus. The Chemistry content in this study is referred to as the SGCSE Physical Science Syllabus 6888 (November 2017 and November 2018 Examinations) Chemistry section-C11.0, electricity and chemistry.

A number of private schools offer different syllabuses at secondary and high school levels. These include the Independent Examinations Board (IEB), International General Certificate of Secondary Education (IGCSE), A-Levels curriculum and the National Senior Certificate of South Africa (NSC), which is commonly referred to as matriculation. The examination results obtained by candidates from the SGCSE, IEB IGCSE, A-Levels and NSC are considered for the admission of learners at institutions of higher learning in Swaziland and in the Southern African Development Community (SADC) region. The focus of this study was on government schools since they offer the SGCSE curriculum. The SGCSE curriculum includes electrolysis as one of its topics, and that is what prompted me to use these types of schools in addition to the fact that most of the Swazi students attend government schools. The topic of electrolysis is covered in Form 5 in the SGCSE syllabus and elaborated on in Form 6 in the A-Levels.

The Examination council of Swaziland (ECOS) is responsible for the external examinations. ECOS has analysed the results for Form 5 in Physical Science from 2009 to 2016 as shown in Table 1.2. The table indicates that few candidates obtained credit passes (for university admission), that is grade A* up to C, and this raises a number of concerns. The highest proportion of learners with credit grades was achieved in the 2010 examinations when 25.2% of the learners obtained A-C grades. In 2014, the percentage credit was at its lowest, at 20.3% (www.examscouncil.org.sz). It was also noted that most of the learners had challenges with the items on electrolysis thus contributing to the low pass rate of physical science as a subject.

Table 1.2: Results of Swaziland Physical Science in Form 5 from 2009 to 2016 (www.examscouncil.org.sz)

Year	A*	A	B	C	D	E	F	G	U	Total	% credit	% non-credits	% ungraded
2016	88	241	746	1385	1552	1853	1331	1123	1759	10078	24.4	58.13	17.5
2015	92	223	731	1286	1422	1767	1298	1311	1708	9338	23.7	58.98	18.3
2014	66	145	509	1108	1246	1776	1406	1237	1496	8991	20.33	63.02	16.6
2013	78	196	495	1072	1208	1723	1439	1343	1360	8914	20.6	64.0	15.2
2012	78	182	580	1100	1264	1648	1419	1446	1155	8872	21.8	65.1	13.0
2011	88	209	588	1217	1412	1642	1392	1426	811	8785	23.9	66.8	9.2
2010	77	196	599	1280	1318	1641	1655	1154	601	8521	25.2	67.7	7.1
2009	81	204	553	1057	1175	1449	1463	1255	514	7751	24.4	69.0	6.6
Category	Credit				Non-credit				Ungraded				

The country requires science-orientated graduates for the attainment of its technological development goals by the year 2022. Moreover, a credit pass is required for university admission. Continuous failure by students to get good results in science subjects, specifically credits in Physical Science, has a likelihood of instilling negative attitudes in learners about science. The learners may not put a lot of effort into the subject or they may not choose it as one of the subjects to be covered in secondary school as they may perceive it to be difficult.

1.4 PROBLEM STATEMENT

Swaziland, although considered a middle-income country, faces similar challenges as those faced by countries that are generally categorised as third-world countries. Some of the challenges, particularly in the education system, include a shortage of qualified science teachers; a shortage of resources such as teaching aids; insufficient teaching time for the subject; the large numbers of learners in the classrooms; a lack of teachers' experience in the teaching of science subjects (physics and chemistry); teachers' beliefs and attitudes about teaching, which also influences the selection of teaching strategies; teachers' specialisation in the subject; teachers' competency in Information Communication Technology (ICT), teachers' use of ICT in teaching and learning; and lastly, learners' prior knowledge and socio-cultural context. These factors may contribute to teachers' limited choice of teaching methods and further reduce their chances of offering individualised attention to learners. This consequently negatively affects the performance of the learners (Ministry of Education and Training report, 2012).

The report generated by the Ministry of Education and Training (2012) further suggests that many teachers who teach science in Swaziland use the lecture method to teach learners because they lack in pedagogical content knowledge (PCK) and subject matter knowledge (SMK). Their use of the lecture method suggests that their PCK and SMK need to be developed. This is because some of the teachers who teach science are not subject specialists and therefore do not know how to best facilitate the teaching and learning of science-based subjects. Researchers argue that using the lecture method as an instructional method is associated with low academic performance (Peterson, 2011). Peterson further notes that information that is not acquired actively becomes inert in the learners' minds because they are not involved in their own knowledge acquisition; rather, they become passive recipients of knowledge.

Physical Science is a practical subject, therefore learners have to develop their processing skills. It has been found that a large number of learners in Swazi schools do not do science practicals because there is a shortage of science laboratories. Even in schools that do have laboratories, most are not functional (Nxumalo, 2014). As a result, quite a number of learners in Form 5 opt to write a paper that is an alternative to practicals in Form 5 (www.examscouncil.org.sz).

The challenges faced by the education system are manifested in low pass rates in Physical Science in the SGCSE syllabus, as reflected in the analysis of the results presented in Table 1.2 (www.examscouncil.org.sz). In order to improve the performance of learners in Physical Science in Swaziland, different ways of learning rather than transmitting information need to be implemented, such as the introduction of modern innovative teaching strategies like the use of CBS. To my knowledge, there are no studies in Swaziland that have explored teachers' use of CBS in teaching chemistry electrolysis. This constitutes a gap that, as the researcher in this study, I hope to fill with the knowledge gained through this study. Electrolysis is one of the topics that learners in Swaziland find difficult, as noted in a report from the ECOS.

1.5 Rationale

Most schools have computer laboratories that are fully furnished with computers, but these computers solely belong to the Information, Communication and Technology (ICT) department. The other departments in schools have limited access to the ICT department as the school departments work in isolation. Essentially, the same facilities (computers) could be used by all departments in the school, including the science department, to support the learning of some abstract concepts. The focus of this study, however, was on electrolysis because it is one of the most challenging topics for both learners and teachers. Despite the challenge of computers being inaccessible, many learners have cell phones and some have laptops which they may use since the computers in schools are not accessible. Unfortunately learners are not allowed to bring these gadgets to school. The use of CBS could enable learners to visualise the movement of ions and thus enhance their level of understanding of electrolysis. In fact, learners could even search for other CBS that they could use for different topics.

Cornwell (2010) argues that computer simulations enhance the learning and remembering of information, as well as strengthening learning that has already taken place. Computers do the enhancing by providing learners with an opportunity to simulate the experience of real-life situations and provide a chance for active learning, which is more effective than passive learning, i.e. sitting and listening to the teacher. The topic of electrolysis was chosen because electrolytic cells have been identified as a challenging topic for learners. In conducting this study, I specifically tried to understand teachers' use of CBS as an instructional strategy in teaching electrolysis, looking at other teaching strategies that teachers use with CBS. However, teachers' computer skills are not the focus of this study.

The use of CBS compels teachers to reflect on the model-based inquiry that they experience to advance their understanding of the pedagogical uses of technology and ways to support students' learning of the subject matter, thus developing teachers' PCK and SMK (Guzey & Roehrig, 2012). A model-based inquiry is based on generating, testing and revising of scientific models. It is based on collbarative and co-operative style of learning and places emphasis on the explanatory model. For example, in a model-based inquiry, learners are expected to question things and to be involved in discussions and explain the collected information (Millar & Abrahams, 2009). Guzey and Roehrig also assert that using CBS adds efficiency, confidence in SMK and also adds value to both teaching and learning. The current worldwide science education reforms require science teachers to integrate science and inquiry-based teaching into their teaching in order to prepare learners for science and technology (National Research Council, 1996). CBS has been found to enhance the understanding of abstract topics in physics since they allow the integration of science and inquiry-based teaching (Jaakkola & Nurmi, 2008; Gilbert, Justi & Aksela, 2003).

The proper teaching of science in Swaziland could lead to improved understanding of scientific concepts. This, in turn, could produce creative, inquisitive citizens and independent thinkers, which is one of the aims of teaching science (Physical Science Syllabus; Examination Council of Swaziland, 2016). It was therefore of great interest to understand teachers' use of CBS in teaching electrolysis in Swaziland in order to make appropriate and informed recommendations to the Ministry of Education. Part of this may include recommending the use of CBS as a teaching strategy for the improvement of learners' performance in the sciences.

1.6 THE PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

The purpose of the study was to understand how teachers use CBS in the teaching of electrolysis.

Research questions

The study attempted to answer the following research questions:

Primary research question

How can teachers' use of CBS in teaching electrolysis be understood?

Secondary research questions

1. What are teachers' views on the use of CBS in teaching and learning electrolysis?
2. How do teachers integrate CBS into teaching electrolysis?

The research questions enabled me to describe how teachers integrate CBS into their lessons and explain their choices and actions in terms of their views.

1.7 SIGNIFICANCE OF THE STUDY

1.7.1 Chemistry teachers

Using CBS during a lesson is one method that can be employed in an effort to improve the teaching and learning process in Physical Science. Science teachers might strive to learn and use CBS in their lessons if they were informed about the use of CBS to improve the teaching and learning of scientific concepts.

1.7.2 Learners

Using CBS could bring about changes in the learning process as learners might change their attitude towards the subject and thus actively participate in lessons. The change in attitude towards Physical Science may lead to improved performance in the subject. Thus, this could ensure that learners become more productive citizens of the country as a consequence of a better understanding of the sciences.

1.7.3 In-Service department

The in-service department, which is the department of developing qualified science teachers of the Ministry of Education and Training, could assist science teachers who are already in the field by exposing them to different computer simulations, and familiarise them with how simulations can be integrated into their teaching. The in-service department is expected to facilitate the teaching of topics that are challenging for most teachers.

1.7.4 Pre-Service teacher training institution

The pre-service department, consisting of teacher training colleges and universities, could include CBS as an instructional strategy during the training of science teachers in the courses, and deliberate on different computer simulations during teachers' training.

1.7.5 Curriculum developers

As the sole curriculum developer of the curriculum that is used in eSwatini, the NCC should consider the findings of this study regarding changes to teaching strategies. These new strategies will be on par with the changes in technology and be relevant to today's generation.

1.8 DELIMITATIONS AND LIMITATIONS OF THE STUDY

The study was conducted in semi-urban and urban schools in Swaziland.

The limitations of the study were related to the participants, the topic covered during data collection, and financial constraints.

Only three participants were involved in the study. To address the limitation of a small number of participants, I selected schools from different socio-economic backgrounds so as to investigate the introduction of CBS in different environments.

The duration of the data collection period was limited, thus data was collected using different instruments, which includes questionnaires, interviews, three lesson observations, and document analysis. Using the different instruments increased the validity of the findings.

Also, the use of CBS was a new experience for the teachers such that they had little confidence in using it to assist learners. As the researcher, I minimised this limitation by providing some training to familiarise teachers with CBS prior to the actual study.

Furthermore, since this was a case study, the findings of the study cannot be generalised. However, the results could add useful insight to the body of knowledge to provide in-depth understanding that supports the teaching of chemistry using CBS, particularly in Swaziland.

1.9 ORGANISATION OF THE STUDY

The study is presented in five chapters as indicated:

Chapter 1 outlines and discusses the background of the study, the education system in Swaziland, and a review of the SGCSE results from 2009 – 2016 to assess the performance of the learners in Physical Science. The statement of the problem, rationale, purpose of the study, research questions and objectives of the study, the significance of the study, as well as the definition of terms are also covered in this chapter.

Chapter 2 presents the literature reviewed to inform the study. The following are addressed: the nature of computer simulations, teachers' use of CBS, teachers' selection of instructional strategies, learner-centred approaches, and the learning of electrolysis. The commonly used teaching strategies to teach electrolysis, the teachers' development of PCK, teachers' use of CBS in teaching chemistry, PCK, and the theoretical framework are also presented in this chapter.

Chapter 3 explains the methodology adopted for this study, which includes the paradigm, approach and the research design used in this study. The selection of participants and sampling procedure, sub-topics to be observed using CBS, the criteria used to evaluate CBS lessons and the pilot study are also covered in this chapter. In addition, the data collection strategies and procedures, teaching electrolysis with CBS, the data analysis, methodological norms, and the ethical issues are presented. The research instruments are also further discussed in this chapter.

The results of the study are presented in **Chapter 4** in terms of the emerging themes.

The conclusions of the study are presented in **Chapter 5** and are discussed based on the literature related to the study. Thereafter, recommendations are made for policy makers and further research.

1.10 Definitions of the key terms/concepts

A number of key terms will be defined in this section. These are:

Pedagogical Content Knowledge: this refers to knowledge about the integration of subject expertise and skilled teaching of a particular subject, being able to combine different types of content.

Subject Matter Knowledge: this refers to knowledge about electrolysis, its structure, the concepts in the topic and procession.

Computer-based simulations: computer-based simulation refers to computer programs that can either be run almost instantly on small devices, or large-scale programs used to represent abstract concepts in science to enable visual representations.

Curriculum: lessons and academic content taught in a school or in a specific course or programme.

1.11 Chapter summary

In this chapter, I presented the background of the study regarding the use of CBS as an instructional strategy. In this chapter, I presented the statement of the problem, purpose of the study, research questions, objectives, and the significance of the study. In the next chapter, I will present a review of the literature related to this study.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the definition of computer simulations is given, and the conceptualisation of the subject under study, including a review of the related literature is presented. Some models of PCK as well as the theoretical framework underlying this study are also discussed.

2.2 DEFINING COMPUTER SIMULATIONS

There is no single, appropriate definition of computer simulations. Typically, computer simulations are computer-based, step-by-step programs that explore the approximate behaviour of real-world processes or models thereof. Bransford, Brown and Cocking (2000) consider computer simulations as abstractions of reality, while Kaheru and Kriek (2010) define computer simulations as simple computer programs capable of displacing or representing concepts, ideas or representations. Kaheru and Kriek also note that a computer simulation is an interactive computer program created from the theoretical (often abstract) model of certain real physical phenomena such as the movement of a pendulum, planetary motions, optical illusions, and the movement of projectiles, amongst others.

According to Bransford *et al.* (2000), there are three different types of simulations, namely: live, constructive, as well as virtual simulations. Live simulations occur in a real environment and they involve equipment, activities and human beings. In contrast, virtual simulations involve human beings and/or equipment in a computer-controlled environment where time is divided into distinct steps. Constructive simulations include humans or equipment as participants. They are motivated by the smooth running of events.

Windschitl (1996) states that when learners use a behavioural model to better understand a system, they use a simulation. Windschitl further reports that simulations describe phenomena that allow learners to interact with the system dynamics, which thus helps them to conceptualise the process. The simulations are therefore complex. When used, it is important that they represent reality and veracity, otherwise learners will not receive the correct information about what is to be learned (Lindgren & Schwartz, 2009).

A complete database of interactive simulations can be found, for example at www.compdre.org/osp. Users of interactive simulations can study physical phenomena, which may not be possible under normal laboratory conditions. This is accomplished by modifying physical parameters through drop-down menus and/or checkbox options. Simulations show a graphical response to changes in physical parameters (output) for users. In this way, computer simulations create visual and interactive media from abstract theoretical models that are difficult to understand and study under normal circumstances.

2.3 CONCEPTUALISATION OF THE TOPIC

2.3.1 Teachers' skill in using computers

Teachers' beliefs and orientations in science education determine the success of the lesson delivery strategy used by the teacher (Grossman, 1990; Magnuson, Krajcik & Borko, 1999). This implies that the effective use of computer simulations in schools will depend on the willingness of educators to use CBS delivery of lessons in class. It may also depend on whether or not teachers understand the importance of using CBS to facilitate the teaching and learning process in schools.

The literature, for example, indicates that insufficient technical support discourages teachers from using ICT in teaching (Mirzajani, Mahmud, Mohd Ayub & Wong, 2016; Habibu, Mamun, Clement (2012). He adds that these few teachers who master computer science use it mainly for administrative purposes, such as record keeping and course development. Carlson and Gadio (2002) notes that while ICTs for teachers are limited, learners often work in untargeted ways, which results in poorer outcomes.

2.3.2 Teachers' use of CBS

Physics Education studies on the use of interactive computer simulations in teaching various subjects show that learners' understanding of physical concepts is enhanced by computer simulations as compared to traditional pedagogical approaches (Fishwick, 1995; Gilbert *et al*. 2003, Jaakkola & Nurmi, 2008). It is argued that the interactive nature of computer simulations facilitates active learning in which learners are actively engaged in acquiring knowledge rather than being passive and merely attending to something presented to them. Learners also carry out practical activities using CBS, which helps them to become aware of the limits of their reasoning. As learners become actively involved, they have the ability to manipulate complicated systems and separate schemas when conducting their autonomous investigations. Interactive computer simulations can help learners to overcome their misconceptions (Minner, Levy & Century, 2010).

Minner *et al*. (2010) have also found that interactive computer simulations expose learners to visual dynamic theoretical representations that are difficult to represent in science manuals. Such representations enable learners to understand concepts better. Minner *et al.* (2010) further argue that CBSs support learners' use of scientific concepts to communicate as they motivate learners to acquire new knowledge. International establishments like the National Science Foundation of South Africa (NSFSA), the National Research Council of America (NRCA) and the American Association of the Advancement of Science (AAAS) have made more efforts to improve science as a field of education (Minner *et al*., 2010). One of the common goals of this effort is to motivate and assist science educators to use learner-centred teaching strategies to enhance learners' comprehension of procedures and concepts in the sciences (Minner *et al.*, 2010).

It is thought that if teaching is learner-centred, learning science might make better sense to learners, thus facilitating critical reflection and transfer of what they learn in real-life situations (Garmstone & Wellman, 1994). This means that CBS could improve learners' understanding of scientific concepts and thus motivate learners to learn.

2.3.3 Criteria used to evaluate CBS lessons

The CBS used must be accurate and up-to-date and should not contain any errors or factual displays that could lead to a misunderstanding of the concepts (Simpkins, Paulo & Whitaker, 2001). Simpkins, Paulo and Whitaker also note that the scope and depth of the information presented by the CBS should be appropriate; in this case, this means that it must comply with the SGCSE program.

2.3.4 Teachers’ selection of instructional strategies

Teaching is a very complex task that requires more than just passing on knowledge; each lesson should be planned and appropriate teaching methods used through which learners must be actively engaged. These teaching methods may be known as investigation. Hiang (2005) believes that investigation includes the search for truth or knowledge, requiring critical reflection, observations, questions, experiences and coming up with conclusions.

When planning a lesson, the teacher considers a number of things, including learner group capacity, learning requirements, learner knowledge, and preconceptions. This knowledge helps teachers to decide where to start when they teach (Magnusson *et al.,* 1999). The educator then decides and selects different instructional strategies and links these to the learners' diverse needs. When planning their courses, teachers should also choose teaching and assessment methods that are adapted to the needs of learners. Research has shown that most science teachers still use traditional teaching methods such as lecturing and the reading method, which promotes rote learning (Peterson, 2011). In the reading method, a teacher passes information to the learners while the learners listen and write notes. In this way, there is little engagement between the educator and learners. Raymond (2010) argues that the problem with the reading method is that learners do not actively participate in the lesson and therefore cannot relate the content to their daily lives. The reading method makes it difficult for learners to apply the knowledge gained to real-world situations and to develop their own creative skills. This leads to learners misunderstanding the concepts and being incapable of applying new knowledge to new situations. Due to the fact that the reading and lecture methods do not promote understanding, teachers should use learner-centred approaches.

2.3.5 The learner-centred approach

In a learner-centred approach, learning involves relying on previous knowledge or experiences. It is therefore important to treat learners individually in meeting their needs (Dalgarno, 2001). A learner-centred approach focuses on learners' needs and interests, as well as their learning abilities and styles, with the teacher acting as a learning facilitator (Garmstone & Wellman, 1994). This approach places more learning responsibility on the learner while the teacher takes responsibility for guiding the process. The learner takes center stage in the learning process. Placing learners at the centre of the learning process helps them learn creative skills and ultimately provides a lifelong learning base. Garmstone and Wellman also note that the learner-centred approach improves learner performance and success.

A learner-centred approach emphasises practical activities and allows learners to study, solve problems, discuss with each other and draw conclusions (Garmstone & Wellman, 1994). Garmstone and Wellman also note that a learner-centred approach stimulates curiosity, imagination and critical thinking, making lessons fascinating for learners. The learner-centred approach may include the integration of computer simulations with other teaching methods such as teaching and discovery that is based on research. All of these teaching methods are embedded in the philosophy of learning called constructivism (Cakir, 2008).

The theory of constructivism is attributed to Piaget. In this theory, knowledge is internalised by the process of adaptation and assimilation (Piaget, 1978). Posner, Strike, Hewson and Gertzog (1982) define assimilation as an occurrence that corresponds to an already existing conception, that is to say that it supports existing beliefs. This means that learners incorporate new experiences into the already existing framework without changing it. The authors also define accommodation as the process of reframing the mental representation of the outside world to fit new experiences, which means that there is a change in design. Individuals build their own knowledge from their own previous experiences. Constructivists insist that knowledge is generated by an individual through active thought.

Cakir (2008) argues that constructivism entails selective attention, organization of information and integration of existing knowledge. He adds that social engagements and interaction are vital in creating a sense of shared knowledge. Thus, learners should be involved mentally and behaviourally in class so that learning can be effective. Killen (2000) explains that constructivism as a teaching and learning theory implies that learners gain understanding if they participate in their own learning and seek solutions to problems. He further finds that learning comes from the learner and helps learners to build knowledge in a way that suits them.

According to Garmstone and Wellman (1994), in the constructivist approach learners are not seen as empty vessels that only absorb information, but actively participate in the learning process. They further argue that learners understand better when they integrate and synthesise information from different sources, creating new categories and developing frameworks and models themselves.

The constructivist philosophy of learning states that learners must build their own understanding of the world in which they live. According to Vygotsky (1997), learners bring their culture and past experiences to the teaching and learning environment, and they build new information based on their previous knowledge and experiences. Constructivist teaching is based on the notion that learning takes place when learners participate in generating knowledge and information rather than being passive recipients of information (Perkins, 1999).

Since the purpose of this study is the teaching of electrolysis, it is important to discuss the nature of the subject of electrolysis and the common challenges faced by learners who need to learn this topic.

2.3.6 The nature of the topic of electrolysis

The subject of electrolysis is abstract in nature because learners have to imagine certain concepts that are not visible. Learners studying electrolysis must operate on three levels of thinking: the macroscopic level (macro), the microscopic level (micro), and the symbolic level (Mbajiorgu & Reid, 2006). According to Mbajiorgu and Reid, the macro level is phenomenological, which can be experienced by the human senses without the aid of an instrument. However, Halim, Ali, Yahaya and Haruzuan (2013); de Jong & Taber (2014) note that learners have a challenge in operating at these three levels of chemical representations because they cannot see a connection between these levels. Dumon and MzoughiKhadhraoui (2014) also concur with these claims. These researchers claim that the phenomenon is generally tangible, for example, during the electrolysis of a solution of copper chloride, when using carbon electrodes, there is visible color change and release of gas that can be smelled.

The micro level refers to what can be observed with the use of instruments or what concerns the inference of chemical processes (Mbajiorgu & Reid, 2006). For example, during the electrolysis of a solution of acidified water, hydrogen gas is generated. The presence of the gas can be tested because it produces a ‘popping noise’ when a flame is brought towards the gas.

According to Mbajiorgu and Reid (2006), the symbolic level refers to the symbols, formula, models, and equations used to symbolise chemical ideas. In this case, learners have to write chemical equations and half reactions that have taken place at the different electrodes.

These three levels act in the mind and must be used competently by the teacher to facilitate learners' understanding. The average learner has difficulty working at all three levels simultaneously (Mbajiorgu & Reid, 2006). The difficulty experienced by the learner is compounded by the fact that the concept also uses scientific language, sometimes rooted in everyday language (Mbajiorgu & Reid, 2006). Learners then seem to mix the meanings of words. This makes understanding the concept even more difficult for learners.

For teachers to effectively teach electrolysis, they must use different teaching strategies. Teachers must understand the difficulties encountered by learners in the different fields of chemistry (Magnusson *et al.,* 1999), in this case electrolysis. In addition, the teaching of electrolysis requires that teachers apply certain skills, for example, by probing learners to determine their level of comprehension. This means that SMK alone is not enough to clearly explain concepts to learners. It is also important that learners carry out practical tasks to improve the understanding of electrolysis and to develop manipulative and inquiry-based skills (Magnusson *et al.,* 1999). Magnusson *et al*. (1999) also argue that a teacher's lack of information, pedagogy and CPK negatively affects learners' performance.

2.3.7 Learners' difficulties in learning and teaching electrolysis

Electrolysis has proved difficult for both teachers and learners according to Finley, Stewart and Yarroch (1982); Shamsudin, Abdullah and Nakhleh (1992); Ogude and Bradley (1994); Sanger and Greenbowe (1997a). Electrolysis is a difficult subject for most learners because learners do not relate to it to their daily life (Taber, 1998). The challenge for most learners is due to a lack of information, learning media, as well as failure to comprehend the language due to conceptual difficulties that are common to physics and chemistry. Learners have challenges with electrolyte conduction, electrical neutrality, electrode processes and terminology, and aspects that relate to components (Ogude & Bradley, 1994). Inconsistent use of textbook language by educators in class is also another source of misconceptions. The authors add that mismanagement of schools, poor teacher preparation and teachers' misunderstanding of content concepts are some of the reasons for the poor performance of learners. However, as seen above, as difficult as it is, it is important for learners to understand this topic.

2.3.8 Importance of electrolysis

Electrolysis is an important subject because of its applications as well as the synthesis of the principles of physics and chemistry. In this study, the use of CBS as a facilitation strategy in the delivery of electrolysis lessons is limited to electrolysis and not to galvanic cells because the Physical Science curriculum does not include galvanic cells. Electrolysis is also important because it is related to thermodynamics, reaction rate, oxidation and reduction reactions, and chemical equilibrium, which are also discussed in chemistry in the SGCSE program. Understanding electrolysis can also improve learners' understanding of other concepts, which can improve the overall performance of the learner in Physical Sciences. Miller (2014) argues that electrolysis has many applications ranging from battery development to neuroscience and brain research. Electrolysis principles are applied generally in electroplating based on the principles of the electrolytic cell.

2.3.9 Sub-topics to be covered prior to electrolysis and in electrolysis according to the SGCSE syllabus

The subject of electrolysis requires that learners understand the equilibrium of chemical equations, the binding, and the identification of redox reactions. These sub-themes are a prerequisite for electrolysis; all of these sub-themes are treated sequentially in the chemistry section of the Physical Science programme. Electrolysis also requires an understanding of electricity, a section covered in physics. The topics related to electricity and chemistry, according to the SGCSE physical program (p10) are:

- Describing electrolysis, describing the electrode products formed during the electrolysis of copper chloride, describing the electrolysis in terms of ions present and reactions to the electrodes.
- Investigation of the electrolysis of sulfuric acid, also known as electrolysis of water.

  Interactive simulations will show the movement of ions and will also indicate reduced and oxidized electrodes.
- The study of the electrolysis of copper sulphate with carbon and copper electrodes

Interactive simulation will show the movement of ions at the anode and cathode electrodes. It will show which electrode will be eaten and vice versa. At the carbon electrode: At the cathode, H^+ and Cu^{2+} are present. Cu^{2+} is preferably discharged, Cu^{2+} is reduced. At the anode: OH^- is preferably discharged, OH^- is oxidized.

- The study of electrolysis of aqueous copper sulphate with copper electrodes
  The interactive simulations will show the movement of the ions at the electrodes and will also indicate which electrode will be reduced and which one will be oxidized. At the cathode: identical to that of the carbon electrodes. At the anode: the copper is oxidized, the Cu^{2+} ions go into solution to replace those reduced to the cathode.

2.4 PREVIOUS STUDIES ON TEACHING AND LEARNING ELECTROLYSIS

Bar, Azaiza, Azaiza and Shirtz (2017) compared the performance of high school and college students. They looked at the effects of instruction of electrolysis, composed of hands on experiences combined with class discussions. The findings show that college students perform better than high school students. The improvements were ascribed to better preparation for chemistry lessons, emphasis being made on the signs of the electodes and distinguishing the current in the wires from the current in the solution during teaching.

A comparison of perceived and actual students' learning difficulties in physical chemistry (electrolysis) was made by Adesoji, Omilani and Dada, 2017. The results showed that many areas of physical chemistry where students perceived no chemistry difficulty were in fact challenging for them.

Ahaji and Angura (2017) examined improving senior secondary students' retention in electrolysis using Collaborative Concept Mapping Instructional Strategy (CCMIS). The study revealed that there is significant difference in the mean retention scores between students taught electrolysis using CCMIS and discussion method in favour of CCMIS. It was thus recommended that CCMIS be used during the lessons since they enhance learners' understanding of electrolysis.

A study by Thompson and Soyibo (2002) examined whether the use of lectures, demonstrations, assignments, and discussions in class improved learners' attitudes toward chemistry and the understanding of electrolysis, and if significant statistical differences existed in their electrolysis performance. The sample consisted of 138 Grade 10 Jamaican students in two high schools. Questionnaires and document analysis were used to collect data. The results revealed that the attitude of the experimental group with respect to chemistry was statistically better than that of the control group.

Ahtee, Asunta and Palma (2002) studied teachers' conceptions of the topic of electrolysis and the challenges that they face. The purpose of this research was to discover how teachers understand the meaning of electrolysis. Eight chemistry educators were chosen and invited to write an electrolysis lesson plan for lower secondary school. Semi-structured interviews were used to collect data and it was found that only two of the eight teachers clearly understood what electrolysis entails. The other six did not understand it. Teachers also had difficulty linking previously taught electrolysis concepts to form an integrated whole. The results revealed that the teachers were mostly concerned about their own knowledge of the subject and expressed their need to study the subject in order to teach it properly.

A study by Garnett and Treagust (1992) was conducted to study the conceptual challenges encountered by secondary school learners in electro-chemistry in galvanic and electrochemical cells after a course of seven to nine weeks. The data were collected using semi-structured interviews. Thirty-two learners in their final year of secondary school education took part in the study. The results of the study revealed that the learners perceived the anode as negatively charged and thought that the cations would go towards it. Those learners who perceived it as negative failed to explain why the electrons were moving away from the anode. In terms of electrolytic cells, the majority of the learners did not associate the positions of the anode and cathode with the polarity of the applied electromotive force (emf.). According to the study, other learners had attempted to reverse the characteristics of electrochemical cells and apply inversions to electrolytic cells. The implications of the study relate to learners' interpretation of the language used to describe a scientific phenomenon and the tendency of learners to generalise their findings due to teachers' comments or statements in textbooks.

2.4.1 Research on using simulations as a teaching strategy

Mirriam (2015) has studied the effects of using CBS and their influence on the understanding of oscillatory movements among secondary school students in Slovakia. A series of thirteen CBSs was used by students working in groups of two or three. Two classes were studied, one was CBS-orientated and the other did not use the experiments used by the CBS. The results showed that the use of CBS helped learners better understand the basics of oscillatory motion. Learners were also able to use their knowledge to solve creative tasks combining knowledge from different areas of physics.

Pinto, Barbot, Viegas, Silva, Santos and Lopes (2014) explored how teacher mediation can foster learners' development of epistemic practices in class using CBS articulated with experimental work. CBS was combined with an Experimental Work approach (EW) as a didactical approach in order to discover what happens when learners work on a path from theory to the observable world. The results highlighted the existence of learners who were promoted differently depending on their use of CBS or EW. When the educators used observed phenomena to encourage learners to find explanatory models, learners tended to follow the path. When the learners began to explore an interpretive model and to simulate observable phenomena, they followed the path. In other words, various mediation options resulted in different epistemic privileges for learners.

Kotoka and Kriek (2014) studied the impact of computer simulations on the performance of Grade 11 learners in electromagnetism in the Mpumalanga province of South Africa. The control group learned electromagnetism through lectures and demonstrations referring to the static images of the manual and actual laboratory experiments. Simultaneously, the experimental group learned electromagnetism through lectures, experiments in the laboratory, computer simulations of PhET and the Plato Learning Centre used by the control group. The results of the study revealed that computer simulations had a positive effect on the Grade 11 learners' performance in electromagnetism. It was further shown that the control group was outperformed by the experimental group.

Sarabando, Cravino and Soares (2014) studied the contribution of computer simulations to the learning of physics concepts in terms of weight and mass. The computer simulation was performed using the Modulus software. The study assessed the comprehension progress made by Grade 12 students aged 12 to 13 after a 90-minute lesson in three different scenarios: using only hands-on activities, using a computer simulation, and using both. The students came from four different schools in northern Portugal and the study involved 142 students and three teachers in a physics and chemistry lesson. The results of the study show that learning weight and mass can be improved by integrating computer simulations into topics that students find difficult conceptually. The results show that the total scores were higher when students used a computer when using this together with hands-on activities. However, the results also show that learners' comprehension gains depended on teachers' pedagogy when using computer simulations to teach the concept of weight and mass.

Dega, Kriek and Mogese (2013) examined the concepts of Electrical Potential Energy (EPE) and Electromagnetic Induction (EMI). They used a quasi-experimental model to study the effects of interactive simulations of cognitive disturbances (CPS) in relation to interactive simulations of Cognitive Conflicts (CCS). The existence of a significant difference between the post-test scores of the groups was revealed. It was thus concluded that a significant difference existed between CPS and CCS regarding the modification of the alternative conceptions of the learners in support of scientific conceptions favoring the CPS. In the abstract conceptual areas of electricity and magnetism in which most learners had incorrect answers, cognitive disruption through interactive simulations had more impact than cognitive conflict through interactive simulations that facilitate conceptual change and improve understanding and classroom instruction.

Plasset, Milne, Homer, Schwartz, Hayward, Jordan, Verkuilen, Wand and Barrrientos (2012) studied the effectiveness of interactive computer simulations in secondary science education in the following concepts: Kinetic Molecular Theory, phase change, and perfect gas laws. One study was conducted in rural Texas and another in an urban area of New York. The computer simulations integrated the three levels of depiction, namely, symbolic, observable, as well as explanatory depiction. The study examined the effectiveness of computer simulations in supporting students' learning objectives when implemented in rural and urban areas. Three hundred and fifty-seven learners in 20 classrooms from four public schools in rural and urban areas participated in the study. Learners' results were measured in comprehension, chemistry transfer, graphic skills, and content knowledge. The results proved that in rural and urban environments, the use of simulations yielded better performance in chemistry. Learners who made use of computer simulations demonstrated advanced knowledge of chemistry. One conclusion gleaned from this study is that the proper design and use of interactive multimedia simulation in a science class contributes to the theoretical understanding of multimedia learning in science.

According to a study by Stieff (2011) on improving representational competence, using molecular simulations in survey activities in the States of Matter, Connected Chemistry Simulations (CCS) can improve learners' representation skills. CCS can assist learners to explain and reinforce their conceptual understanding of the key concepts of chemistry, improve learners' aptitude to simulate macroscopic experiments in the laboratory, and foster understanding of the relationships that exists between the molecular interactions and the chemical representations. Four chemistry teachers and 460 students from two different secondary schools participated in the study. Of the 460 students, 228 were taught solely using the lecture method and 232 using CCS. They worked in pairs exploring a computer simulation in order to understand the nature of microscopic interactions accountable for the macro-level seen in the laboratory. The study concluded that CSC increases chemistry students' learning, suggesting that computer simulations could improve chemistry students' results and understanding.

Jaakkola, Nurmi and Veermans (2011) compared learners' learning outcomes using simulation only with the results of those using parallel simulation with real-world circuits. They also explored how the learning results in these settings were facilitated by procedural guidance and guidance on instruction in the discovery process. The conclusions drawn from the cited study show that the combination of laboratory activities with computer simulations improves learners' understanding of concepts more than when computer simulations are used alone.

Kriek and Stols (2010) have studied the beliefs of South African physics teachers in Grades 10 to 12 on their use of interactive PhET simulations in their lessons. The study examined the effect of the behavioural beliefs of Grade 10 - 12 science educators, and the effect of normative beliefs on their attitudes, subject norms and perceived behavioural control. In addition, the impact of teacher attitudes, subject norms and perceived behavioural control were identified and their use compared to their intentions to use the PhET simulations. The research used the circuit construction kit from the interactive PhET simulations. Seven high school Physical Science teachers from semi-urban areas and 17 from urban schools participated in this study. The results revealed that educators' attitudes towards the effectiveness and perceived compatibility motivated their attitudes towards using simulations in their lessons. In other words, the use of PhET simulations by the teacher is based on their attitude towards PhET, the subjective norm, and perceived behavioural control. The results also show that teachers' attitudes towards perceived usefulness and compatibility influence their attitudes towards the use of PhET in their courses. The behavioural and control beliefs of teachers further influenced their behaviour. Another conclusion made was that there is no correlation between the effects of teacher attitudes, a particular norm, and the perceived behavioural control on their motive to use PhET during lessons.

Another study by Kaheru and Kriek (2010) investigated the use of interactive collaborative simulations in science education. Some teachers were convinced to use computer simulations, while others had to be supported before using computer simulations. The findings showed that there was more understanding, that is, there was more effective learning when teachers used the interactive computer simulations than when they used the traditional methods of teaching.

Fonseca, Aredes, Fernandes, Batalha, Apostollo, Martins and Rodrigues (2016) conducted a study on the cognitive learning of nursing students during the neonatal clinical evaluation of a combined course using computer and laboratory simulations. The conclusion of the study was that participants' cognitive learning had increased significantly. The use of technology may be partly responsible for the success of the course and this shows that it is an important tool for innovation and learning motivation in the health sector.

A study by Molefe, Lemmer and Smit (2005) compared the learning effectiveness of CBS demonstration to that of conventional demonstration when teaching kinematics concepts in a South African school. Forty-eight Grade 11 learners in South Africa took part in the study. The conclusion drawn from the study was that computer-based methods produced lower average gains than conventional apparatus. The lower gains in the computer-based methods were ascribed to the inexperience of teachers' and learners' in using computers, measuring and data processing.

Windschitl and Andre (1998) conducted a study on the effects of constructivist versus objectivist computer simulation environments on learners' conceptual change in classrooms. This investigation also explored the possible relationship between students' epistemological beliefs and the nature of the simulation setting in terms of developing conceptual understanding. The conclusion reached in their study was that a constructivist experience could more effectively modify learners' misunderstandings than a confirmatory simulation experiment. Another conclusion of the study was that the provision of detailed procedures to come up with solutions to problems in a setting could be detrimental to the change of concepts. This investigation also supported the notion that computer simulations provide an appropriate cognitive setting where self-resolving students can test other conceptions, performances, as well as overall responses to the constructivist class.

Eylon, Ronen and Ganiel (1996) conducted a study on CBS as an instructional tool using an optical simulation setting. The results show that students who worked individually performed better than those watching demonstrations carried out by the teacher.

Clayton (1991) studied the effectiveness of simulations in higher education focusing on the following research questions: How does role-playing simulations improve the understanding of theoretical concepts and how does role-play simulations favor an increase in the level of preparation and participation of students? The results suggest that students' comprehension of theory was improved and that students spent more time preparing for their lessons. The participating learners enjoyed the simulations and further got an opportunity to apply the knowledge they had acquired through the course. A conclusion drawn from the study was that simulations have positive effects on student learning and development.

2.4.2 Summary of the research conducted on the effectiveness of simulations in teaching chemistry

Molefe *et al.* (2005) compared the learning effectiveness of computer-based demonstration with conventional demonstration in teaching kinematics in South Africa in two afternoon sessions comprising eight hours. The result they obtained was that there was no noteworthy difference between the groups in terms of knowledge gain. There was, however, a slight gain in the conventional demonstration. The minor difference between these two groups could be caused by the duration of the teaching period as it was done in only two afternoons. If more observations were conducted, perhaps different results could have been obtained. Another factor that could have affected the findings was the teacher's beliefs regarding teaching the topic, that is, unfamiliarity with the simulation.

Teachers' beliefs regarding teaching have an impact on the teaching and learning process. This statement is supported by Kriek and Stols (2010), who studied teachers' beliefs using simulations in teaching Physical Science lessons. The outcomes of their study revealed that the effective utilisation of simulations depended on the teachers' attitude towards the PhET simulations that they used in the study. The attitude of the teachers, in turn, contributed to the performance of the learners.

In contrast, a study by Kotoka and Kriek (2014), which investigated the performance of learners in electromagnetism, showed that the performance of Grade 11 students was improved by using computer simulation. This was the case as the control group in the post-test was outperformed by the experimental group. Their findings concur with a number of scholars such as Dega *et al*. (2013), who investigated physics undergraduate learners' conceptual gains in electric change, energy and electromagnetism. Plasset *et al*. (2012) examined the effectiveness of interactive computer-based simulations in secondary schools in ideal gas law, phase change and kinetic molecular theory. Lastly, Jaakkola *et al.* (2011) compared the learning outcomes of learners learning through simulations with learners using real circuits. Their results suggest that simulations improve learners' understanding of scientific concepts and thus lead to the better performance of the learners.

In an attempt to understand teachers' use of CBS, the researcher also considered how the teachers integrated the CBS with the other teaching strategies. This also includes how each teacher introduced, used and assisted the learners while using CBS, the kind of questions asked, and how s/he referred to the CBS. Such practice also depends on the teacher's PCK. Thus, there is a need to discuss the meaning of PCK in detail.

2.5 Reviewing some PCK models

The PCK concept was introduced for the first time by Shulman in 1986, describing it as a teacher's ability to simplify the knowledge of content into simpler, easier-to-learn units for learners. Shulman (1987) argues that teachers' knowledge should be divided into seven groups. These are:

- Content knowledge;
- General pedagogical knowledge;

- Curriculum knowledge;
- Pedagogical content knowledge;
- Knowledge of learners and their characteristics
- Knowledge of contexts and
- Knowledge of educational ends (goals and objectives).

Shulman (1986) goes on to explain that PCK is a form of knowledge that is used by teachers to guide their teaching in a contextualised classroom setting. For example, learners in a group differ in their learning ability, background knowledge, and learning styles. These differences might influence the choice of a teaching strategy that a teacher prefers. The choice of a teaching strategy is both unique and personal, depending on the individual teacher's PCK, which may also influence how s/he structures and presents Subject Matter Knowledge (SMK) in directly teaching to learners, knowledge of common conceptions, misconceptions, and difficulties that learners have when learning about certain content (Shulman, 1986). It is a type of knowledge that is unique to teachers, and is based on the manner in which the teachers themselves relate their pedagogical knowledge, that is, what they know about SMK and what they teach (Grossman, 1990). The current study adapted the consensus Model of PCK, which resembles a complex version of the PCK Models discussed by Magnusson *et al*. (1999), among others.

Shulman's (1986) PCK model has evolved over the years and other scientists have developed their own theories related to it. Grossman (1990) agrees with the way in which Shulman perceives PCK, but has added a few additional components for his PCK theory to include teaching strategies, knowledge about science, SMK, science education, and a science programme. His theory contained three components as compared to that of Shulman. Grossman (1990) argues that SMK supports teachers' selection of factual, conceptual and competency-based learning objectives. The curriculum includes information on the aims and objectives of teaching specific subjects and on science education. It also includes the teacher's beliefs about science education.

Veal and MaKinster (1998) argue that PCK is structured in levels based on general PCK, as shown in Figure 2.1. The general educational pedagogy is the lowest and the widest. This includes the teacher's competencies in the application of pedagogical practices in different subject areas (Veal & MaKinster, 1998). Below this level is the specific PCK domain, which separates teachers from different subjects, such as physics or chemistry.

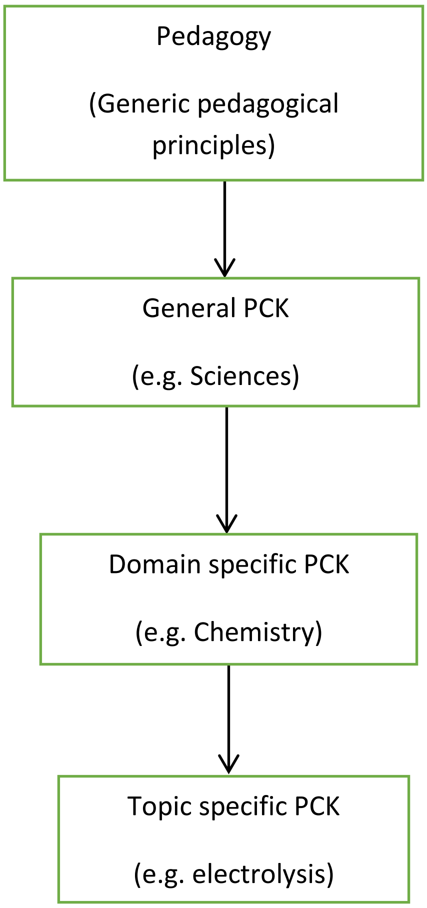

Figure 2.1: PCK taxonomy model (Veal & MaKinster, 1998)

Magnusson *et al.* (1999) present a PCK model similar to that suggested by Grossman (1990). However, they omit SMK and instead add the knowledge of the notation in their model. Assessment knowledge includes orientation in science education, programme information, students' information regarding science, information regarding instructional strategies, and information on what to evaluate (Magnusson *et al.*, 1999).

2.5.1 Teachers' orientation towards the teaching of science

Magnusson *et al.* (1999) use the word "orientation" to classify different methods for facilitating science. They also define the direction of science education in that the teacher knows and believes in the goals and objectives of teaching students in each class. These knowledge and beliefs give teachers the opportunity to choose course approaches at a specific time. Magnusson *et al*. (1999) also place emphasis on science education as a general means of perceiving or conceptualising science education. The list contains nine orientations, namely: activity-orientated, didactic, discovery, rigor, conceptual change, process, academic, project, and survey orientations. All of these orientations influence the classroom practices of a teacher. The aim of activity-driven orientation is to have learners be occupied with materials. The teacher acts as a facilitator and allows students to discuss concepts in order to determine how much the learners know. Didactic orientation is concerned with transmitting the facts of science. The teacher may do this by giving facts through using the lecture method or through the question and answer method. The discovery method gives learners the opportunity to discover something for themselves. This method focuses on the learner. Conceptual alteration concerns the expansion of scientific information by challenging learners with situations that explicate thinking about concepts where academic coherence requires particular knowledge. For example, learners receive challenging problems and activities to solve. The goal of the process is to help learners develop the skills of the scientific process. Learners participate in actions to develop shared intellectual processes and thinking skills. In project-based science, students study and develop products that reveal their understanding. Although research presents science as an inquiry, it is learner-centred. alternatively, the guided survey organizes a group of students whose associate members share the responsibilities of understanding the physical world.

Magnusson *et al.* (1999) further describe four knowledge domains related to the orientations to teaching science, which are represented in Figure 2.2.

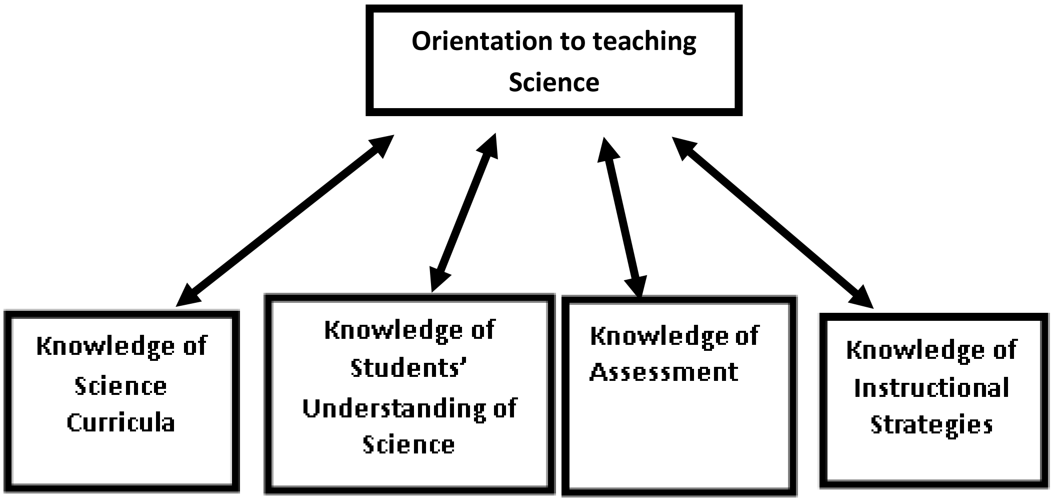

Figure 2.2: Relationship of the four components of PCK to orientation towards science teaching, as adopted from the Magnusson Model (source: Magnusson *et al.,* 1999)

2.5.2 Teachers' knowledge of the science curriculum

Curriculum may be defined in a number of ways. It can be viewed as what learners learn, what teachers teach, or the content of the suggested textbook (Bishop, 1985). In this study, curriculum is defined as what the teacher aims to teach, e.g. electrolysis in the chemistry section of the Physical Science syllabus. This includes teaching the materials to use, including equipment, the knowledge of time allocated for each sub-topic, and the textbooks to use in teaching electrolysis.

Magnusson's *et al.'s* (1999) knowledge of a scientific programme is divided into two categories: knowledge of the objectives and goals of science, and knowledge of specific curriculum and instructional materials that may contain relevant or informative manuals that can be used.

2.5.2.1 Knowledge of goals and objectives

Knowledge of objectives and goals refers to the educator's understanding and interpretation of the guiding principles for teachers, such as the syllabus (Magnusson *et al*. 1999). Goals and objectives guide the teacher on what is to be taught. The articulation of goals and objectives helps in that the teacher knows exactly what to emphasise when teaching. For example, one of the lesson objectives in the topic 'Experimental Techniques' is for the pupils to be able to state the differences between pure substances and mixtures and the teacher has to stress this when teaching. Knowledge of objectives and goals also comprises a teachers' skill in arranging related concepts. Arranging concepts includes the knowledge required to understand the next topic. Goals and objectives are illustrated in the national curriculum and assessment documents (Magnusson *et al.,* 1999). Official national documents that are used in teaching in Swaziland include the daily preparation book and the scheme of work. The scheme of work specifies information such as subject matter to be taught, the teaching materials necessary for each topic, and the actual date for completing a topic. The daily preparation books have lesson plans, which have information such as the knowledge required for each topic and the lesson objectives.

2.5.2.2 Knowledge of curriculum programmes and materials

Magnusson *et al.* (1999) argue that knowledge of curriculum programmes and materials denotes information about what teaching programmes and materials are suitable for a particular concept. In Swaziland, teachers employ the long-term and short-term planning of lessons that use objectives to guide the use of teaching and learning materials (Magnusson *et al*., 1999). Since preparing for a lesson involves long and short-term planning, one expects teachers to prepare for a year, giving details such as the anticipated date of finishing a chapter in their scheme of work. The lesson plans, alternatively, provide short-term planning for each lesson.

The textbook is a resource material that most educators describe as the primary teaching material (Bishop, 1985). Additional resource materials that can be used also include the internet. In this study, science teachers are also expected to be well-informed about the different programmes at each grade level. In Swaziland, the SGCSE is offered in all public schools while private schools choose to do Matric or the SGCSE, IGCSE and CIE syllabuses.

2.5.2.3 Sequence of instruction

According to Magnusson *et al*. (1999) understanding what learners learn in the course allows the teacher to articulate scientific knowledge vertically in a planned course sequence. Knowledge of what is taught in other disciplines provides educational support that promotes the learning of cross-cutting ideas (horizontal articulation).

2.5.3 Teachers' knowledge of learners' understanding of science

Magnusson *et al.* (1999) explain that knowledge of learners' scientific comprehension refers to teachers' knowledge of the level of understanding of scientific knowledge to help students acquire specific scientific knowledge. This means that a teacher needs to pay attention to the knowledge and skills that learners need to learn about specific topics, the common misunderstandings that learners bring to the classroom, and the concepts that learners find difficult to learn. For example, some students find electrolysis difficult to understand. In this section, learners usually have difficulty with which electrode has been oxidized/reduced. Magnusson *et al*. (1999) classify learners' understanding into two categories: information of the prerequisites for learning, and information on learning challenges.

2.5.3.1 Knowledge of the requirements for learning

Teachers' information about the requirements for learning refers to knowing what concepts and skills learners bring to class. Knowledge of learners' prior conceptions on the topic assists the teacher to know where to begin with instruction. Some learners may have misunderstandings in certain topics that may inhibit effective teaching. For example, teachers should ensure that learners are able to write and balance ionic chemical equations at the electrodes. Knowledge of the requirements for learning also include teachers acknowledging that learners have unique learning styles. This refers to a teacher's awareness that some learners learn best by listening, while others learn best by visualising and others by doing. To accommodate the different learning styles of learners, a teacher may highlight a point verbally and then write that point on the board and also, where possible, allow learners to do a practical activity.

2.5.3.2 Knowledge of learners' difficulties

According to the Magnusson Model, information about the areas of learners' challenges refers to educators' awareness of the challenges that the learners have in a particular topic and why a topic is difficult for them. Certain topics in chemistry are too abstract for some learners, making it difficult for them to learn with understanding. For example, most learners find stoichiometry very challenging. Knowing topics that are difficult for learners helps the teacher to come up with special interventions that support student learning and also help the teacher to decide on the appropriate methods to use. Knowledge of learners' difficulties includes teachers' knowledge of the common mistakes that learners make in different topics.

2.5.4 Teachers' knowledge of instructional methods

Magnusson *et al.* (1999) describe instructional methods as the methods and actions that educators choose to engage in to support learners. The activities embarked on are instructional events that teachers use in class to deliver lessons. Teachers' knowledge of instructional methods consists of two groups, namely, knowledge of subject and topic strategies.

2.5.4.1 Knowledge of subject strategies

Magnusson *et al.* (1999) asserts that knowledge of subject strategies refers to the different approaches that may be used by a teacher for science instruction. Teachers' information on subject strategies depends on his/her orientation towards the teaching of science. For instance, the learning cycle consists of investigation, introduction of the term, and then application of the concept. This means that a teacher may find out from the learners what they know, then introduce the new concept thereafter for ease of understanding. After the concept has been understood, learners have to be able to apply that concept. For example, a teacher may start by recapping the properties of ionic compounds.

2.5.4.2 Knowledge of topic strategies

Information on topic strategies deals with educators' knowledge of particular techniques that are suitable for assisting students to understand certain scientific concepts (Magnusson *et al.,* 1999). There are two categories of knowledge on topic specific techniques, namely: topic specific representations and topic specific activities.

<u>Knowledge of topic specific representations</u>

Information on topic representations refers to educators' knowledge of different techniques to denote particular concepts and principles in order to expedite the learning of students. It also includes the educators' information on the strengths and weaknesses of the different representations. Topic specific representations can include analogies, models and examples or illustrations that teachers use to make concepts clearer for learners.

<u>Knowledge of topic specific activities</u>

Knowledge on topic activities refers to teachers' information on various activities that can be utilised to assist students to understand concepts and how concepts relate to each other. Examples of topic specific activities include a demonstration done by the teacher and practical experiments done by the learners, as well as their use of CBS in teaching electrolysis.

2.5.5 Teachers' knowledge of assessment in science

Magnusson *et al.* (1999) identify two categories of assessment knowledge in science, namely: knowledge of proportions of science learning to assess, as well as knowledge of the methods of assessment. To demonstrate knowledge of assessment, teachers have to be able to set their own tests that are balanced in terms of assessment objectives and content coverage. The tests should also test the main ideas according to the Physical Science syllabus.

2.5.5.1 Knowledge of assessed science learning dimensions

Teachers' awareness of the proportions refers to awareness of which science learning areas are important to be assessed (Magnusson *et al*., 1999). This requires the teacher to have a deep understanding of the subject matter in order to identify key concepts, principles and skills to assess learners' learning. For example, the tests that teachers set have to test the main ideas that are given in the chemistry syllabus.

2.5.5.2 Assessment methods knowledge

Knowledge on the means of assessment refers to educators' understanding of various techniques that can be employed to assess the outcomes of learning (Magnusson *et al.,* 1999). For example, there are traditional strategies such as written tests. Written tests can include true or false type questions or multiple choice questions. There are also non-traditional assessment strategies, which include assessment using the writing of a project. One of the objectives of teaching Physical Science is for students to be able to use techniques, apparatus and materials following a sequence of instructions. From this objective, it is expected that chemistry teachers give practical tests to assess learners on their experimental and investigative skills.

2.6 LATER PCK MODELS

Ball, Bass and Hall (2004) note that PCK involves teachers' knowledge, teaching context and purpose for teaching. Ball *et al.* (2004) further observe that teachers' knowledge of context encompasses the teacher's ability to handle large classes, deal with time limits, and scarcity of resources, as well as learners' attitudes towards the subject. The purpose for teaching also includes the aims of delivering a certain subject or curriculum (Ball *et al*., 2004).

Kind (2009) concurs with Veal and MaKinster (1998) that PCK is centred on a hierarchical structure and that teachers need to be subject specialists in order to become effective and expert teachers. Possession of specific and specialist SMK provides a foundation for the planning of a lesson and knowing how to engage with students (Childs & McNicholl, 2007). Good SMK indicates a sense of self confidence. Where good SMK is not available, teachers demonstrate a poor comprehension of learners' learning challenges linked to science. Such teachers tend to use instructional strategies that lead to learners being passive during lessons (Childs & McNicholl, 2007).

When teachers fail to contextualise the content knowledge that they possess, there is a danger that their lessons will not go according to plan, even if they are specialists in the subject (Kind, 2009). Such a failure lowers the teacher's confidence, a situation that impacts negatively on the student. This study was thus carried out on the basis that teachers are expected to possess TSPCK in the subjects they teach. This study thus sought to explore teachers' use of CBS when teaching electrolysis and note teachers' views about using CBS. There is no evidence in the literature that there exists a study to discover teachers' views when doing CBS in Swaziland schools, and this constitutes a gap which this study hopes to fill.

2.7 THE MODEL OF ROLLNICK, BENNETT, RHEMTULA, DHARSEY AND NDLOVU

Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) constructed a PCK model to examine the impact of educators' content knowledge on the construction of their PCK. The aim of the model was to capture the effect of teacher knowledge spheres on their PCK from observable displays of educator knowledge in the classroom. The 2008 model of Rollnick *et al.* (2008) consists of four components: subject expertise, knowledge of students, general pedagogical knowledge, and contextual knowledge. These play a major role in the combination of indicators in the classes, which they refer to the manifestation of teachers' knowledge. The teachers must demonstrate an understanding of the domains.

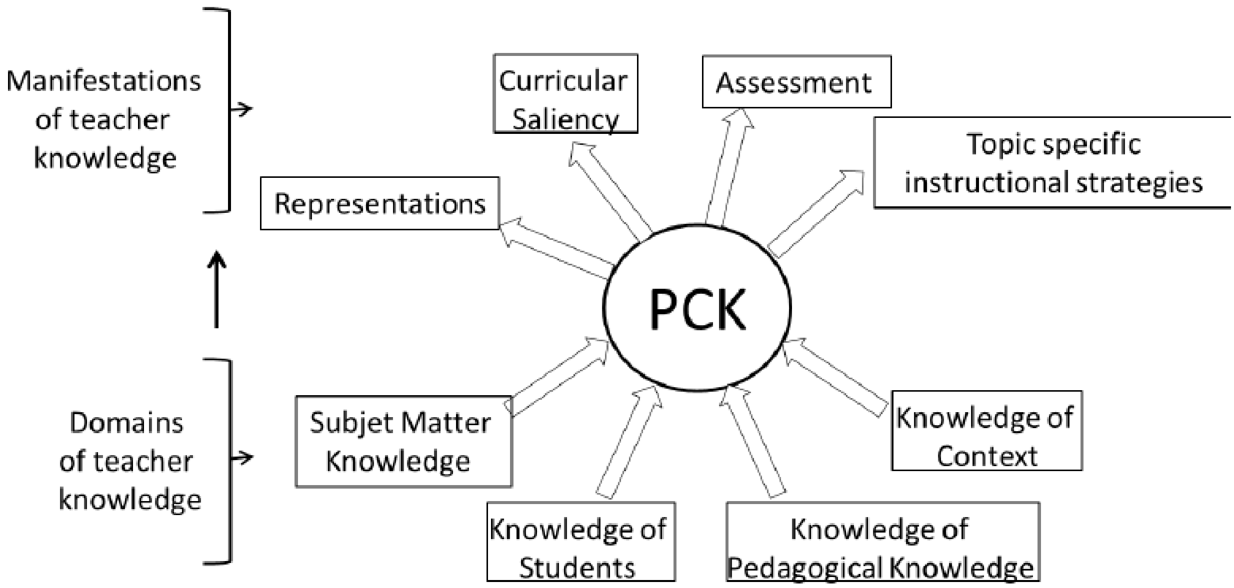

Figure 2.3: Rollnick *et al*.'s (2008) model of PCK

2.7.1 Domains of teacher knowledge

Knowledge of students

The possession of SMK and pedagogical skills is not enough to be an effective teacher. It is also important that teachers have an understanding of the prior knowledge, skills and beliefs that students bring to class (Bransford, *et al.,* 2000). These aspects influence how students view and interpret the environment and develop the ability to recall, reason, acquire new knowledge and solve problems (Bransford *et al.,* 2000). They further find that in planning a lesson, it is important to discover the learners' previous knowledge and misconceptions. Therefore, a teacher who overlooks students' prior knowledge will be ignorant of the topics that students find difficult and not know how to assist them (Bransford *et al.,* 2000). Teachers' understanding of the common misconceptions is also important. They need this understanding so that during a lesson they can place emphasis on those concepts.

Subject Matter Knowledge (SMK)

Content knowledge refers to a good understanding of what to teach (American Council on Education, 1999). It also includes information on theories and conceptual frameworks, including knowledge of development and accepted ways.

Knowledge of pedagogical knowledge

General Pedagogical Content Knowledge (GPCK) and PCK are central cognitive elements in the professional competence of teachers. Therefore initial teacher education focuses at the acquisition of this relevant knowledge. It has not been found however how GPCK and PCK can be separated from each other (. comprises knowledge of how learners learn, pedagogical techniques, assessment strategies, and information about various theories of PK learning. PCK is the knowledge of how pedagogy and content can be effectively combined. It is the knowledge of how to make a topic understood to learners. Archambault and Crippen (2009) argue that PCK embraces information on what makes a particular subject easy or challenging to learn, as well as popular misunderstandings and prejudices that learners bring to the classroom. This study focused on the instructional strategies that were used by the teachers, especially the use of and views regarding computer simulations as an instructional strategy. The use of computer simulations requires computer literacy. As such, there is a need to discuss what technological pedagogical content knowledge entails.

Knowledge of context

Educators are restricted in terms of what they can do in their own setting. For instance, educators with inadequate technological equipment cannot teach CBS to students. School time, training and assessment also affect how technology is utilised in classrooms. Background is therefore a significant factor.

2.7.2 Manifestations pf PCK

Assessment

Assessment is an integral part of the instructional process where it helps students to learn (Goodman, 2012). This requires teachers to be able to develop appropriate strategies to promote learning through assessment, as well as ascertain such learning. Lacking knowledge of assessment results in teachers relying mostly on assessments offered by the publishers of their textbook or learning materials (Goodman, 2012). Goodman further observes that when there is a non-availability of suitable assessment, teachers come up with their own in a chaotic manner where the tests that are set do not cover content at different levels. The test items may be at knowledge and comprehension levels only and not require students to apply knowledge. Such tests are therefore not balanced in terms of level of demand and assessment objectives. According to Goodman (2012), assessment has to reflect the concepts and skills that the teacher emphasises in class.

Curricular saliency

Curricular saliency relates to the understanding of both goals and objectives of teaching a specified topic. Knowledge of curricula enables a teacher to have enough knowledge about a topic such that they can prepare a lesson plan indicating teaching method, teaching material to use, teacher activity and student activity. A teacher has to present the content to students in a confident manner during a lesson, emphasise the main ideas and answer questions about the subject. According to Bransford *et al.* (2000), teachers who lack knowledge of the curriculum will fail to write appropriate lesson plans with relevant objectives, or know what to emphasize during the lesson. Teachers also have to understand vertical curriculum, that is, prerequisite knowledge of each topic and thus start from simple to abstract for related topics, that is, the sequencing of related concepts. Teachers also have to understand the horizontal curriculum, that is, related topics in different subjects so that they can discuss these with other teachers to cover related topics at the same time.

Representations

Knowledge of representations refers to teachers' knowledge of the subject matter, the symbols and the chemical equations that are used in science which are suitable for a specific topic.

Topic Specific Instructional Strategies

Topic specific instructional strategies refer to the selection of appropriate teaching methods for a specific topic. Once a teacher has identified that specific teaching method, s/he has to be able to integrate it smoothly into the content.

2.8 MAVHUNGA'S PCK MODEL

Mavhunga (2012) designed a PCK model based on teachers' beliefs, PCK components and the transformation of specific content, as presented in Figure 2.4. The model is divided into two sections, the upper and lower part. The lower part includes four areas of teacher knowledge, namely: subject knowledge, student knowledge, contextual knowledge, and general pedagogical knowledge. The lower section also contains teachers' beliefs as an underlying factor that influences the teacher's knowledge and vice versa. The field of knowledge integrates the production of PCK, which manifests itself during class in various forms. The upper part of the model consists of the manifestation of the teacher's knowledge.

Teachers' beliefs towards the teaching of science

Teachers' beliefs towards the teaching of science refers to what teachers know and believe the goals and objectives are for instructing science learners at each grade level. This information and belief guide the teacher's choice of teaching strategies to use at a particular time. It can also be referred to as a manner of seeing or conceptualising science facilitation in a general manner. For example Volkinsteine, Namsane and Cakanes (2014) examined teachers skills for organizing learners' scientific inquiry noted that teachers fail to understand that the inquiry process requires active participation by learners in the teaching process and a change in the teachers' role from an information provider to a facilitator is not practiced. Teachers still use the teacher centred approaches. This finding concurs with Milner, Sondergeld, Denir, Johnson, Czerniak (2012) who argued that teachers' beliefs about teaching science remained unchanged despite policy changes implemented in 'No Child Left Behind' (NCLB). They pointed that teachers' beliefs related to their perceptions of what their administrators think and they mostly teach the way they themselves were taught, that is, the traditional approaches of teaching.

Subject Matter Knowledge (SMK)

Subject Matter Knowledge may be viewed as what students learn, what teachers teach, or the content of the recommended textbook (Bishop, 1985). In this study, SMK is defined as what the teacher intends to teach in the electrolytic cell, a section of the Physical Science syllabus. It also includes the teaching materials to use, pre-requisite knowledge needed for the topic of the electrolytic cell, curricular saliency (understanding what learners learn in the subject area makes it possible for teachers to articulate scientific knowledge vertically in a planned sequence of instruction). Also, what is difficult to teach and the use of appropriate of teaching methods, the use of appropriate examples and questions during the lesson and in testing fall under this domain.

Learners' knowledge

Students' knowledge refers to the knowledge that teachers have about their students' level of understanding of scientific knowledge. This assists students to develop specific scientific knowledge. It means that a teacher has to be aware of the skills and knowledge that learners need in order to learn particular content. Teachers have to acknowledge that students have different learning styles (audio, visual and kinaesthic). When teaching, they have to combine different teaching strategies to reach all of the learners. This means that the teacher has an awareness that some students learn best by listening while others learn best by visualising. To accommodate the different learning styles of students, a teacher may emphasise a point verbally and then write that point on the board and also, where possible, demonstrate the use of CBS and let the students use the CBS.

Pedagogical Knowledge

Pedagogical knowledge is a generic aspect. It refers to what teachers know about teaching in general. It is not subject specific, but it is the understanding of basic concepts used in teaching.

Students' contexts

Student context refers to the different background of the learners. It also refers to there being a large number of pupils in the class. The teacher has to be able to overcome the challenges that may be faced by the group of learners taught. The challenges may include shortage of teaching materials.

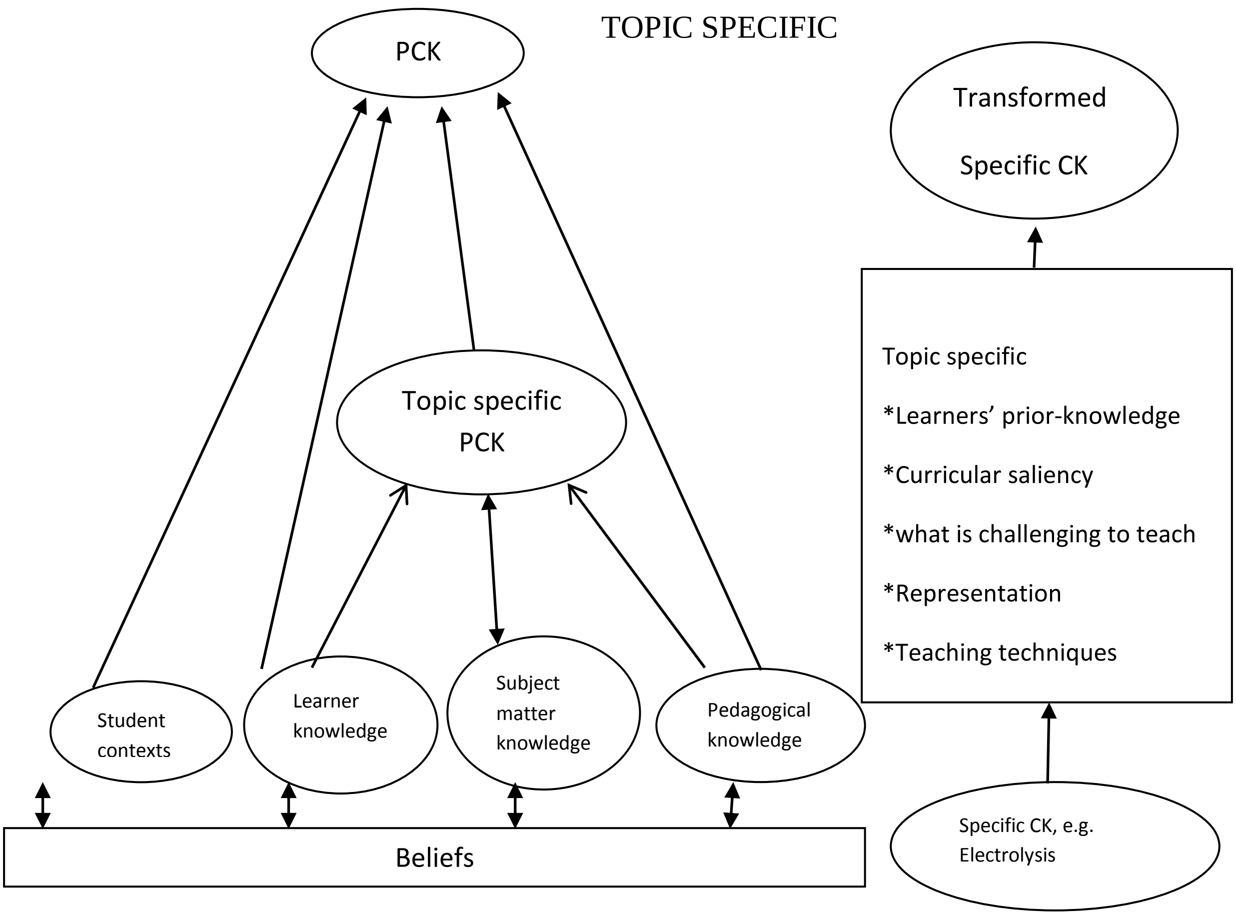

Figure 2.4: Mavhunga's (2012) PCK Model

Topic Specific Pedagogical Knowledge

Mavhunga's (2012) Model also indicates that teachers are expected to have PCK for a specific topic, the topic of interest in this study being electrolysis. The teacher applies this knowledge to transform their own content knowledge into a form that is understandable to learners. The aspects of this TSPCK, according to Mavhunga (2012), are described as: representations, teaching strategies, topics that are challenging to teach, curricular saliency, and learners' prior-knowledge.

Teaching strategies

Teaching strategies are the different teaching methods that a teacher may use and feel are appropriate to teach a certain topic. These teaching methods may be group discussions, practical activities and/or the question and answer method.

Representations

Representations refer to the examples and illustrations that a teacher may use to enhance learners' understanding of the topic.

Learners' prior knowledge

Learners' prior knowledge refers to what learners are expected to know about the topic before it is covered. This may also include the common misconceptions that learners hold.

Topics that are difficult to teach

This refers to teachers' knowledge of the challenging concepts in electrolysis and the means of assisting learners to overcome those challenges.

Curricular saliency

Curricular saliency refers to the vertical order in which concepts have to be taught, that is, starting from simple to complex in a topic.

2.9 The Consensus Model of PCK

Teachers' use of CBS in teaching electrolysis depends on their PCK. This is because they have to be able to demonstrate their skill in combining it with other teaching strategies, such as discussion, be knowledgeable about learners' misconceptions, and be able to use these differently from other teaching strategies, showing how it improves teaching and learning. Thus, this study adapted a theoretical framework known as the Consensus Model, which was developed at a PCK Summit in Colorado Springs. This model was chosen because it involves the relevant components of PCK which was used in this study as an indicator of teachers' views about using CBS in teaching electrolysis. The Consensus Model was used in this study because it clearly states what each component entails. It became easy for the researcher to identify the indicators and that made it possible for the researcher to know what to look for during data collection and data analysis.

The model assumes the existence of a broad Teacher Professional Knowledge Base, which also comprises knowledge of assessment, knowledge of pedagogy, content, and learners. Knowledge of subject-specific content is recognised as professional knowledge resulting from research literature and best practices in teachers' professional knowledge base. This knowledge underpins Topic Specific Professional Knowledge, which contains information on teaching techniques, content descriptions, learners' understanding, scientific practices, and thought patterns. Between subject-specific expertise and pedagogical practice, there are amplifiers and filters, which are the beliefs, orientations and contexts of the teachers. These amplifiers and filters impact the decisions and behaviour of teachers. The teachers' classroom practice provides the basis of learner outcomes, yet student behaviour, beliefs and previous knowledge act as amplifiers and filters in terms of their learning outcomes.

This model is not simply a linear process. The student outcomes influence pedagogical practice, specialised knowledge and curricular knowledge. Thus, each part of the model has a major impact on the other parts and offers opportunities for professional development. However, in this study, students' results were not investigated as this study did not focus on the learners but rather only on teachers.

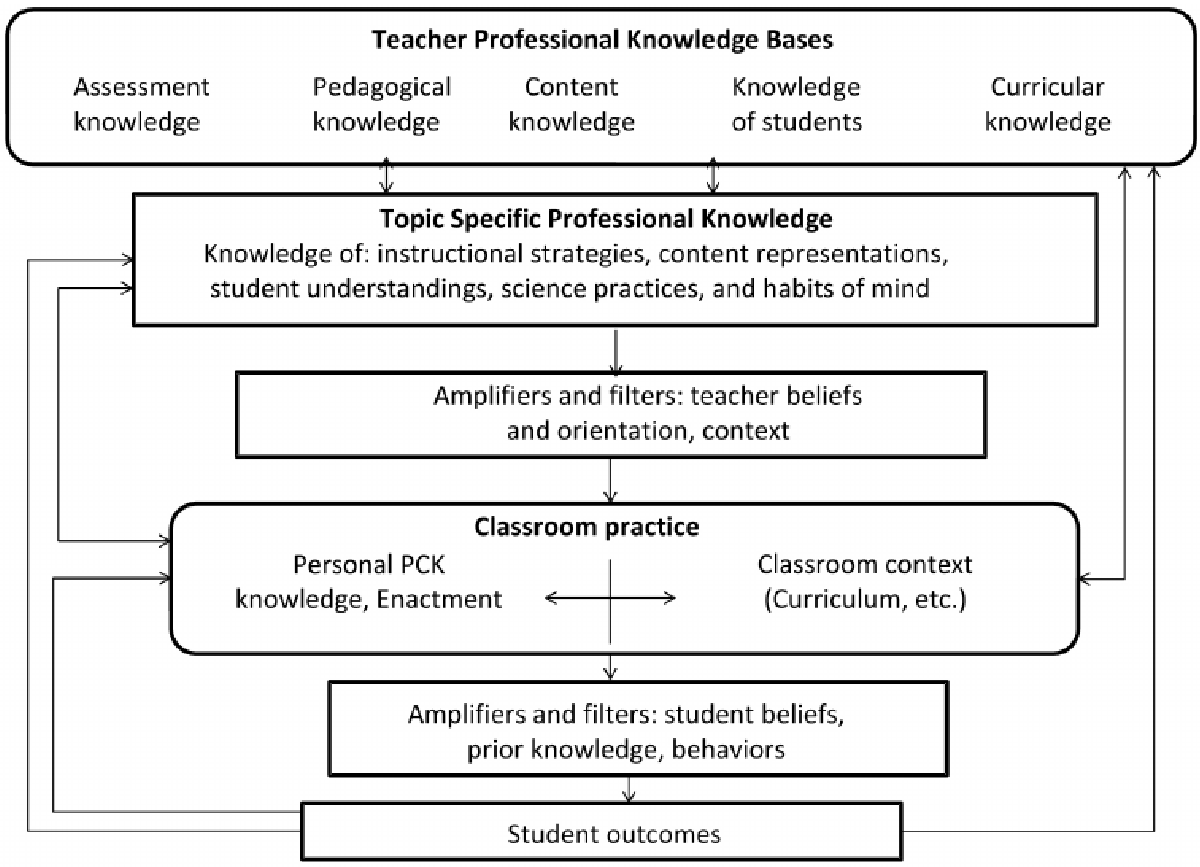

Figure 2.5: Theoretical framework: the Consensus Model of PCK from the PCK summit (Helms & Stokes, 2013; Gess-Newsome & Carlson, 2013).

2.9.1 Teacher professional knowledge bases

There are four components in the professional base, namely: knowledge of students, content knowledge, pedagogical knowledge, curricular knowledge, and assessment knowledge. Each of the components is discussed below:

Knowledge of students

Teachers' possession of SMK and pedagogical skills is not enough to make them an effective teacher. It is also important that teachers have knowledge of the prior knowledge, skills and beliefs that students bring to class (Bransford, Brown & Cocking., 2002). These aspects influence how students view and interpret their environment and develop the ability to recall, reason, acquire new knowledge and solve problems (Bransford *et al.,* 2002). The authors further explain that in planning a lesson, it is important to find out the previous knowledge of learners as well as learners' misconceptions. Therefore, a teacher who overlooks students' prior knowledge will be ignorant of the topics that students find difficult and not know how to assist them (Bransford *et al*., 2002). Teachers' understanding of the common mistakes that students make is also important as during a lesson the teacher can then place emphasis on those concepts. Knowledge of students also influences teachers' choice of instructional strategy. While planning for a lesson, teachers have to use teaching strategies that promote effective learning and thus lessons have to be interesting for learners.

Content knowledge

Subject knowledge comprises a thorough comprehension of the subject material to be taught (American council of education, 1999). It also includes information concepts, theories, conceptual frameworks, and information about recognised ways of generating knowledge. In this study, content is described as what the teacher anticipates teaching in the electrolytic cell, a section of the Physical Science syllabus. It further includes teachers' use of appropriate examples, analogues and representations to explain abstract concepts.

General pedagogical knowledge

PCK is defined as being specific to a subject, it exists in a specific class context, and can be considered as a knowledge base and a skill group. General pedagogical information contains information on how learners learn, pedagogical methods, and assessment techniques. Understanding the various theories of PK learning alone are inadequate for educational purposes.

Curricular knowledge

Curricular knowledge includes teachers' knowledge of the main ideas in the topic being taught, that is, Subject Matter Knowledge (SMK). It also includes teachers' ability to sequence topics starting from simple to abstract topics. Curricular knowledge, understanding what students learn in the topic, makes it possible for the teacher to articulate vertical scientific knowledge in a planned sequence of instruction. It also comprises the knowledge required for the topic of the electrolytic cell, and teachers' knowledge of the importance of teaching electrolysis.

2.9.2 Topic specific professional knowledge

Within the professional knowledge base of teachers there is specific expertise on the subjects that affect each other. Subject-specific expertise consists of understanding teaching techniques, content depictions, and learners' comprehension of scientific habits and practices.

Strategies of instruction

Instructional approaches refer to the diverse teaching that may be used by a teacher that is topic specific, for example, practicals that relate to electrolysis or CBS being used to teach electrolytic cells. It also includes how teachers introduce, use and assist learners while using CBS.

Content representation

This refers to the chemical and ionic equations, the symbols that can be used in electrolysis to represent, for example, the electrons.

Student understanding

This refers to teachers' knowledge of the common mistakes that learners make in electrolysis, as well as how to assist learners.

Science practices

Science practices include the observation, measuring and manipulation of data. Topic specific professional knowledge influences the amplifiers and filters below it, which are discussed in the sections below.

2.9.3 Amplifiers and filters

Amplifiers and filters consist of teachers' beliefs and orientation towards the teaching of science.

Teachers' beliefs and orientation

This mainly concerns teachers' views on why it is important to teach electrolysis as it influences their choice of teaching method. For example, a teacher may teach mainly for learners to pass an examination, not for understanding the syllabus. Such a teacher may talk at the learners and not engage the learners in the lesson.

Context

Context, alternatively, refers to the environment in which learners are learning. A teacher has to be able to teach in trying conditions such as overcrowding and having a shortage of teaching material. However, teachers have to improvise when there is a shortage of teaching materials, which means that they have to be innovative in their teaching. The amplifiers and filters then influence classroom practice, which is discussed next.

2.9.4 Classroom practice

This category includes personal PCK and enactment. These both influence the classroom context, which is a component of classroom practice. This includes what teachers do in class. What teachers practice is influenced by the challenges in the classroom, such as a shortage of equipment may force teachers to demonstrate the concept. The classroom practice then influences the amplifiers and filters that include students' beliefs, prior knowledge and behaviours.

2.9.5 Amplifiers and filters: students' beliefs, prior knowledge and behaviours

This component includes learners' understanding of why they learn electrolysis, learners' prior knowledge, and their behaviours, which may include their enthusiasm towards learning electrolysis, i.e. how interested they are in the topic.

2.10 TEACHERS' DEVELOPMENT OF PCK

Several scholars have distinguished aspects that contribute to PCK development. According to Brownlee (2007), the first source is teaching experience. Empirical studies have shown that visible improvements in PCK are made during the early months of someone's teaching career. The second PCK aspect is disciplinary knowledge, which concerns CK. Possession of CK is necessary for the presence of PCK. CK positively influences teachers' decisions and beliefs regarding the relative importance of particular subject content and their selection and use of curriculum materials. Brownlee (2007) showed that a course on CK had a positive influence on teachers' content knowledge in facilitating mathematics, which is related to PCK. Fourthly, "apprenticeship of observation" has been distinguished as another aspect of PCK development. Apprenticeship of observation refers to the influence of teachers' previous experiences as a learner in their current facilitation models. These memories, however, may limit teachers to only rely on familiar curricular materials and approaches. Haston and Leon-Guerrero (2008) have empirically revealed that educators consider their memories of previous education as a significant PCK source. Fifthly, teachers' cooperation with colleagues has been described as a possible source for PCK development. According to Kind (2009), the provision of a supportive working environment that encourages collaboration may benefit teachers' PCK development. Haston and Leon-Guerrero (2008) have empirically shown the importance of cooperation with colleagues for PCK development. Finally, the sixth possible source for PCK development is reflection on educational practice.

A study by Evens, Elen and Depaepe (2001) investigated intervention research on PCK without being restricted to a particular disciplinary domain. It is not clear what elements should be incorporated in interventions in order to make them effective for PCK development. Thus, the study sought to discover the effective elements by comparing several intervention studies. When looking simultaneously at the main actors and the locations of the interventions, the most frequent combinations are those with an expert facilitator and an off-site location, and those with an expert facilitator and both an on-site and an off-site location.

Recent Australian policy papers and curricula highlight the importance of digital technologies as tools for teaching mathematics in Australian schools to improve the quality of learning and teaching in mathematics classes (Butt & Smith, 1987). The Standards of Excellence describe excellent mathematics teachers as determined and professionals who responsibly use a wide range of methods and techniques to utilise Information and Communication Technologies (ICTs) in the classroom. Goos and Bennison (2008) used a survey to examine the nature of knowledge about the technological education content (TPCK) of mathematics teachers at high schools. The results show that the integration of teachers' technology skills into teaching and learning needs to be improved to meet high quality standards in schools. In addition, the teaching skills of ICT teachers are of great value to professional development planning. More recently, the Australian Mathematics Curriculum Document highlighted the important role of digital technologies as a mathematics learning tool (Norton, McRobbie & Cooper 2000, Chinnappan & Thomas 2008). Teachers' perceptions of their technological abilities and the perception of the benefits of ICT for teaching were considered to be strong predictors of intended and actual use. Although technology can improve the learning and teaching of mathematics, ICT tools are often used for certain established practices.

2.11 STUDIES ON PCK IN TEACHING CHEMISTRY

A study by Rollnick *et al.* (2008) explored the influence of SMK on PCK when teaching the mole concept. The findings show that teachers were more comfortable with procedural approaches than conceptual understanding. Another study by Vokwana (2013) evaluated the extent to which educators of organic chemistry are able to change their content knowledge to topic-specific PCK. The findings from the study revealed that most teachers demonstrate more content knowledge as compared to TSPCK. Vokwana (2013) concurs with Rollnick *et al.'s* (2008) study as it reflected high scores obtained in SMK compared to TSPCK. In both studies, two types of knowledge were explored, that is, knowledge of content and TSPCK.

Mavhunga and Rollnick (2013) investigated whether teaching student teachers to explain PCK in one subject could be applied to another topic. The study used a model for TSPCK based on five components, namely: prior knowledge of the teacher, curriculum saliency, what makes a subject easy or difficult to understand, representations, and conceptual teaching. The results of the study by Mavhunga and Rollninick (2013) showed that the development in a methods course allows a transfer of pedagogical knowledge from one topic to another, provided that teachers have the knowledge of the necessary content. These results are consistent with those of Vokwana (2013), who showed that inexperienced teachers had lower TSPCK levels than more experienced teachers.

Mulhall*,* Berry and Loughram (2003) conducted a study in Australia exploring teachers' PCK. In the study, they investigated whether it was possible to enhance a teacher's topic-specific PCK in using Content Representations (Co-Res). Co-Res is a tool that presents science teachers' understanding of particular aspects of PCK in terms of what they consider as main ideas to be learned by students in a topic (Loughran, Mulhall & Berry, 2004). According to Mulhall *et al.* (2003), the framing of Co-Res has the potential to trigger teachers' thinking about why it is important to choose a certain teaching approach for a certain topic and for certain groups of learners. They assert that Co-Res helps teachers to think about what to expect and not to expect from learners when teaching a certain topic. Their findings concur with those of Magnusson *et al.* (1999) and Veal and MaKinster (1998) in that teachers need to have topic-specific PCK for them to teach specific topics in ways that improve learners' understanding.

The difficulty of science subject matter and time constraints were some of the concerns highlighted by five novice and experienced science teachers in America in a study by Davis, Petish and Smithey (2006). Davis *et al.* (2006) compared the PCK of novice and experienced teachers using classroom observations and interviews. They found that teachers need to develop their subject matter knowledge, and also apply PCK in order to become effective teachers. They also found that the novice teachers lacked confidence in teaching due to inadequate subject matter, although they were fully qualified and were subject specialists. This constrained novice teachers in converting abstract concepts into transmittable simple concepts that learners could easily understand. These findings concur with those of Mbajiorgu and Reid (2006), who attested to the notion that chemistry is a complex subject. Therefore, teachers who have not developed PCK have challenges in manipulating subject matter knowledge to enhance students' understanding of concepts. These scholars seem to concur that science teachers need to develop their subject matter knowledge and PCK for them to become effective teachers.

Technological advances challenge teachers to enhance their PCK by venturing into information technology as a resource for teaching. Strong PCK can be a good base when exploring how teachers could tap into technology to boost the learning process. A study by Niess, Sadri and Lee (2009) on measuring teachers' PCK in the US showed that a good base of PCK can influence the choice of technological teaching strategies, making lessons learner-centred.

Subject-specific PCK is another trend that has been a subject of interest in educational research. Okanlawon (2010) constructed a framework for teaching stoichiometry using PCK in Nigeria. The novice secondary school science teachers in his study had difficulties integrating content knowledge with pedagogy into a comprehensible form for learners. He further stated that conveying content knowledge was strongly influenced by contextual factors such as the teachers' classroom management ability, the constraints of the curriculum, and the teaching experience of the teacher. To improve on these challenges, he suggested that teachers need to be equipped with adequate topic-specific pedagogy. He described this pedagogy as knowledge that enables teachers to vary and improve the methods used in teaching stoichiometry. Regarding the same issue, Okanlawon (2010) concurs with Veal and MaKinster (1998), who find that teachers need to have topic-specific PCK to be effective in their facilitation of the content. Magnusson *et al.* (1999) also indicate that an educator with topic-specific PCK is able to use appropriate examples and analogies in a lesson. Mulhall *et al.* (2003) also observe that topic-specific PCK is important in improving science teaching.

Park, Jang, Chen and Jung (2010) attempted to find out if teacher PCK is needed to improve science education. They found that teachers' level of PCK is positively linked to the ability to teach. A teacher who has more PCK will probably use more advanced science teaching methods than a teacher who has poor PCK.

Petersen (2011), who conducted a study in South Africa, reported on the approaches and problems experienced by Life Sciences teachers in the implementation of a learner-centred, inquiry-based curriculum that was meant to improve the teaching of science. The study indicated that the use of the lecture method in science teaching in South Africa remains the daily practice in a number of classrooms. The reasons for the use of the lecture method included teachers' lack of PCK, a constantly changing curriculum, poor functioning of supportive communities of teaching, as well as a shortage of science and computer laboratories. One of the solutions suggested in the study was the introduction of a Training Development Programme (TDP) to cater to the individual needs of Life Science teachers and to enhance their PCK.

The measurement of teacher learning during a problem-based learning approach to professional development in science education was researched by Weizman, Covitt, Koehler, Lundeberg, Oslund and Low (2008). They measured changes in the understanding of science teachers (content knowledge) and PCK in problem-based learning from professional development. Preliminary tests and post-tests were used as data sources to capture the teachers' concept map for the great scientific ideas associated with the chosen focus topic. Forty-five teachers took part in a one-week professional development workshop. The teachers were grouped according to the subjects that they taught, namely Earth Science, physics, and Life Sciences, but only the physics group showed a significant change in conceptual understanding. The level of knowledge and assessment of the curriculum had increased significantly for all. The results show that only one group developed conceptual understanding, and that professional development did not result in increased profits for all teachers.

2.12 The research gap

The studies discussed above explored how CBS enhances learning, difficulties in teaching and learning electrolysis, and science teachers' PCK. The researcher identified a gap in understanding how CBS can be used to enhance the learning of electrolysis. Therefore, this study was undertaken to understand teachers' use of CBS in teaching electrolysis using the consensus model of PCK as a theoretical frame.

2.13 Theoretical Framework

This is the philosophical basis on which the study was conducted and relates the theoretical aspects to the practical components of the study. A research process is a step-by-step process for finding answers by effectively locating information for a study (Williams, 2007). Every study is based on something. This is generally a broad theoretical area in the existing literature. A theoretical framework therefore refers to the philosophical foundations of a study. Decisions at each stage of the research process are shaped by such a philosophical foundation (Mertens, 1998). The theoretical framework provides the lens through which research is considered. To explain a theoretical framework, Sinclaire (2007) notes it can be defined as a map that people refer to when travelling in a foreign country, not only asking for directions, but also using past experiences and consulting people who have been there before.

It is therefore clear that a theoretical framework indicates the direction of a study. This ensures that the research process and the resulting decisions in each step are guided by clear philosophical assumptions. Sinclaire (2007) further notes that at the beginning of a research activity, the relevant theory underlying the knowledge base of the phenomena to be explored must be taken into account. In this study, which aims to understand teachers' use of CBS in electrolysis, it is important to consider teachers' PCK in the topic of electrolysis as their decisions are expected to be based on their PCK. Therefore, the Consensus Model of PCK was chosen as a theoretical frame as it not only describes teachers' knowledge components, but also the amplifiers and filters that represent teachers' views.

2.14 CHAPTER SUMMARY

This chapter reviewed the literature related to CBS as a teaching strategy, followed by literature about teaching electrolysis. Some PCK models were also reviewed to present a background to the theoretical framework that was used in this study. The next chapter focuses on the methodology that was used to carry out this research.

CHAPTER 3 METHODOLOGY

3.1 Introduction

Research consists of a series of phases in which information is collected and analysed to deepen the reader's understanding of the problem. It involves three phases: asking questions to gather empirical evidence, generating answers to the questions, and presenting answers to the questions (Creswell, 2008). Research methodology refers to a planned way of collecting information to answer research questions (Grove, Burns & Gray, 2013) or the phases, techniques, and approaches to generating and reviewing data in research (Polit & Beck, 2012). It should be noted that the research tactic identifies research approaches to be utilised, and shapes the way of conducting research. Basically, it concerns the processes of generating information and analysing its meaning. Research methods, however, must be consistent with a predefined research strategy (Guba & Lincoln, 1994).

This chapter includes an articulation of the research paradigm, design, and data generation, as well as data analysis methods. In addition, issues of rigor in research are discussed to ensure that factors that affect trustworthiness have been considered. The chapter concludes with ethical questions that were considered before the data collection. Therefore, in this chapter, I focus on the contextual practical arrangements with the participants, and the practical decisions made regarding the interpretation and synthesis of the data.

The various steps that I, as the researcher, adopted are discussed and explained in this chapter. This section justifies the data collection strategies and their selection. In addition, the sampling techniques are discussed and the trustworthiness addressed.

The following research questions guided the study:

Primary research question

> How can teachers' use of CBS in teaching electrolysis be understood?

Secondary research questions

1. What are the teachers' views on the use of CBS in teaching and learning
electrolysis?

2. How do teachers integrate CBS into teaching electrolysis?

These questions were used to obtain in-depth understanding of the phenomenon, therefore a qualitative research approach and a case study were chosen to observe the participants in their natural setting.

3.2 PARADIGM

A paradigm is a world view, a perspective about the complexity of the world (Polit & Beck, 2012). Nieuwenhuis (2007a) defines a paradigm as "a set of assumptions or beliefs about fundamental aspects of reality that lead to a particular worldview" (p. 47). Cohen, Manion and Morrison (2007) consider a paradigm as the philosophical intention to conduct a study. The paradigm that a researcher takes contains important assumptions about how he/she views the world. These assumptions point to the research strategy and methods chosen within this strategy.

The paradigm of research can be discussed in terms of positivism and post-positivism (McGregor & Murnane, 2010). Saunders, Lewis and Thornhill (2007) classify a paradigm in terms of the concepts of objectivity and subjectivity. The grouping of philosophies based on objectivity and subjectivity generates pragmatist philosophy. It can also be said that positivism corresponds to objectivity, while post-positivism corresponds to subjectivity or the combination of objectivity and subjectivity. Zaminto (2004) describes post-positivism as the over-arching word for a paradigm that denies a positivist approach. Thus, post-positivism could be called non-positivism (Hunt, 1991 & Niglas, 2001). The current study accepted Zaminto's (2004) claim that post-positivism is a philosophy that is not positivistic.

In social research, positivism argues that in reality, social entities exist outside of social actors who are concerned with existence (Saunders *et al.,* 2007). Positivism explains how social entities exist independently of social actors. Objectivism is thus associated with the paradigm of positivism (Polit & Beck, 2012). The ontological position of a positivist is that the real world is driven by real natural causes and the consequent effects (Wardlow, 1989). Epistemologically, the positivist is independent of researchers; and findings are not influenced by the researcher (Gall, Borg & Gall, 1996). Values influence the knowledge that is generated or information that is collected. Thus, a positivistic researcher retains values and bias in check to safeguard objectivity (Saunders *et al.,* 2007). A researcher looking at the world through the positivist paradigm describes the following attributes: emphasis on specific discrete concepts, focus on objective quantifiable data, and confirmation of the prediction of researchers. The researcher is external and separate; uses a solid, pre-specified design; has close control of the environment; uses large samples; collects measured quantitative data; uses statistical analysis; seeks generalisations; and focuses mainly on research outputs (Polit & Beck, 2012).

Research can also represent a post-positivist or subjectivist paradigm. In this paradigm, a social phenomenon is formed from the views and regular actions of the social actors who are concerned with their being (Saunders, Lewis & Thornhill, 2000). The post-positivist paradigm was coined in the mid-60s. The post positivism paradigm argues that there are numerous different types of knowledge besides making use of a scientific method (McGregor & Murnane, 2010). Post-positivism or subjectivism is associated with social constructionism (Saunders *et al.,* 2000). Social constructionism aligns with the interpretive philosophy, which investigates subjective meanings that motivate the actions of social actors in order to enable the investigator to understand these actions. Social constructionism sees reality as constructed socially (Gall *et al.,* 1996, Polit & Beck, 2012). The ontological position of social constructionism is that reality is subjective, multiple, and is constructed by individuals mentally shaping it simultaneously, not through cause and effect (Gall *et al.,* 1996; Wardlow, 1989). In post-positivist epistemology, the social constructivist interacts with those who are investigated; and insights are the creation of the interactive process (Saunders *et al*., 2000). The social constructivist uses the inductive processes that are basically aimed at the generation of theory. In social constructivism, subjectivity and values are unavoidable and desirable (Gall *et al.*, 1996; Saunders *et al.*, 2000. The paradigm of socio-constructionism is linked to the interpretive paradigm. In this paradigm, the emphasis is on the totality of some phenomena. The focus is on the subjective, unquantifiable data and all emerging insights. It uses small informative examples, generates narrative unstructured information, uses qualitative analysis, and focuses on the product and the process (Polit & Beck, 2012).

Finally, an emerging paradigm called pragmatism combines the paradigms of positivism and social constructivism. Pragmatism is the best philosophical basis for justifying the combination of different methods within a study (Ivankova, Cresswell & Plano Clark, 2007). Pragmatists argue that the truth works ‘best’ to understand a research problem (Patton 2002; Teddlie & Tashakkori, 2009). The main argument is that qualitative and quantitative methods are compatible. This means that both approaches have similarities in their core values that allow their combination in a single study (Reinhardt & Rallis, 1994). Therefore, a mixed methods study collects and analyses both numeric and textual data to address and fully understand the different aspects of the same general research problem (Ivankova *et al.,* 2007). Basically, the pragmatist paradigm tries to answer question such as how best to answer a research question. While the methods of positivism and social constructivism suggest different ways that can be used to answer research questions (Creswell & Plano Clark, 2011), the pragmatist philosophy contends that research approaches should be mixed in such a way that they give the best opportunity of answering key research questions (Johnson & Onwuegbuzie, 2004) and should be mixed in a complementary manner without overlapping weaknesses (Johnson & Turner, 2003).

From the foregoing discussion of paradigms, one can observe that there are different approaches to conducting research. These are largely dependent on the researcher’s objectives for undertaking a particular study. It begins with thoughts and eventually leads to action being taken, that is, put into practice. It further involves the way in which a researcher eventually interprets reality. The researcher has to choose an approach that best suits the study and helps guide their actions and beliefs.

Social scientists explore the behaviour, attitudes, beliefs, and perceptions of people, which are often unmanageable. The interpreters believe that the world is changeable and that people define and construct the meaning of a particular situation or phenomenon. Moreover, these meanings and constructions can be explored through qualitative data generation techniques. The interpreters believe that it is not possible to discover all the rules and laws of the social world, but it is possible to understand how people understand the context in which they live (Maree & Van der Westhuizen, 2007). Sarantakos (2005) defines interpretivism as the process of construction and reconstruction loaded with personal input. Sarantakos further argues that interpretivisim refers to people's views, opinions and perceptions as experienced and expressed in daily life. According to the interpretive paradigm, the goal of social science is to discover how people in natural environments build meaning and develop an understanding of social life. Interpretive researchers are interested in knowing what is relevant to the people being studied, as well as how these people experience their daily lives in their environment (Neuman, 2006). Interpreters have perception, meaning and understanding as the source of primary data or information (Mason, 2002).

Nieuwenhuis (2007b) explains that interpretation is rooted in hermeneutics, the study of theory and practice of interpretation. This philosophical theory of meaning and understanding and literary interpretation was developed in the 19th century. The interpretive perspective has the following assumptions. Firstly, the life of humans can only be understood from within. It can-not be observed by any external reality, which means that it cannot be viewed from the outside. Interpretivism therefore focuses on the subjective experiences of people, the way in which people 'construct' the social world by sharing meanings. Secondly, social life is a specifically human product; the interpretive approach assumes that reality is not objective, but socially constructed. The underlying assumption is that putting people in their social contexts gives researchers a better chance of understanding people's perceptions and activities. After all, the human mind is the source of meaning. By exploring the depth, and complexity of phenomena, one can start to understand the meaning that people give to a phenomenon and their social context. An important aspect of interpretive research is trying to make sense of the phenomenon from the perspective of the person being studied.

The current study was carried out within the interpretive paradigm as I tried to understand the behaviour of the participants. The interpretive paradigm was suitable for this study because it presented insight into the teachers' views of CBS, as well as their use of CBS in teaching electrolysis. Denzin and Lincoln (2008) point out that any interpretive research is guided by the perspectives, beliefs and feelings of the researcher about the world and how they should be understood and studied. While Hesse-Biber and Leavy (2006) argue that the interpretive ideology takes into account that social meaning arises when interacting with participants. In this study, I interacted with the chemistry teachers as they conducted their electrolysis lessons to observe how they used the CBS provided to them as a teaching strategy. Valid knowledge claims emerge as contradictory interpretations and possibilities are discussed. This refers to asking questions in interviews, gauging reactions from participants and then interpretating these. For these reasons, this research followed a qualitative approach.

Table 3.1 shows the methodological features of the current study. This is described in relation to the main question, the purpose of the study, the epistemology and the tools used in this study.

Table 3.1: Summary of the research methodology used in the current study (Adapted from: Huff, 2009)

Aspect	Description
Main question	How can teachers' use of CBS in teaching electrolysis be understood
Main purpose	To understand teachers' use of CBS in teaching electrolysis
Epistemology	This study used the interpretive paradigm
Approach	Qualitative
Instruments	Document analysis, interviews, questionnaires and observations

3.3 RESEARCH APPROACH

Basically, there are three approaches in research: quantitative, qualitative and mixed methods. The quantitative approach in research is where the researcher decides what should be studied, uses specific focused and narrow questions, gathers quantifiable data from a large number of participants, analyses data statistically, and carries out investigations objectively and impartially (Creswell, 2012). A quantitative approach is useful in answering the kind of questions that require quantitative answers. An examples of this is: What is the pass rate in science? Quantitative methods are suitable if the researcher wants to find out something about the statistical size of phenomenon being studied. Finally, quantitative research is particularly suitable for hypothesis testing, for example, if one would like to establish whether there is a relationship between student performance and self-esteem and social background (Geoff, 2010). McMillan and Schumacher (2006) note that quantitative research is based on data collection techniques such as questionnaires and methods for collecting and analysing the resulting information. Quantitative research involves the presentation of results using numbers, tables, graphics, and lacks in-depth analysis of the data or detailed information.

There is also the qualitative approach to research. Creswell (2012) asserts that in qualitative research, the researcher relies on the views of the participants, asks general questions, collects data consisting of participants' words, describes and analyses these words narratively, and directs the investigation. Creswell (2013) elaborates on this by defining qualitative research as an exploratory process of understanding based on a specific methodological tradition of investigation that examines a social or human problem - where the researcher builds a holistic picture, analyses words, and detailed views are recorded from informants. Such research is conducted in a natural environment. McMillan and Schumacher (2006) claim that qualitative data relates to everyday events and renders investigation techniques as inconspicuous as possible. They add that qualitative research is valuable in gathering specific details about opinions, behaviours, and relationships within a defined population, and highlighting the social implications of the subject being studied. Similarly, Polit and Beck (2012) argue that qualitative research provides detailed descriptions of human experience. Qualitative research deals with exploration, investigation and inductive logic (Patton, 2002). Moreover, it collects information through a human instrument (Creswell, 1994). Creswell also notes that qualitative data is descriptive and expressed in words. Qualitative studies support human perspectives, judgments, understanding and decision making (Muijs, 2004). Qualitative studies aim to understand people's everyday experiences and activities in their social life, thus capturing people's beliefs, views and values (McRoy, 1995). In qualitative research, the researcher assumes that social reality is constructed by those involved and that social reality is continually built up in local situations (Gall, Gall, & Borg, 1999). Qualitative researchers are concerned with how individuals perceive their world (Krathwohl, 1998) and these researchers interact with what, or rather who is being researched (Creswell, 1994).

Qualitative researchers are part of the data gathering process because the researcher is immersed in the data generation. This is the case as the researcher attempts to understand or interpret observed phenomena relating to the meanings attributed to particular events or situations. The researcher further spends a lot of time in the field, working closely with the natural environment of the research participants and working with the research participants to document and develop interpretations of events or situations (Creswell, 2013; Streubert & Carpenter, 2002). The data is context dependent and the researcher must be context sensitive (Morrell & Carroll, 2010). Qualitative researchers immerse themselves in the natural environment and focus on emic perspectives - perceptions, meanings, and interpretations known to the insider (Morris, Leung, Ames & Lickel, 1999). The researcher should also use, describe, analyse and interpret a dense description (Nieuwenhuis, 2007c). Data collection methods include, among others, unstructured interviews, focus groups, observations, and analysis of documents (Mason, 2002).

There is also the mixed methods approach in research. In a mixed methods approach, the researcher uses a combination of quantitative and qualitative methods in a single study (Tashakkori & Creswell, 2007). There are several reasons for using mixed methods. McMillan and Schumacher (2010) show that mixed methods are used for the following reasons:

(i) There is insufficient argument from either quantitative or qualitative approach;
(ii) A multiple angles argument is necessary
(iii) Creating more evidence for a better argument
(iv) Mixed methods may be the preferred approach within a certain scholarly community.

This study required a qualitative approach that is exploratory, i.e. it answers questions regarding the why and how of phenomena. Exploratory studies comprise an in-depth study of the phenomenon. This study followed the interpretative exploratory approach of Elliot (1999), who finds that an interpretive approach is open and that truth is achieved through dialogue between participants. Creswell (2007) agrees with Elliot in noting that in this world view, individuals seek understanding of the world in which they live and work and develop subjective meaning of their experiences.

The approach of qualitative research tends to be inductive, looking for a pattern of meaning based on the data collected (Musingafi & Hlatywayo, 2013). The qualitative approach examines methods and techniques that are described as naturalistic, ethnographic or observational. It emphasises the consideration of variables in their natural environment. Qualitative methods of data collection include a detailed study of a small sample and the collection of quality information (McMillan & Schumacher, 2010).

The qualitative method was deemed appropriate in the current study because it is used when examining the quality of relationships, actions, and situations. The method used by the researcher in data collection and analysis fits the characteristic features described in qualitative research (Fraenkel & Wallen, 2006; Hittleman & Simon, 1997; Lincoln & Guba, 1985). Researchers collect data within the natural environment of the information sought. Lincon and Guba (1985) state that humans are used as instruments due to their greater insight, ability to use unspoken knowledge, and ability to process and attribute data simultaneously with their capture. As the researcher, I explored the process of integrating CBS into electrolysis lessons and therefore had to take note of the overall context of electrolysis education and the school to describe the ongoing interactions during the teaching process. Musingafi and Hlatywayo (2013) also note that a qualitative research approach concerns recording, analysing and trying to uncover the deeper meaning. This study was purely qualitative because it allowed observations of practices that arise through interviews, observations, and interaction interdependencies between people (Hogan, Dolan & Donnelly, 2009). The qualitative approach allowed me to understand the phenomenon under study because I asked the teachers to clarify their understanding of the use of CBS in teaching electrolysis. The qualitative approach also enabled me to capture the real experiences of the classroom participants and consider their attitudes (Cohen *et al.,* 2007). The qualitative approach further uses information gathering methods that are more flexible.

The advantages of a qualitative approach are that topics and participants can be evaluated in detail (William, 2007). In this study, the participants were observed using CBS in their electrolysis lessons. This gave me the opportunity to observe them in their natural environment. This gave me a clear picture of how these chemistry teachers used CBS in their lessons, for example, how they introduced CBS to their lessons and how they supported the learners. Another advantage is that qualitative data depend on human experience and this is more compelling and powerful. Welman, Kruger and Mitchel (2012) note that a qualitative approach enhances researchers' understanding of the phenomenon under study.

According to William (2007), a major drawback of a qualitative approach is that it depends on the skills of the researcher (such as interview skills) and can be influenced by personal beliefs, which leads to bias in the findings. In addition, the quality of the data makes interpretation and analysis time consuming. Another disadvantage is that the presence of the investigator during data generation can influence the answers of the participants. To compensate for these limitations, I used a number of tools to increase the validity of the results.

3.4 Research design

I opted for a case study. Merriam (1998) argues that a case study is a detailed description and analysis of a limited system. An example of this would be a limited phenomenon such as a programme, an event, or a person. A case study is best suited to answer ‘how’ and ‘why’ questions (Yin, 2009). As in the current study, according to Hitchcock and Hughes (1995), a case study involves constructions through an interactive dialogue between the researcher and the participants. Opie (2004) further explicates this point by arguing that a case study can be considered as an in-depth interaction of a single entity in a closed system.

A research design explains how and where information was collected and analysed (Parahoo, 2006). It covers how the data was collected, which instrument was used, how the instrument was used and what means were used to analyse the data collected (Creswell, 2005). Cresswell (2008) also notes that a research design is a specific qualitative and quantitative process that has been integrated into the last three phases of research procedures, these phases involve: data gathering, analysis, and reporting. In other words, the research design formulates what data is needed, and what methods will be used to collect and analyse that data to answer research questions. McMillan and Schumacher (2006) furthermore describe a research design as a descriptive method that is used to answer research questions.

The types of research designs are influenced by the research approaches. Quantitative research approaches use descriptive, correlative or associative, ex-post-facto, quasi-experimental and real experimental designs. Descriptive research gives information about situations and events that take place in the present (Morrell & Carroll, 2010). Correlation studies compare two or more different characteristics of the same group of people (Ary, Jacobs & Razavieh*.,* 2002). Ex-post-facto studies are retrospective as they seek to determine the cause of an existing disease, and the researcher has no control over the exogenous variables (Kerlinger, 1986). Quasi-experimental design involves the use of a natural social environment in which researchers can introduce something like an experimental design (Polit & Beck, 2012). Finally, the experimental quantitative design is characterised by manipulation, control, and random assignment (Maree & Pietersen, 2007, Polit & Beck, 2012).

Qualitative research approaches use phenomenological, ethnographic, case study and historical design, as well as narrative analysis and Grounded Theory (Glorgi, 2009). Phenomenological design means that the researcher explores the lived experiences of individuals through the phenomenon that they describe (Glorgi, 2009; Moustakas, 1994). Ethnographic design refers to events that take place in the life of a group, with specific reference to the interaction of group members in the context of their socio-cultural norms and beliefs (Postlethwaite, 2005). Cohen *et al.* (2007) state that Grounded Theory pertains to the development of theories to explain phenomena. These theories emerge from data rather than from predetermined theory. Furthermore, it is noted that a case study is an analysis that focuses primarily on exploring the unique quality of the phenomenon being studied. Lastly, historical research is a systematic, objective location, evaluation and synthesis of evidence to identify facts and come up with conclusions pertaining to past events (Gall *et al.,* 1999).

Finally, the mixed methods approach uses convergent parallel, explanatory sequential, exploratory, sequential, and embedded research designs (Creswell & Plano Clark, 2011). The convergent parallel design envisages performing the qualitative and quantitative strands separately but simultaneously, and bringing them together at the point of interpretation (Creswell, 2009). Explanatory sequential methods are used when the researcher wants to use qualitative results to help interpret or contextualise quantitative results. The researcher starts by gathering and analysing quantitative data and then collects and analyses qualitative data as a follow up to qualitative results. The researcher then combines the phases with the quantitative results for the design of the qualitative research questions (Creswell & Plano Clark, 2011). Similarly, in explorative sequential design, the researcher first collects and analyses qualitative data, followed by quantitative data. The analysed qualitative data are then used to build up the subsequent quantitative phase (Creswell, 2000). The embedded research design involves performing a qualitative or quantitative study, with the researcher embedding a smaller portion of the other method as an extension. The secondary strand can be simultaneous or sequential (McMillan & Schumacher, 2010).

This study thus used the qualitative approach because the research questions require teachers' views on CBS which require some in-depth. The teachers had to express their views in order for them to be understood, thus enabling the reseracher to understand their views on the use of CBS in teaching electrolysis. The qualitative approach is also suitable because it gives a detailed explaination of how teachers integrate CBS into teaching. The researcher had to describe the teachers' practices in order to answer that question.

3.4.1 Different types of case study designs

The design of the current study was a case study. The use of a case study allowed for an intensive investigation that allowed a deeper understanding of the phenomenon, leading to fruitful interpretations (Denscombe, 2007). The main focus of a case study is the organisation of social data with the objective of viewing social reality in order to obtain detailed information regarding a small sample (Patton, 2002). The purpose of the in-depth study of interactions described in this work was to gain an understanding of teachers' use of CBS in the teaching of electrolysis.

Yin (1994, 1998) identifies three types of cases in case studies, all of which appear to form important components of my study. He distinguishes them with regard to their final product as explorative, descriptive and explanatory.

Following these identifications, exploratory case studies are used as pilot projects mainly to generate further research questions or to try out data collection methods (Yin, 1994). Saunders, Lewis and Thornhill (1997) state that the exploratory case is included in a research problem when there are very few or no previous studies or information about the problem The goal is to look for patterns, ideas or hypotheses rather than testing a hypothesis. The focus is on gaining knowledge and familiarity with the subject for a more detailed study to be conducted later. This approach allows the researcher to grasp the social situation (Yin, 2003). Although the approach produces many details; there is little theory in the development of possibilities, so it is less suitable for some studies. However, exploratory case studies can be used to either generate a new theory or test an existing theory.

Descriptive research portrays phenomena as they exist. It is used to identify and obtain information about the essence of a particular problem or challenge and answer the 'what' questions (Saunders *et al.,* 1997). Descriptive research attempts to "present a precise profile of persons, events or situations" (Robson, 2002, p. 59). It describes what is going on, fills in the missing parts, and expands our understanding. Morrell and Carroll (2010) assert that descriptive research provides information about a situation or an event that occur in the present.

Explanatory research establishes causal relationships between variables. It mainly focuses on the exploration of a situation/problem to explain the relationships between variables (Saunders *et al.,* 2007). Exploratory research can either be relational or predictive. Relational studies attempt to establish correlations between variables (Ary, Jacobs & Razavieh, 1996)., while predictive research goes further to predict the likelihood of a similar situation elsewhere (Saunders *et al.,* 2007).

Another description of case studies comes from Stake (1994), who classifies these into intrinsic and instrumental studies. Intrinsic case studies are considered appropriate if intentions are meant to assist in understanding a particular case, while the latter is used when the intention is to examine a particular case in order to gain insight into a particular problem. Stake (1994) also gives a third category, which includes an investigation of several cases. However, all of these classifications involve some overlap and the implications are that using more than one model would be beneficial.

3.4.2 Multiple case studies

A case study may follow a specific case or a collection of case studies (Stake, 1994, Yin, 1994). A case study design refers to two or more cases that have been researched to improve the understanding of a specific phenomenon (Yin, 2009). In this research, a multiple case study was conducted to understand how teachers use CBS as they teach electrolysis and how they integrate it into their teaching. In the study described by this thesis, several case studies were considered more relevant than a single case study. This was mainly because I considered the diversity of three individual teachers from three different schools. Several housing designs have certain advantages that are suitable for such situations because it allows investigations, which is specific to individual persons, individual classrooms or individual schools. Different views are allowed as they lead to multiple realities that become visible in each of the case studies. The evidence from several cases is often considered more convincing than in individual cases (Yin, 1994).

The researcher, however, must be open-minded about the daily lives of people over a long period and gather available evidence to explain the topic being investigated. Data is collected through observations, listening to what is said, and conducting formal and informal interviews (Hammersley & Atkinson, 2007). The basic requirement for the method is that people (for example, science teachers) do not act in isolation. Their behaviour and actions are influenced by social groups, cultures and institutions and can therefore be studied in their natural environment.

Therefore, the case study provided opportunities to consider the life experiences of the participants in using CBS. This method further allows people to tell stories about their situation in order to make sense of the worlds that they inhabit (Yin, 1994). Moreover, it is focused and intense as it is done in well-defined environments (Denzil & Lincoln, 2000, 2006).

According to Denzil and Lincoln (2006), a case study can be simple and straightforward or complex and extended, yet focused on inner coherence within a unique situation.. The core of its identity lies in its idea of unity, which limits the system as well as the school, and it is part of this unity that is being studied. According to Opie (2004), the goal is to present a picture of a particular characteristic of social behaviour or activity in a given environment and the factors that influence that situation. In this way, the interactions of events, human relationships and other factors are examined in a unique location. It is clear that the interest in case studies is focused on the activities of the case and not on the generalisation of the results. Hitchcock and Hughes (1995) argue that a case study is useful because it attempts to identify something unique or particular to a situation. These features allowed me to discover the important issues used to collect data. It also enabled intensive analysis (Cohen & Manion, 2011) of data, providing an understanding of the use of CBS during the teaching of electrolysis.

There are a number of advantages to using a case study design. Yin (2003) states that a case study examines an existing phenomenon in a real context. Strauss (1994) finds that a case study is a research strategy that involves an empirical investigation using multiple sources of evidence. Soy (2006) agrees with Strauss, noting that the benefit of a case study design is that different sources and methods can be used in the data collection process. The use of various instruments and analytical techniques offers researchers the opportunity to triangulate. The advantage of triangulation is that it increases the validity, which strengthens the results of the study and also the conclusions that are drawn from it.

In a case study, it is possible that the researcher is biased because s/he can get too close to the participants and being to identify with them. This results in the researcher losing his/her perspective as an outsider. Another limitation is that the generalisation of the results is limited since case studies involve a small number of participants. Case studies can also be time consuming and tiring because data collection can be intense and take long, coupled with a large amount of data that require detailed analysis.

This study was thus intrinsic. In this study, I identified, researched and described questions and existing practices with the intention of establishing a link between current literature in an attempt to understand how teachers use CBS during the teaching of electrolysis. A case study approach was used because it provided the researcher with a profound understanding because of its in-depth nature.

3.5 SAMPLING

The population refers to the overall number of elements from which data is gathered (Parahoo, 2006). Orodho (2005) attests that items or people under consideration in the field being investigated form the population of the study. The target population in this study were chemistry teachers in public schools in Swaziland offering the SGCSE syllabus. Public schools were used because the majority of Swazi learners attend public schools and these are government schools.

A sample is a subset of the population chosen to take part in the study in order to give information on the topic being investigated (Polit & Beck, 2012). Matale (2008) contends that a sample reflects the overall picture of the total population. A sample is essential because if the entire population cannot be studied, then a representation of the population is examined. Matale further notes that sampling is the process of using smaller parts of the entire population to draw conclusions about the general population.

De Vos (2002) agrees with this, and states that as it is not feasible to study the whole population, thus conclusions can be drawn through studying a small part or group of the population. For example, a qualitative approach seeks to find members that allow us to study the phenomenon more closely and more intensively (Saunders, Lewis & Thornhill, 2000). In addition, the sample must be able to provide information that answers the research questions. In this way, information-rich participants and research sites can be assigned to a study based on their knowledge and experience (De Vos, 2002). Therefore, taking into account costs and time pressures, I selected participants who met the requirements associated with the purpose of the study (Johnson & Christensen, 2012).

In this study, a targeted sample was used to fulfill the purpose of the study, i.e. to understand the use of CBS in teachers' electrolysis teaching, so this limited the study to schools having computer equipment. Thus, it was in line with my original interest of understanding the teachers' use of CBS in teaching electrolysis. Targeted sampling is viewed by Patton (2002) as a strategy where the attitudes of people, as well as events are selected deliberately to supply salient information that cannot be accessed anywhere else. In support of this, Merriam (1998) emphasises that the targeted sampling method is used when the investigator is interested in discovering, understanding, as well as gaining insight into the phenomenon under study. The merits of a targeted sample are that the investigator selects the cases to consider based on his or her assessment of their suitability (Cohen & Manion, 1994).

According to McMillan and Schumacher (2011), convenience sampling selects participants based on accessibility and convenience. While Cohen *et al.* (2007) define it as the choice of the participants closest and available to participate in the research. Maree (2016) defines convenience sampling as a selection of participants based on the fact that they are easily available and easy to reach. This means that the choice of each school depended on how far away it was from my workplace. Therefore, travel costs and distance were some of the factors that I considered when choosing the three schools.

Swaziland has four regions, namely, Hhohho, Manzini, Lubombo and Shiselweni.Two public schools in the Manzini region and one school in the Hhohho region were used in this study. The three schools were selected because they were reacheable; they were withini a radius of 30 km from the workplace of the reasercher. All three schools offer the SGCSE syllabus. Public schools were used because the majority of Swazi students attend public schools. The schools in the Manzini region are located in a semi-urban area, while the Hhohho region is in an urban area. The learners from School C, which is in an urban area were more exposed to computers than the learners in the semi-urban area. The computer lab for School C also had internet, yet Schools B and C did not. For all three schools, learners had access to the computer labs only during ICT lessons. The selected schools were mixed gender schools consisting of both boys and girls. According to Musingafi and Hlatywayo (2013), targeted sampling is a method of selecting elements based on the goal of the study. Thus, these three schools were used to meet the requirements for a school utilising computer and science laboratories. To select the three schools, a sample selection was also carried out to ensure that the teachers were qualified chemistry teachers with more than five years of teaching experience. The teachers responsible for teaching chemistry in Form 5 in their respective schools were selected as the topic of electrolysis is dealt with in Form 5 in the SGCSE syllabus. I went to the three schools to seek permission from the headteachers who granted me the permission and then referred me to the heads of the science departments. The heads of department told the chemistry teachers about my study, and the ones who participated are the ones who were willing to take part in the study. These teachers had not used CBS in their lessons before.

3.6 DATA COLLECTION STRATEGIES

When using a case study design, data can be collected using a variety of methods. This study gathered data through questionnaires, face to face interviews, observation, and document analysis. Questionnaires and interviews were used to assess the teachers' views on using CBS to teach and learn electrolysis. The teachers were also observed as they used CBS in their lessons and document analysis was used to determine how the teachers planned to integrate CBS into their lessons. The instruments were designed so that it would be possible for the researcher to get rich information data. The questionnaires were open-ended. This allowed the teachers to explain their understanding of CBS in writing. The interviews also allowed the teachers to justify the way they combined CBS with other teaching strategies and also voice out the challenges of using CBS. It was possible for the researcher to probe to seek for clarity from the participants where necessary. The lesson plans showed how each teacher planned to use the CBS in her/ his lessons. The observations allowed the researcher to observe teachers’ practices during the lessons, noting if they allowed learners to manipulate with CBS or not and to observe their attitude while using them.

3.6.1 Questionnaires

Questionnaires are a mechanism to get information. The questionnaires were used to capture the beliefs and understanding of the teachers regarding the use of CBS in teaching electrolysis. Some of the questions were derived from the content representations (Co-Res). Co-Res is a research tool for accessing the PCK of science teachers on any specific topic (Loughran *et al.,* 2004).

Questionnaires are one of the cheapest ways to collect data, especially online questionnaires. It allows participants to remain anonymous, making it a private communication, which allows the participants to feel more comfortable in answering questions. This facilitates participants' participation and encourages them to respond truthfully. Questionnaires have no time limit; thus, participants can take their time when completing a questionnaire. They will answer more truthfully than in an interview, while research has shown that the presence of a researcher can lead to a less honest response (Loughran *et al.,* 2004).

Inaccuracy or even dishonesty can be a problem, that is, there is no way to know if respondents have really thought the question through before they answer. Sometimes participants may skip some of the questions, which affects the validity of the data. Another disadvantage is that some participants have challenges in understanding the meaning of some questions that may seem clear to the researcher. However, even questionnaires cannot capture emotional responses and therefore some useful data can be omitted. Some questions in open questionnaires can be difficult to analyse. Given the disadvantages of questions, they should be triangulated with other data collection tools.

3.6.2 Interviews

Interviewing in qualitative research is a technique used to discover what others think and feel about their worlds. Interviews are considered a two person conversation generated by the interviewer. Aminuzzaman (2012) describes the interview as a two-way communication where participants are asked questions by the interviewer in order to get their views and opinions about a certain topic being studied. According to Bogdan and Biklen (2003), an interview is defined as a purposeful conversation between two people. Opdenakker (2006) argues that in qualitative research, the researcher can conduct in-depth face to face interviews, telephonic interviews with participants or focus group interviews. In-depth interviews were conducted in this study. Through interviews, I was able to gain comprehensive information for the study.

The responsibility of the interviewer is to provide the interviewee with an atmosphere of trust and accountability throughout the interview period (Johnson, 2002). Throughout the interview, the interviewer must be self-confident and know their participants before starting the actual interview (Bogdan & Biklen, 2003). There must also be mutual trust and respect (Johnson, 2002). In addition, the interviewer should give appropriate instructions to ensure that the research focus is not lost. The purpose of the interviews was to obtain information about the participants' feelings, perspectives, beliefs, experiences and encounters. In other words, in-depth interviews were conducted to fully understand the teachers' views on the use of CBS as a teaching strategy for electrolysis education. In the one-on-one interviews, I examined the teachers' understanding of CBS as a strategy for teaching electrolysis in the classroom. Chenail (2011) notes that interviews combined with observations and analysis of documents are one of the most important ways to generate qualitative research data. I used an open interview guide to optimise the collected data. This approach assisted the participants to speak freely, allowing me to assess their understanding of the use of CBS in teaching electrolysis. The participants were also able to voice their challenges in teaching electrolysis with CBS and suggest how this can be improved in schools if implemented. The interviews were also recorded and transcribed to increase the trustworthiness of the results.

There are many benefits of interviewing, which include in-depth data collection and comprehension as the interviewer can search for answers. It gives the researcher the opportunity to observe verbal and nonverbal cues, which include body language and facial expressions.

3.6.3 Observation

According to Johnson and Christensen (2012), observations are defined as looking at the behavioural patterns of people under certain conditions to obtain clues to the phenomenon of interest. Observations, according to Kumar (2011), are a purposeful and systematic way of viewing or recording an action as it takes place. Observations provide real experiences in a real world (Robson, 2002). Patton (1994) argues that observation gives researchers the ability to see what is going on in a natural environment instead of using second-hand accounts. Patton also notes that observation allows researchers to understand the context of the situation, to see things that might otherwise be unconsciously missed, and to discover things that the participants do not freely speak about during the interviews or of which the participants are unaware.

Research observation can take the form of participatory and non-participatory observation (Creswell, 2005). In participatory observation, the researcher fully immerses himself in research and becomes a member of the group. As a result, the researcher begins to get a feel for and understand what the participants are actually doing (De Vos, 2002). In other words, the researcher participates in the activities and becomes a participant. Through participatory observation, the researcher is able to make sense and give meaning to the world. Alternatively, the researcher in a non-participant observation has no impact on the study because s/he is not fully immersed in the study.

To successfully conduct the observation, I had to take a specific position in the data collection, which was as a non-participant observer. The aim and research questions of the study required me to be non-intrusive in order to observe the natural setting. Creswell (2005) defines a non-participating observer as one who visits a research facility and records notes without being involved in the participants' activities. According to Morrison (1993), the observation allows the researcher to observe and record information as it occurs in its natural environment. This data collection strategy allowed me to study the actual behaviour of the participants.

The observation in this study provided an overview of the situation being studied as it was supported by interviews and documentation analysis. The combination of observation, interviews, and documentary analysis made it possible to holistically interpret the use of CBS as a teaching strategy. The lessons were also recorded so that I could access the data when analysing it. I noted how the teachers assisted learners in using CBS, the teaching strategies that they used, and the use of analogies and examples during class. It was also observed when teachers used traditional or learner-centred approaches in their teaching.

The observation in this research study focused on teaching and learning activities. According to Cohen and Manion (1980), “The main advantage of observation is that, researchers can observe ongoing behaviour as it occurs, and be able to make appropriate comments on its salient features” (p.103). Observation is time consuming and takes time and effort. Moreover, it can be very stressful, especially if it is secret, which can lead to ethical difficulties. In this study, observations were pre-arranged with the consent of all parties and conducted according to the ethical requirements of the university. Another disadvantage is that there is a risk of interfering and therefore providing distorted data. Again, to minimise this limitation, I combined observation with other data collection strategies. In the current study, I was a non-participant observer to capture the natural behaviour of the teachers when implementing CBS during lessons in their natural setting.

3.6.4 Document analysis

Document analysis is a way of gathering information that is used in a formal description of a text (Taber, 2007). Taber also notes that document analysis involves the content and organisation of the document by identifying and naming the components of some document classes. Documentary analyses used in this study were as follows:

i) The daily preparation books;
ii) The science curriculum.

The curriculum guided me in the selection of the CBS that should be made available to chemistry teachers. The daily preparation indicated the lesson development of the lesson from the beginning of the lesson, just as the CBS should be integrated during the lesson. The Daily Preparation Book also showed the lesson strategies used by the teachers and the prior knowledge identified for each sub-topic and the planned lesson development.

Document analysis eliminates the effect that a researcher has on events when conducting research. Document analysis is relatively inexpensive, especially if the documents are easily accessible and readily available. Some documents can be more detailed and contain more information than can be seen from questionnaires or interviews.

A document may not contain all the required information because it was not created with the purpose of serving as a research source of information. Sometimes there is a lack of information in the documents or the information is wrong or inconsistent (Bowen, 2009). Bowen also notes that it is vital to analyse the quality of documents. It is also paramount to thoroughly analyse the subjectivity of the document used. In addition, a researcher should protect themselves from personal bias when interpreting documents.

3.7 TRAINING

The training was conducted to familiarise the teachers and learners with the use of CBS as a teaching and learning method. It was also done to identify problems that may occur occur in order to avoid them during the actual data collection exercise and to ensure that the results of the study would be valid and trustworthyTraining helped estimate the time needed for each phase of the lesson, i.e. the distribution of time for discussion and the time it took to use the CBS. Training also helped in the sense that in their first hour, the learners were very excited when using the CBS, which was chaotic. The other lessons were better organised as the teachers were also better organised in how they guided the learners in the next lessons, once they had become familiar with using CBS themselves.

3.8 DATA COLLECTION PROCEDURE

Three CBS and one video were provided by the researcher and were given to the instructors upon completion of the training. The video was a summary of electrolysis that could be used as an introduction or as a summary depending on the teacher's discretion. The three CBS consisted of basic electrolysis, electrolysis of acidified water, and electrolysis of brine. Teachers were expected to use their discretion in how to use these in the classroom.

The participating teachers received questionnaires to complete one week before the lesson observations and interviews were conducted. After the three observations, follow-up interviews were conducted to inquire about the teachers' experiences with the use of CBS in teaching electrolysis. For example, they were asked what other teaching strategies they used and how the CBS improved the students' understanding of electrolysis. They were also asked if they were any advantages of using CBS in their lessons. This was done to capture teachers' personal ideas and behaviour, uncontaminated by outside influences and academic knowledge.

The first visit was just to familiarise the learners and teachers with my presence so that when I started collecting data, I could get real results. During the first visit, the teachers did not use CBS and so no data was collected. During the three lesson observations, the teachers were expected to integrate CBS into their lessons with other teaching methods such as lecturing, the question and answer technique, and demonstration. The teachers were observed as they supported the learners in their groups as the lessons continued and as they led discussions before the end of each hour and afterwards. The learners were expected to also work in groups when using CBS in their lessons. They also had to respond to worksheets prepared by their teachers.

As a result of the observation, I was able to observe how the lessons progressed from beginning to end. I was able to examine their thought processes and interpret their discussions and reflections. This helped me to determine whether the learners understood the lessons or not. As a researcher, it was important to me to observe the participants' facial expressions, attitudes, and beliefs about the use of CBS. It was important for me to understand the challenges that they faced when using the CBS in their lessons.

I was able to identify the emotions of the participants during the use of the CBS. They were able to explain their opinions and positions as seen in the data. All the teachers' lessons were recorded, which helped me to be thorough in analysing the data. The recordings helped me to be more objective in analysing the data, preventing the observations from becoming subjective (Silverman, 1993).

Documentary analysis, such as daily preparation, allowed me to see how the teachers planned a lesson, how they had planned the introduction of the CBS, and how they integrated into the lesson what the learners should be doing.

After interviewing the teachers, individual interviews were conducted and the second questionnaire was completed to determine how the use of CBS affected the electrolysis technique employed.

3.9 COMPUTER SIMULATIONS USED IN THIS STUDY

For each lesson in which the three teachers used the computer simulations, they decided on the teaching method and the kind of questions to ask the students. All of them used the CBS that I provided them. The three CBS provided to the teachers are discussed below.

3.9.1 The process of electrolysis

This process is depicted in Figure 3.1.

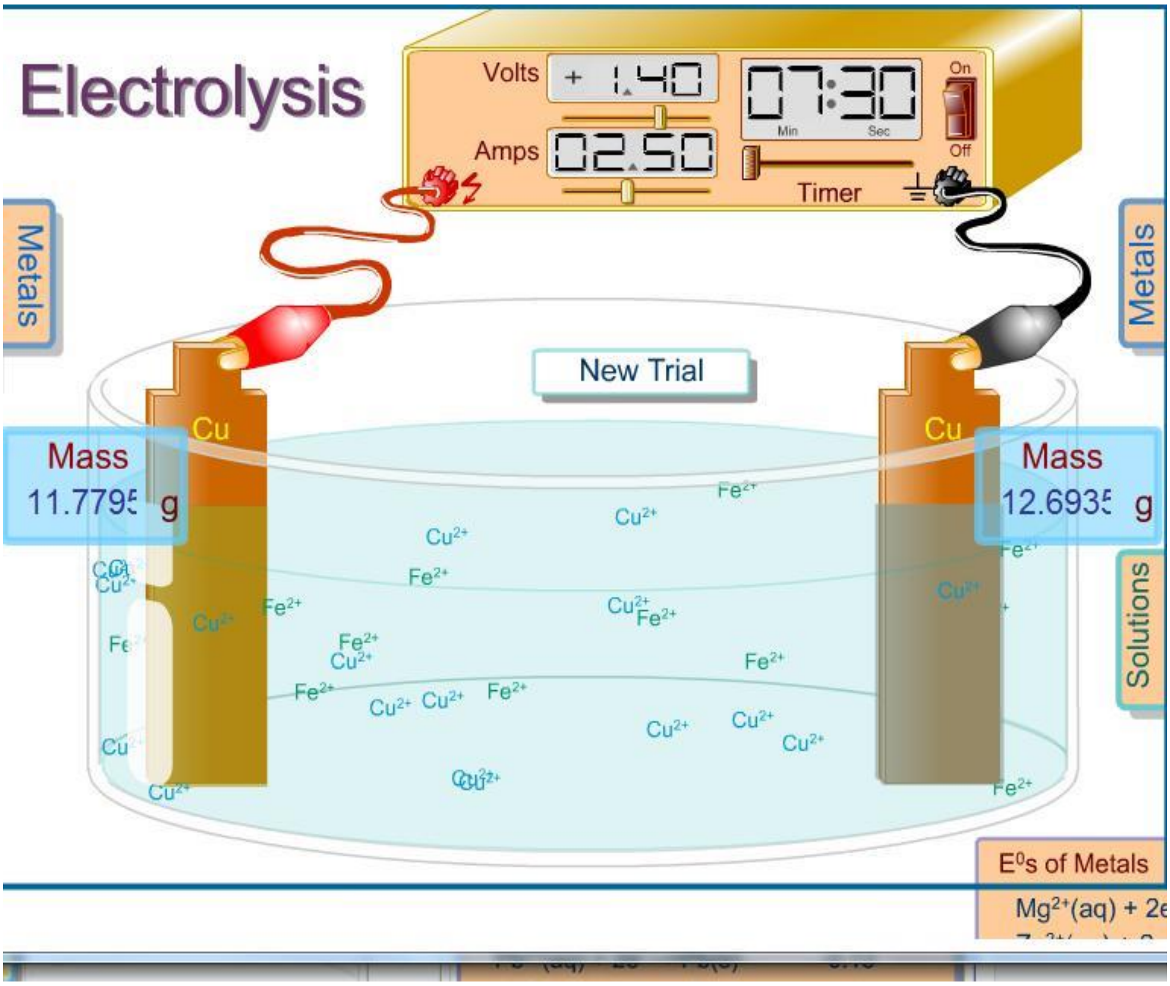

Figure 3.1: Electrolysis using copper electrodes (source: Butts, & Smith, 1987)

Aim: To demonstrate electrolysis

Procedure: The learners were supposed to adjust the voltage and the current for a chemical reaction to occur. They were then expected to select metals from the available ones to use as electrodes, and also select the electrolytes from the available solutions and time the reaction. After which, they were to switch on the CBS and observe the migration of electrons and ions and the change of mass. They would then have become aware of which electrode had been reduced/oxidised and were then supposed to come up with a half reaction at the electrodes. This had to be repeated for different electrodes and electrolytes.

3.9.2 Electrolysis of water

Electrolysis of water is illustrated in Figure 3.2 below in which the learning goals are:

- To describe an oxidation-reduction reaction.
- To define the following terms: electrolysis, electrolyte, anion, cation, anode, cathode, electric current.
- To know how to read a net equation.

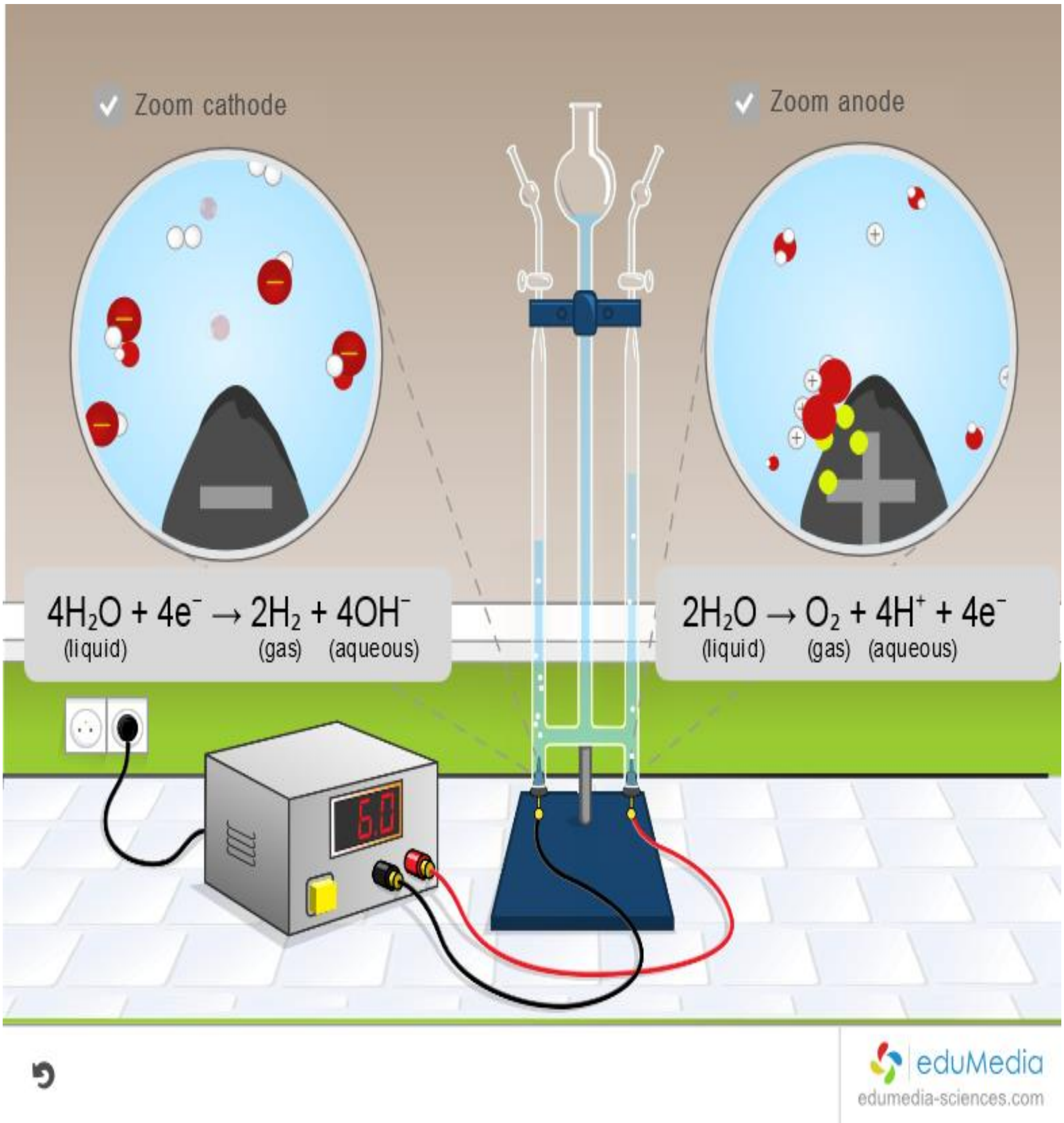

Figure 3.2: Electrolysis of acidified water (source: Butts, B. & Smith, R. (1987)

Procedure:

The students were to switch on the CBS and observe the reaction at the electrodes. The CBS showed the water molecules dissociating. The reduction of water molecules, receiving electrons to form hydroxide ions and hydrogen gas can then be seen at the cathode. They also observed the hydroxide ion and the sulphate ions migrating towards the anode, but only the hydroxide ions were oxidized. Hydroxide ions lose electrons to form water molecules and oxygen gas at the anode. The hydrogen and oxygen gases were observed in the tubes covering the cathode and the anode. The learners also observed that the oxygen gas produced at the anode was less than the hydrogen gas produced at the cathode. They were then expected to come up with equations for the half reactions that had taken place at the electrodes and the overall reaction.

A summary of electrolysis of water is given below:

The cathode releases electrons, which reduce the water according to the reduction reaction:

$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

At the anode, the water molecules undergo the following oxidation reaction:

$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$

The net outcome gives the following equation for decomposition:

$2H_2O \longrightarrow O_2 + 2H_2$

The reaction produces twice as much dihydrogen as dioxygen. This justifies Avogadro's Law, showing that the volume of gas in the left tube (H_2) is twice as great as the volume of gas collected in the right tube (O_2).

3.9.3 Electrolysis of Brine

Procedure:

The learners used carbon electrodes and concentrated sodium chloride solution as an electrolyte. From sodium chloride, there are sodium ions and chloride ions. From water, there are hydroxide and hydrogen ions. When the CBS was switched on, current flowed and bubbles were observed at both electrodes, indicating the formation of chlorine gas at the anode and hydrogen gas at the cathode. Since the anode is positive, the learners observed the negative chloride and the hydroxide ions being attracted to it. However, the chloride ions give up their electrons and are oxidised to chlorine molecules. Since the cathode was negatively charged, it attracted the sodium and hydrogen ions. However, the hydrogen ions gained electrons and became hydrogen gas. The sodium ions and the hydroxide ions were left in solution and formed sodium hydroxide solution. The learners were then expected to be able to write the half equations at the electrodes and the overall chemical equation.

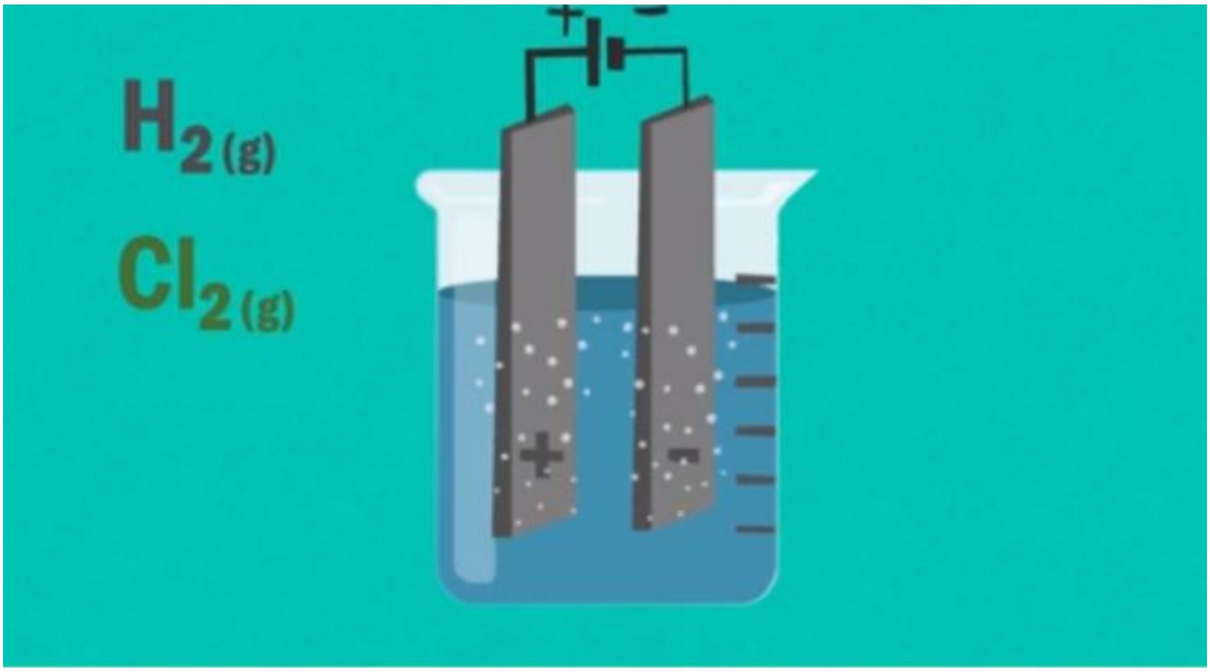

Figure 3.3: Electrolysis of brine (source: Butts & Smith (1987)

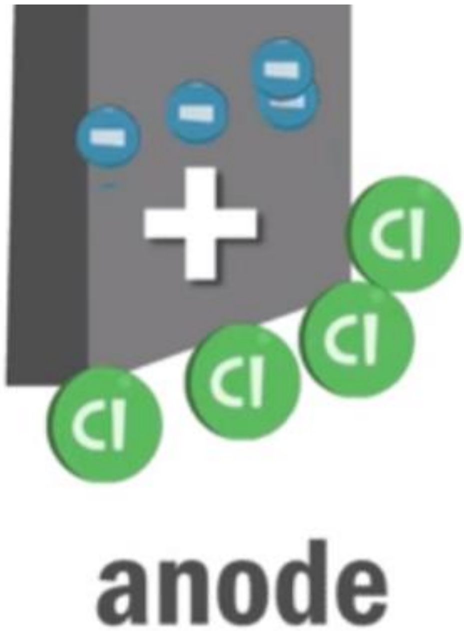

Figure 3.4: Electrolysis of brine at the anode (source: Butts & Smith (1987)

3.10 METHODOLOGICAL NORMS

According to Singleton and Straits (2005), validity refers to the quality of correspondence between an operational definition and the concept that is supposed to be measured. The validity of an instrument refers to the ability of the instrument to measure what it should measure. Reliability in qualitative research refers to the certainty that the study is reproducible, that is, when another researcher investigating the same problem or problem receives the same results (Spencer, Ritchie, Lewis & Dillon, 2003). Creswell (2005) postulates that there are different approaches to addressing validity and reliability in qualitative research. These include triangulating information between different data sources, reviewing members, and reviewing experts.

3.10.1 Trustworthiness

Since the study was based on the qualitative approach, trustworthiness was sought rather than validity and reliability. According to Lincoln and Guba (1985), qualitative researchers should consider the criteria for a trusted study, namely credibility, neutrality, reliability and portability. The concepts of credibility, neutrality, reliability and transferability are essential quality criteria in a qualitative study (Lincoln & Guba, 1985).

According to Lincoln and Guba (1985), credibility in qualitative research refers to ensuring that a true picture of the phenomenon is presented by the study. They also note that credibility observes how participants project their views on what they consider to be social constructs (Guba & Lincoln, 1994). Credibility ensures that the results of the study are reasonable and trustworthy, and this understanding is improved if the researcher tries to remove all prejudices and errors (Cohen *et al.,* 2007). In this study, credibility was enhanced by piloting before the actual data collection was performed to ensure that the newness of the situation did not affect the results. In addition, various tools such as lesson observation, interviews and questionnaires were used to examine the situation. Various instruments were used to triangulate, that is, to verify that the results from each instrument were consistent with the other instruments. The use of triangulation further enabled me to review the data and thereby ensure its credibility (Guba & Lincoln, 1994). In summary, credibility requires that the researcher be completely honest throughout the study (Henning, Rensburg & Smit*.,* 2004).

Transferability means giving enough detail to the context of the field of work to decide if the results of the study can applied to a different situation or environment. (Lincoln & Guba, 1985). According to De Vos (2002), portability is the extent to which the results of one study can be transferred to the results of another. It refers to the similarity between the actual research and the receiving context. The transferability was thus enhanced by giving a clear description of the selection criteria used in the sampling, the context and using quotations.

In a qualitative study, reliability is described as dependability (Henning *et al.,* 2004). According to Lincoln and Guba (1985), dependability refers to the stability, trustworthiness, or consistency of the query processes used over time. Dependability is ensured by the concept of triangulation of data obtained from different data collection instruments (Cohen *et al.,* 2007). Dependability is also enhanced by the orientation of the participants and the expansion of activities in the field of study. In order to enhance the reliability of the study, during the pilot study I based the data collection on the use of CBS in another topic (ionic binding), as participants used it for the first time. Reliable researchers also return to their participants to verify that the results are valid. Thus, the interviews were conducted before and after the observations and the questionnaires were also completed before and after the classroom observations. I did not allow my experience as a teacher to influence the interpretations, opinions, views and discussions of the participants and this ensured the reliability of the research results.

Neutrality in qualitative research means that the researcher should only use information from the participants, not his/her views (Lincoln & Guba, 1985). I deliberately focused on being objective when interpreting the data and presenting the results, while refraining from involving my personal interests and opinions. My supervisor also read all of the transcripts and discussed interpretations to reach an agreement. This eliminated bias and supported the trustworthiness of this study.

Confirmability refers to how the research results are supported by the data collected (Musingafi & Hlatywayo, 2013). Cohen *et al*. (2007) state that the ability to confirm focuses on whether the results of the study can be confirmed by others without subjectivity. According to Babbie and Mouton (2001), adaptability refers to the extent that the findings are free from all distortions and errors, and demonstrates the objectivity of the findings. The problem of adaptability could be achieved through audit trails. This means that the same observations could be made at a different time and show similar results. Adaptability means that the interpretation given by the researcher is not an invention of his/her imagination, but that the qualitative data can be traced back to its original sources and was logically explicit (Guba & Lincoln, 1994).

Throughout the study, I did not include personal feelings and emotions to make sure that these did not influence this study. I moreover did not allow personal views and attitudes to override my bias during the interviews. In this way, I minimised the possibility of distortion. By constantly reviewing the respondents' responses, I was able to review the consistency of the responses. In addition, I was able to improve the confirmability of the participants' comments and answers. To improve adaptability, I supported the results with excerpts from the transcripts of the instruments used to collect the data.

The trustworthiness of data is related to authenticity, neutrality, adaptability, consistency, applicability, credibility, portability and reliability. The trustworthiness of the results was further improved by using several sources to triangulate the data. Classroom observations, interviews, documentary analysis and questionnaires were used in this study. Triangulation uses multiple data sources in one study to gain understanding (Creswell & Miller, 2000). Creswell and Miller also note that this is done because a single method can never properly illuminate a phenomenon. Qualitative researchers use this technique to ensure that the explanation or report is rich, understandable and well-developed. In order to ensure the credibility of the researcher, the interviews in this study were also recorded and all sessions recorded. In this way, I was able to present a close-up of the teachers' views on the use of CBS and note how they used CBS in their lessons. The recordings were kept in a safe place at the University of Pretoria, and will continue to be kept there.

The participants were also given an opportunity to voice their own ideas and views, and in this way I was able to ensure the trustworthiness of the study. In addition, I did not influence the participants in the pursuit of my own thinking, but remained as neutral as possible (Descombe, 1995). To ensure the trustworthiness of the study, I also had a good relationship with all of the participants. Also, I was mindful of the development of the interview questions and the observation guide, thus reducing possible bias (Oppenhieim, 1992).

3.10.2 Data triangulation

Triangulation refers to comparing the data gathered from two or more research instruments. These are known as multi-method approaches. Through its use, qualitative research explains the complexity and wealth of human behaviour from more than one viewpoint (Cohen & Manion, 1985). To ensure that the data collected accurately reflects the research, I used more than one technique (Leedy & Ormrod, 2004). In other words, the multi-method approach helps explain the richness and complexity of human behaviour.

The study of phenomena from more than one point of view increases the informative value of the research (McMillan & Schumacher, 2006). In order to make sure that data collected is satisfactory, an investigator must use two or more methods of collecting data. In relation to the present study, this was related to the challenges and experiences of using CBS as a teaching strategy. Triangulation ensures that the investigator considers more than one method to understand the difficulty of human behaviour (Cohen *et al.,* 2007). In this way, the investigator can look for re-emerging patterns when comparing different perspectives (McMillan & Schumacher 2006). In this study, I used observations, interviews, documentary analyses and questionnaires to gain an overall understanding of the phenomenon. The use of several methods allowed me to combine different methods to understand this particular phenomenon.

The validity of retrieved data can be maintained through triangulation as the researcher reflects on the similarity of information gathered through observations, interviews and document analysis (Lincoln & Guba, 1985). The more the outcomes are used in contrast to one another, the greater the similarities that are created. Instead of limiting it to one method, the researcher endeavours to use more than one method to validate the data. Since triangulation is necessary when investigating a complex phenomenon, through triangulation, contrasts, differences and similarities of data can be checked (Cohen *et al.,* 2007). However, as Patton (1990) has argued, triangulation does not necessitate consistency and repetition. Accordingly, triangulation is both significant and relevant when a complex phenomenon is being researched.

McMillan and Schumacher (2010), argue that the triangulation of data involves gathering data from various sources. This process avoids the possibility of a simplified or biased incomplete view. This will improve the validity of the conclusions. Triangulation is used to strengthen qualitative research with the intention of grasping different dimensions of the same phenomenon in order to gain a holistic understanding. The data in this study were triangulated by collecting data from three different chemistry teachers from different schools using a variety of data collection instruments. Interviews, observations, questionnaires and document analysis were utilised in order to triangulate data. Each and every data collection method has its own strengths and weaknesses, so using various methods support data triangulation and compensates for the weakness of others (Cohen, Manion & Morrison 2000; Johansson, 2006).

3.11 DATA ANALYSIS

The data in this study was obtained from personal interviews, classroom observations, questionnaires and document analysis to provide a complete picture of how the use of CBS as a teaching strategy can be understood.

3.11.1 Qualitative data analysis

Bogdan and Biklen (2003) assert that data analysis is the process of systematically working with data collected through interviews, questionnaires, amongst other collection methods. The process requires organising it, breaking it down into manageable units, synthesising it, looking for patterns, discovering what is important, and deciding what to report on. In line with this view, Boeije (2010, p. 76) points out that:

> *Qualitative analysis is the segmenting of data into relevant categories and the naming of these categories with codes while simultaneously generating the categories from the data. In the reassembling phase the categories are related to one*

another to generate theoretical understanding of the social phenomenon under study in terms of the research questions.

The analysis of data is a technique for the systematic description of written, spoken or visual communication. It can also be defined as the method of summarising the content by counting its different aspects. The purpose of data analysis is to answer the research questions (Merriam, 2009). Gay and Airasian (2003) identified methods that can be employed in data analysis. These are shown schematically in Figure 3.5.

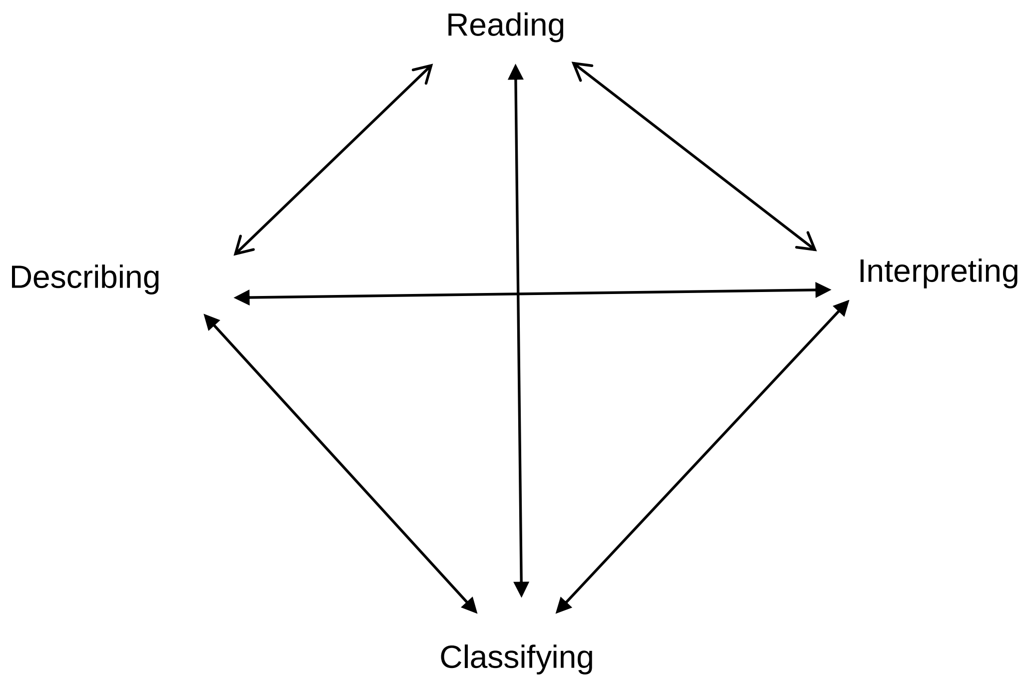

Figure 3.5: Procedures in analysing qualitative research data (Adapted from: Gay and Airasian, 2003)

According to Merriam (2009), the researcher repeatedly reads data and writes memos on the transcripts and observer comments to get a first feel for the data. Reading and memos allowed me to become familiar with the data. From the memo, I was able to develop potential topics. By reading the transcribed notes, I also identified and discovered recurring themes. The reading and memo phase helped me understand the interviews, lesson observations and questionnaires that were carried out for the purpose of understanding the use of CBS as a teaching strategy.

The step of describing is focused on the processes that take place in the environment and among the participants so that the researcher understands the context in which the study takes place. In this research, I studied the data in depth to give deep descriptions of the setting, the participants and their activities. These descriptions enabled me to get an idea of the attitudes of the participants and the events that took place there. I took stock of the content of the interviews, documents, and memos that were written during data collection (Straus & Cobin, 1998). Stenbacka (2001) notes that description helps researchers to decide the type of analysis to be performed on the data. In this study, I presented the data based on the topics that emerged from the data and literature collected.

Saldana (2013) notes that when working with various participants in a study, it may be handy to first encode a participant's data before moving on to the second participant's data. It could be observed that the second data record influences the recording of the data of the first participant and the subsequent coding of the data of the remaining participants. Classification ordered and tagged data by subject allows the researcher to easily access all data at any time during the analysis. The classification of the data was done manually, and a computer was used to enter the transcriptions and memos.

In this study, I used notes and interpretations from the collected data to form an interpretive document containing my views on what I learned from the study.

3.11.2 Content analysis

In this study, content analysis was used. Content analysis looks for patterns that are derived from the data collected to draw a general conclusion (Musingafi & Hlatywayo, 2013). According to Hancock (1998), content analysis is a method of categorising verbal or behavioural data. The content can be analysed using either a descriptive account or an interpretive account. A descriptive report concerns what is said without reading anything into it or any of it being adapted, while interpretive analysis deals with what is meant by the answers given (Musingafi & Hlatywayo, 2013). Content analysis involves classifying and categorising data. Content analysis is suitable for capturing the issues that have arisen from the data collected since its interpretation. The information is obtained from the various instruments. The observations, interviews and questionnaires per teacher were classified to capture the patterns or themes that emerged from each instrument. The resulting patterns were divided into two groups. The categorisation was informed by the research questions provided below:

1. What are teachers' views on the use of CBS in teaching and learning electrolysis?
2. How do teachers integrate CBS into teaching electrolysis?

3.12 ETHICAL CONSIDERATIONS

Welman, Kruger and Mitchell (2007) argue that ethical behaviour is vital in research. Ely (1991) claims that the naivety of many research participants makes it all the more compelling to protect them carefully. As with the determination of rigor, I believe that ethical issues are critical in any research and that a researcher must ensure that all practices are ethically considered, performed, interpreted and reported. Cohen *et al*. (2000) notes that participants may occupy the world that they inhabit or explore, but their effect may not be neutral. This suggests that the question of consent cannot be overlooked. In the following paragraphs, I will discuss how I ensured that the research met the standards of morality, fairness and worthiness.

Cohen *et al*. (2000) argue that carrying out research requires that the researcher obtain the consent and cooperation of participants, including schools and institutions. There were four institutions involved in this study, i.e. the university under whose name the study was conducted, the three secondary schools, the science teachers, and their students in the three schools that were involved in the study. Cohen *et al*. (2000) point out that the issue of access and acceptance is very important when carrying out a study. Since the study was conducted under the name of the university, I requested ethical clearance before collecting the data.

After being approved by the Ethics Committee, a letter was written to the Director of the Ministry of Education in Swaziland. After the Director's approval was obtained, other letters were addressed to the headmaster, the subject teachers and to the learners and their guardians, which included a declaration of consent. According to Kent (1996, p. 19), the following aspects for informed consent should be considered:

a) Give information that will help participants to decide whether to participate or not.
b) Make sure that participation in the study is voluntary.
c) Get parental consent when dealing with children under 18 years of age.

Taking into account the above guidelines, the letters explained the purpose of the study to the participants. All learners returned the letters signed by them and their parents or guardians. All indicated teachers agreed to participate. To protect the participants, the confidentiality and anonymity of the participants and schools were ensured during reporting (Cohen *et al*., 2000). All names used in the transcripts are pseudonyms.

This study used questionnaires, interviews, observations and documents as data collection tools. Therefore, ethical questions about each instrument need to be addressed. Cohen *et al.* (2000) warn that interviews may be distorted due to the characteristics of the researcher and respondents. Cohen *et al.* (2000) identified informed consent, confidentiality and the consequences of interviewing as problematic areas that need to be addressed in interviews. Oppehein (as cited in Opie, 2014) argues that prejudice in interviews can be minimised if "the interviewer retains control of the interview, gentle but concise, and a measure of authority and assurance of confidentiality." Tuckman (1972) cited in Cohen *et al.,* 2000) illustrate the problems with interviews by saying:

> *The interviewer should brief the respondent as to the nature or purpose of the interview (being as honest as possible without biasing responses) and attempt to make the respondent feel at ease. He should explain the manner in which he will be recording responses, and if he plans to record he should get the respondent's assent. At all times the interviewer must remember that he is a data collection instrument and try not to let his own biases, opinions, or curiosity affect his behaviour* (p 279).

Confidentiality and anonymity were guaranteed in this research. I applied for permission from the Education Director in Swaziland to study at the participating schools. Permission was also obtained from the learners, chemistry teachers and the principals of the three schools. The parents of the learners were also asked to sign consent letters that allowed their children to participate in the study. The parents were informed about the process and the reasons for the study. The participants were assured that the names of the schools and the names of the participants would not be disclosed. Teachers were coded as teachers A, B and C and their schools were coded as schools A, B and C.

The participants' rights to decline or withdraw from participating were discussed. The participants were also guaranteed that the findings would be used for the study only and that it would be kept in a safe place (Welman *et al.,* 2012). The learners and parents were guaranteed of risk-free situations during the data collection. I also assured the participants that no one would have access to the data that was collected since the data is kept in a locked safe where only the researcher and the supervisor have access. The collected data will be destroyed after fifteen years, as required by the University.

3.13 CHAPTER SUMMARY

This chapter outlined the research paradigm, research design and data collection instruments. The data collection procedures as well as data presentation and analysis methods were theno presented. The ethical issues of the research were also deliberated on. The next chapter presents the results of the study.

CHAPTER 4 RESULTS

4.1 INTRODUCTION

This study explored the use of CBS as an instructional strategy for teaching electrolytic cells. The focus is on teachers' views regarding how CBS enhances learning. I was also interested to discover how the teachers integrated CBS into teaching electrolysis, searching to explain their behaviour in terms of their views. Three chemistry teachers were purposefully and conveniently selected from different schools, two being in the Manzini region and the other one in the Hhohho region. To ensure anonymity, the teachers are referred to as Teacher A, Teacher B and Teacher C.

In this chapter, the findings obtained from four data collection strategies are presented. These were questionnaires, interviews, lesson observations and document analysis. Two questionnaires were administered per teacher, that is, one questionnaire before using CBS as an instructional strategy and the other after they had used the CBS. Two interviews were also conducted, one before the use of CBS and the other after the use of CBS to explore the teachers' understanding of the use of CBS as an instructional strategy. In addition to the questionnaire and interviews, lesson observations were conducted for three consecutive days within the same week for each teacher while the teachers used CBS, combining this strategy with other teaching methods chosen by the teacher. The duration of the lessons for Teacher A and B was 40 minutes while it was 35 minutes for Teacher C.

Finally, document analysis was also done to collect data from the lesson plans on electrolysis. The findings are presented as narrative reports to reflect the participants' experiences regarding their understanding of the use of CBS as a teaching method. The presentation of findings is guided by the research questions. The findings are presented using the themes that emerged during data analysis. These themes are presented for each research instrument that was used to conduct the study. There were a total of six themes that emerged.

The study attempted to answer the following research questions:

1. What are the teachers' views on the use of CBS in teaching and learning electrolysis?
2. How do teachers integrate CBS into teaching electrolysis?

4.2 THEMES EMERGING FROM THE DATA

From my analysis, six themes emerged from the data, namely:

- The advantages of CBS;
- Learners' difficulties in electrolysis;
- Challenges in using CBS;
- Teaching strategies;
- Teachers' curricular knowledge; and
- Teachers' attitudes

The above themes emerged from the data and were found to be in agreement with the literature. A summary of the categories and themes that emerged from the data are presented in Table 4.1. The questionnaires were based on the literature and experience, while the themes emerged from the data.

Table 4.1 Themes that emerged from data

Themes	**Categories**
1. Advantages of CBS	CBS promotes critical thinking. Learners become more engaged. Interest of learners is improved by the use of CBS. Learners ask more questions. Learning by manipulation. Visualisation.
2. Learners' difficulties in electrolysis	Common mistakes made by learners. How teachers assist learners overcome mistakes. Misconceptions held by learners. Strategies teachers use to overcome misconceptions.
3. Challenges in using	Shortage of equipment. Shortage of resources.

CBS	Socio-economic challenges. Large number of learners. Background of learners. Learners' prior knowledge. Learners' attitude towards the learning of science.
4. Teaching strategies	How teachers assist learners while using CBS during the lesson. Lesson focus. How teaching methods other than CBS enhance understanding of electrolysis. Disadvantage of using other teaching methods. Examples. Analogies. Textbooks. Diagrams. Assessment. Emphasis of key points during the lesson. Writing key points on the chalkboard. Mentioning in the introduction of the lesson and in preparation book lesson objectives.
5. Teachers' curricular knowledge	Concepts that have to be covered before electrolysis. Concepts that link with electrolysis. Teachers' knowledge of subject matter. Previous knowledge.
6. Teachers' attitudes	Teachers' beliefs and orientation towards teaching science. Teachers' perspective of students' beliefs regarding learning science. Willingness to change/learn. Accepting challenges/advice.

The findings are presented using the themes that emerged during data analysis in the different data collection strategies. These were the interview before using CBS, the questionnaire before using CBS, the lesson plan, observation, the questionnaire after using CBS and the interview after using CBS.

4.3 Presentation of the findings

Each of the three teachers was given three CBSs. One was for electrolysis, another for electrolysis of acidified water, and another for electrolysis of brine. They were also given a video that each could use either as an introduction in the beginning or at the end as a summary. Each teacher used these using her/ his discretion.

The findings are presented separately for each of the participants. For each teacher, the findings are presented according to the data collection sequence to give a realistic sense of the unfolding narrative. First to be presented is the profile of the teacher, followed by the findings from the interview and questionnaire before the teacher used CBS in the classroom. The next finding is from the lesson plans; three lesson observations are discussed starting with a short narrative, followed by an analysis of the lessons. This is followed by the analysis of the second interview and questionnaires after using the CBS. Finally, a summary for each teacher is presented.

4.4 Findings from Teacher A

4.4.1 Profile

Table 4.2 is a summary of Teacher A's profile. Teacher A is a qualified chemistry teacher holding a Bachelor of Science. He also had a Post-Graduate Certificate in Education (PGCE). He had been teaching chemistry for 24 years at the time of this study, and was the Head of the science department in his school. His school was located in a semi-urban area and had a furnished science and computer laboratory, which included workbenches and chairs. He had a teaching load of 24 periods, each period being 40 minutes during the time of data collection. In the class that was observed there were 44 learners.

Table 4.2 Teacher A's profile

Aspect	**Details about Teacher A**
Gender	Male
Teacher's qualification	B.Sc. and PGCE
Teacher's experience	24 years
Number of learners in observed class	44
Teaching load (periods per week)	24

4.4.2 Interview before use of CBS as an instructional strategy

Teacher A had been showing non-interactive videos in his teaching before the study, which he inappropriately referred to as 'CBS'. However, he had not used interactive CBS prior to the study.

Theme 1: Advantages of CBS

Teacher A believed that CBS offers an advantage compared to practical work:

> *…. when you are carrying out the practical you do not actually see the ions migrating to the different electrodes, but comparing with computer simulations the students are able to see that. Or maybe another is that learners during the practical only do, with computer simulation they can see the migration of ions and also what is formed when the bonding takes place* Appendix F (L24).

His response showed that he understood that CBS enables learners to visualise what they cannot see in the practical.

Also, he mentioned that CBS may improve learners' interest, this was noted when he said, "Yes because the learners become more interested with, when you show them, that is what is applied, the attention they give" (L56). His response suggests that he believed that CBS enabled learners to pay more attention in the lesson because their interest was piqued when they visualised what they were learning.

Theme 2: Learners' difficulties in electrolysis

When Teacher A was asked about the misconceptions that are held by learners regarding electrolysis, he replied as follows:

> *Ok student, one of the misconceptions they make is that insoluble salts do no conduct electricity. Whereas, ok then, we may have insoluble salts but the insoluble salts conduct electricity when they are in the molten state, and that requires the salts to be heated first. So then once they are in the molten state then they can conduct electricity* Appendix F (L30).

His response indicated that he was aware of one of the common mistakes that are made by learners with the concept of electrolysis. However, there are many mistakes that learners may make in this topic, yet he only mentioned one. This may mean that his knowledge of the common mistakes that learners make in electrolysis was limited.

Theme 3: Challenges in using CBS

While elaborating on the limitations of practical activities, Teacher A also mentioned the challenge of inadequate equipment:

L18 Teacher A:	…*Ehm maybe the limitation could be how do you show a student that a molten substance can conduct electricity because we do not have enough equipment to demonstrate or to carry out practicals on the passing out of electricity between molten substances ma'am. So maybe that could be the limitation.*
L19 Interviewer:	*Ok*
L20 Teacher A:	*In-availability of chemical, chemicals on equipment of ionic solutions.*

A shortage of resources is therefore a challenge in practical work, which implies that there would probably also be a shortage of computers, posing a challenge to using CBS.

Theme 4: Teaching strategies

Teacher A regarded practical work as an important teaching strategy:

L12 Teacher A: *The practical activity is for students to be involved on the topic, because electrolysis is about the passing of electricity through solutions and molten ionic substances*.

L13 Interviewer: *Mhm*

L14 Teacher A: *So when doing the practical, we make the solutions so the learners will do … for example the electrolysis of copper chloride whereby the learners are able to see the gas being given off at the anode and also at the cathode the students actually see copper being coated on the carbon electrode, that is, the cathode.* (Appendix F)

The extract above indicates that Teacher A believed that for learners to internalise better what they have learnt, they have to observe the phenomenon in real life to make sense of what they have learnt theoretically.

When he was asked about the strategies he used during teaching to assess learners' understanding, he indicated that he asked questions in class and gave homework:

> *Ok, by asking questions and also by giving them work they will do while in class, then also give them homework, quiz and tests* (L44).

The extract above shows that formative assessment was included in the lessons in order to improve learners' understanding.

Theme 5: Teachers' curricular knowledge

When he was asked about the limitations of practical activities, Teacher A revealed his knowledge about some concepts needed for electrolysis:

> *Actually, I see there are no limitations, it's just that the students have to do chemical bonding, that is ionic bonding. So, from ionic bonding the students are able to compare ionic equations ehm ionic compounds and covalent compounds. So one, when looking at the properties of ionic equations is that*

ionic compounds conduct electricity, so once the student have done that, after the student have looked at ionic properties they are able to appreciate the fact that ionic solutions conduct electricity and also molten ionic compounds. So when we, after having done ionic bonding then we move on to electrolysis. And electrolysis is all about passing electricity through solutions and molten ionic compounds (L16).

He highlighted a number of concepts explaining how these concepts link with electrolysis, showing his understanding of the content knowledge. Also, when he was asked regarding the pre-requisite concepts for electrolysis, he responded saying "Ok, it is electricity and the properties of ionic compounds, and also solubility, and of course melting" (L28). His response agrees with what he mentioned earlier as it it is important for learners to understand these concepts because it influences their understanding of electrolysis.

When he was asked why it is important for learners to understand electrolysis he said,

Ok, it is that important so that students should be able to know that it is not only metals that conduct electricity, and also solutions can conduct electricity and also the industrial application of electricity is also important because it addresses some of local issues (L42).

His response indicated that he focused on the conduction of electricity and the industrial application of electrolysis. However, he did not mention the importance of the two half reactions taking place and the energy conversion in the cell, which is expected for a course in chemistry. This may imply that his knowledge of chemical reactions was limited.

Theme 6: Teachers' attitudes

When he was asked how he assisted learners to correct their misconception about insoluble ionic compounds, he indicated that he borrowed equipment to show that molten ionic substances can be electrolysed:

> *Ok because at the school we do not have enough equipment for carrying out that, so we normally do borrow some of the equipment from the university* Appendix F (L34).

His concern for learners was observed in the effort he made to borrow equipment. This reveals a positive attitude towards teaching and enabling learners to do the practical so that they understand the concept better.

4.4.3 Questionnaires administered before using CBS

Theme 3: Challenges in using CBS

Regarding the challenges he faced in teaching electrolysis, he wrote that it is *"*laboratory chemicals and equipment unavailability*"* (q5). In another answer, he mentioned the "availability of chemicals, equipment and learners with a science inclination" (q6) as other challenges. A shortage of chemicals and equipment can make it difficult for a teacher to teach electrolysis with understanding. Also, he considered learners' lack of interest in science as another challenge.

Theme 4: Teaching strategies

He was also questioned regarding the strategies that he used in teaching electrolysis in chemistry. He indicated *"*practical, question and answer as well as demonstration*"* (q3) as teaching methods. He also emphasised the "importance of learners' participation" (q7) as factors that influence his teaching and repeated questioning (q8), Appendix W).

Theme 5: Teachers' curricular knowledge

Teacher A provided correct answers to all the questions in the questionnaire, which required his content knowledge. When Teacher A was asked what he intended learners to know in electrolysis, his response was:

> *Ionic solutions conduct electricity, electrolysis can be used as a separating technique, industrial application of electrolysis, electroplating and its use in extraction of metals* (q1, Appendix W).

When he was asked why it is important for leaners to know electrolysis, his response was "so that learners appreciate electrolysis and to look at how electrolysis addresses local issues” (q2). Altogether, these responses suggest that he regarded the conduction of electricity by ions and the industrial applications of electrolysis as the most important. He did not mention the value of understanding the chemical process.

According to Teacher A, the pre-requisite knowledge for electrolysis is “the properties of ionic and covalent compounds and solubility” (q4). This reveals his own knowledge of how electrolysis is based on the ability of ions to move in a liquid.

4.4.4 Lesson plans

Two lessons plans were analysed for Teacher A, which he planned to use for teaching electrolysis using CBS in this study. It was agreed that three lessons on electrolysis using CBS would be observed. However, he prepared only two lesson plans. No lesson plan for the third lesson was prepared. The topic indicated in both lesson plans was electricity and chemistry, electrolysis was stated as the sub-topic. In the first lesson plan, “video” was stated as a teaching aid and the battery, lamp, connecting wires, clips, carbon electrodes, crucibles, tripod, Bunsen burner, tongs and copper chloride as teaching aids in the second lesson. In the lesson plan, he considered the CBS that he used as a video, indicating that he had confused a video for CBS.

Theme 4: Teaching strategies

For the first lesson, he planned to use the question and answer teaching strategy together with the CBS, while in the second lesson he planned to use practical work and a group discussion. He also drew a diagram of an electrolytic cell in his first lesson plan.

Theme 5: Teachers’ curricular knowledge

His lesson focus was also indicated as objectives in both lesson plans. For the first lesson he stated that learners should be able to:

a) Describe electrolysis.

b) Draw a labeled circuit diagram for an electrolysis of copper chloride (aqueous solution) between inert electrodes (platinum or carbon).

c) Describe electrolysis in terms of ions present and reactions at the electrodes in examples given.

d) State the general principle that metals or hydrogen are formed at the negative electrodes and that oxygen or halogens are formed at the positive electrode. (Appendix U).

In the second lesson plan he stated the following as the objectives:

a) Describe electrolysis.

b) Draw a labelled circuit diagram for an electrolytic cell using the terms electrode, electrolyte, anode and cathode.

c) Describe the electrode products formed in the electrolysis of copper chloride between inert electrodes. (Appendix X).

By stating the lesson objectives, Teacher A revealed that he was aware of some of the key points in this topic and thus placed emphasis on that when teaching so that learners could recognise that it is important for them to know it. However, he omitted several concepts in the topic, which include the electrolysis of molten lead bromide, electrolysis of copper sulphate solution using carbon and copper electrodes, as stated in the Physical Science syllabus, yet the CBS gave users the option to select a wide choice of metals and electrolytes.

Curricular knowledge was also observed in the prior knowledge that he stated in both lesson plans. In both lesson plans he stated that *"*students should have learnt about conductors of electricity and insulators and the differences between pure liquids and solutions.*"* This indicates some knowledge of curricular saliency for Teacher A.

4.4.5 Observations

Three lesson observations were done while Teacher A was teaching electrolysis. He used the CBS only during the first lesson, and the CBS was on simple electrolysis. The observation guide was used by the researcher regarding what to look for during the lesson observation. I observed how the teacher introduced the lesson, used learners' prior knowledge, used examples, used analogies and used CBS. Lesson delivery was also noted during the lesson, that is, how he involved learners during the lesson, which teaching methods were used, how he introduced the CBS during the lessons and how he assisted learners during the lessons. I also observed if the learners were using the CBSs that were provided, as well as their involvement in the lessons. This was noted by the questions they asked.

4.4.5.1 Narrative

The first lesson began at 11.40 and ended at 13.00 and was held in the science laboratory. The duration for each period was 40 minutes; and this lesson constituted a double period. The lesson was an introduction on electrolysis, focusing on the definitions of electrolysis, cathode and anode. Teacher A started the lesson by asking learners to give the properties of ionic compounds. He then asked learners to work in groups to do a practical experiment using carbon rods in copper chloride solutions to observe how it conducts electricity. After a few minutes he repeated the experiment using the chemicals at the front desk after the learners had done theirs and asked learners what they observed in their groups. They responded by saying that there was a change of colour on the surface of the electrodes, indicating that a chemical reaction had taken place and also that gas was observed at the anode. There was no mention of smell. He also asked them which ions would be found at the electrodes. The practical was completed in the first 40 minutes.

He then instructed learners to work in groups using the CBS on simple electrolysis. The CBS allowed a choice of metals and solutions. The learners had to select metals of their choice as electrodes, select solutions of their choice, and make their observations. There were about ten learners at each computer and they used the remaining lesson time trying out different metals and solutions given by the CBS. While the learners were working, the teacher moved around from one group to another checking what the learners were doing without giving instructions to the learners. The lesson ended without discussions.

The second lesson was held in the computer laboratory and was a double period. The duration of the lesson was also held from 11.40 until 13.00 o’ clock. The teacher started the lesson by recapping the content from the previous lesson, asking learners if they noted what was happening in the computer simulations that they used in the last lesson. The lesson was mainly on the discussion of the observations from simulated experiments that learners had done using the CBS. He discussed the copper chloride and copper sulphate solutions, asking learners what they expected to happen at the anode and the cathode, and to identify ions to be preferred at the different electrodes. He also referred the learners to the practical experiment the learners had done in the previous lesson. The lesson plan that was presented was not followed. This lesson was a continuation or a discussion of the results from the previous lesson that had been done using the CBS and the actual experiment using chemicals. However, in the discussion he did not ask learners about the chemical reactions and equations at the electrodes, but was only concerned with the ions present at the electrodes. What is interesting is that the lesson was held in the computer laboratory, yet he did not use the computers in this lesson and this suggested poor planning.

The third lesson was held in the science laboratory and it was on the electrolysis of acidified water. He explained that since water has a covalent bond, it does not conduct electricity. The electrolysis of acidified water was explained using sulphuric acid to acidify the water to allow conduction. Therefore, the water should be acidified by adding sulphuric acid to allow conduction. The learners were expected to be able to identify ions that are formed at the electrodes. It should be noted, however, that there was nowhere in this lesson where Teacher A asked the learners to write the half reaction equations at the electrodes, as well as the overall equation. The teacher taught the third lesson using traditional methods and did not use the CBSs that were given to him. He instead used the questioning method to engage the learners in a discussion. Towards the end of the third lesson, he also discussed the electrolysis of sodium chloride solution, creating an impression that this also represents the electrolysis of water. It seems that he was confused, mixing the topics of the second CBS (electrolysis of acidified water) and the third CBS (electrolysis of brine). Unfortunately, he did not use either of these two CBSs during the lesson.

4.4.5.2 Analysis of the lesson observation using CBS

Theme 4: Teaching strategies

Teacher A combined a number of teaching strategies when delivering his first lesson, which included the simulated experiment in the CBS, the practical experiment and a discussion. This was observed when he said, “Okay please form your groups, [each group has its copper chloride solution]. So this is the solution.” (L10 Appendix H). This was when copper chloride was used to explain that electrolysis is the process by which a current is passed through a solution. However, it was observed that these teaching strategies were only used in the first lesson. In the second and third lessons, he used mainly the questioning/discussion strategy.

He focused mainly on conduction to explain electrolysis, yet there is a lot involved in electrolysis, which includes oxidation and the reduction half-reactions at the electrodes, chemical reactions which result in the formation of ions and energy conversion. When directing learners to use CBS as an instructional strategy, he said:

> *Okay in your groups use the computer simulation on electrolysis and select the different metals of your choice as electrodes and select a solution of your choice to use with each metals. Make your observations* (L20).

After he had allowed the learners to do an experiment, he then let the learners also use the CBS, allowing them to be hands-on and making their own observations. This indicates that he believed that the CBS should be used together with practical experiments for them to be more effective.

He also drew a diagram of the electrolytic cell in the first lesson on the chalkboard, showing learners the electrodes and the electrolyte:

> *Okay go back to your seats.* [teacher draws a diagram of the electrolytic cell on the board]*. This is a circuit and this is a solution.* [pointing to the diagram on the board]*. The bulb is part of the circuit. Then you have these two carbon rods which are called electrodes* (L14, Appendix H).

He also made use of the chalkboard, writing the key points on the board and using relevant examples when delivering his lesson. He used copper chloride and copper sulphate solutions as examples in his second lesson:

Teacher A: … *But when you electrolyse a solution, for example, copper (II) sulphate, you would expect copper two ions to migrate to the anode.So what happens at the electrodes?*

L6Student: *Copper is deposited at the cathode.*

L7Teacher: *What about the anode?*

L8Student: *A gas will be given off.*

L9Teacher: *Where is the gas coming from? So here copper (II) ions and sulphate ions, since this is dissolved in water. Some of the water will be converted to hydrogen ion and also hydroxide ions…*

Using relevant examples helps learners to understand which products were formed at the electrodes.

Theme 5: Teachers' curricular knowledge

In the beginning of the first lesson he told learners what they were going to learn about, and linked the new lesson with what the learners already knew:

L1Teacher: *Morning class. What we are going to look at today is electrolysis. We'll start by giving me the properties of ionic compounds, all the properties of ionic compounds.*

L2Student A: *They conduct electricity in molten state* [teacher writes responses on the board].

L3Student B: *Ionic compounds have strong ionic bonds* [teacher writes on the board].

The way in which Teacher A introduced the lesson shows that he understood that a new concept is built from what learners already know, and was aware that ionic bonding is a pre-requisite for electrolysis.

In the second lesson, he referred to the reactivity series of metals, a topic that is to be covered before electrolysis as it determines which metal is deposited at the cathode and which gas is released at the anode. Referring to the reactivity series and the displacement reactions indicates that he was aware of the concepts that are linked to electrolysis:

> *….at the cathode, it will be deposited with a brown substance to show that what is produced is copper. So in electrolysis, the least reactive metal is preferred. But in displacement reactions, the most reactive metal is preferred. More reactive metals cannot displace least reactive metals. So in electrolysis, we use the electrolysis series not the reactivity series. However, if you use the*

reactivity series, don't forget that the least reactive metal is preferred (L15, Appendix I).

From the extract above, Teacher A used previous content familiar to the learners in order to explain the process of electrolysis. He mentioned the reactivity series and the displacement reactions in an effort to explain which ions will be 'preferred' at the electrodes. However, he did not explain that 'preferred' refers to what is produced at the electrodes. He emphasised that the learners had to remember that the 'preferred' metal is not the same as in the reactivity series. It thus seemed as if he expected learners to memorise it as he did not explain why. The failure of Teacher A to explain the concept thoroughly may mean that his content knowledge was limited and may also mean that he was not confident in his knowledge of the content.

His knowledge of subject matter seemed to be limited in the third lesson. He discussed the content of both the second and third CBS in this lesson without actually using the CBS. The lesson started with a discussion of the electrolysis of water. He correctly explained the formation of hydrogen at the cathode and oxygen at the anode. However, when discussing the electrolysis of dissolved sodium chloride, he was not sure which gas would be liberated at the anode. Furthermore, he was not able to use the reactivity series to work out which ion would be oxidised. When a learner attempted to answer the question, he confessed that he was not sure of the correct response and did not elaborate on the learner's response:

L7Teacher: *So at the cathode you will see bubbles, what will happen at the anode? So this chlorine (pointing to the board) is more reactive than a hydroxide ion, sorry, hydroxide is more reactive than chlorine. Which means if the hydroxide is less reactive than the chloride ions, so the hydroxide ions, which is more reactive between the two, the problem I have now, I am not sure which ion is more reactive but I will give you this as a homework. The homework is, which amongst the two ions is more reactive?*

L8Student: C*hlorine is more reactive.*

L9Teacher: *So this is the ion that will be preferred. If that is the case, what will happen at the anode? At the anode the hydroxide ions are preferred, what would you see at the anode … [*pause*] what* *would you see at the anode? We are going to stop here for today.*

This event confirmed that teacher A did not have a clear understanding of the meaning of the reactivity series. If he had used the CBS that was available for each case, he may have been able to learn from it and may have been able to understand why the gas produced at the anode is different in the two cases.

Theme 6: Teachers' attitude

Teacher A was observed in three lessons; however he presented only two lesson plans. In the three lessons he was observed teaching he used the CBS only once, in the first lesson. He focused on the electrolysis of copper chloride solution yet the CBS gave the users different options of metals and electrolytes to use. This indicates a negative attitude towards using CBS and an unwillingness to use them in his lessons. The negative attitude is evident in presenting only two lesson plans while it was agreed that he would teach three lessons.

The second lesson was a continuation of the first lesson, where the class discussed their observations focusing mainly on copper chloride solution.

4.4.6 Analysis of the interview after using CBS

Theme 1: Advantages of CBS

When Teacher A was asked about how his teaching of electrolysis had changed when using CBS, he suggested that CBS increases learners' participation in the lesson as they asked more questions than usual during the lesson:

> *What we noticed is that the learners became more involved in the lessons. Most of them, even those learners who before did not ask questions were … asked ... ok … more … Ok more questions were asked by the learners which is something that did not happen before* (L10, Appendix G).

He also believed that CBS enhances learners' understanding:

L11 **Interviewer:** *Ok, so do you think the use of computer simulation improved the learner's understanding of the topic?*

L12 **Teacher A:** *Yes, yes of course?*

L13 Interviewer: *Ok, how do you think it improves their understanding?*

L14 Teacher A: *In the computer simulations, more things were explained.*

L15 Interviewer: *Ehm.*

L16 Teacher A: *And the learners they actually saw ions migrating to the different electrodes?*

L17 Interviewer: *Ehm …*

L18 Teacher A: *Eh in a practical we only see what is being produced in the, at the electrodes.*

He believed the learners' understanding was increased because the leaners were able to see the migration of ions, and that more things were explained using the CBS.

When he was asked directly what he considered the advantage of using CBS as an instructional strategy to be, he said that:

> *They were good because they cover, the CBS, I found that they were because one, in a practical the learners only see what is being produced but when using the computer simulation, they see the migration of the ions for the different electrodes and they are also able to see what is being produced at the electrodes. With the computer-based simulations a lot of ground is being covered within a short space of time and the learners, they get to understand some of the concepts* (L20).

His response again showed that he understood that CBS enables learners to visualise abstract concepts such as migrating ions, which cannot be observed in practical work. He also mentioned that when using CBS, he spent less time explaining, which thus shortens the teaching time. As such, he was able to cover a lot of content within a short space of time.

Theme 2: Learners' difficulties in electrolysis

When he was asked about the common mistakes that learners make in electrolysis, he explained:

L34 Teacher A: *One common mistake they did is that they think electrolysis can only take place in solution, some ionic compounds are not insoluble and they think those ionic compounds which are* *insoluble, the learners think that they cannot conduct electricity.*

L35 Interviewer: *Oh, ok.*

L36 Teacher A: *But they … all ionic compounds conduct electricity in solution or in molten state. Those ones soluble, they have to be heated first so that they are in a liquid state.*

He regarded this as a major mistake:

> *Eh. I can … ok … that is a major mistake, but they are … maybe you may find that they are also … they are mistakes but too minor. They can be easily corrected* (L38, Appendix G).

He also referred to unspecified minor mistakes that are easy to correct. It was noticeable that he did not mention oxidation/reduction reactions as something that is difficult for learners to understand. It seems that teacher A did not focus on chemical details.

Theme 3: Challenges in using CBS

When he responded regarding what he thought the challenges of using CBS while teaching electrolysis are, he was concerned about the cost of equipment and large classes:

L46 Teacher A: *You ... the challenges, maybe our classes are too big and maybe that the equipment which is used in the computer simulation may be a little bit expensive for the school to purchase them*.

L47 Interviewer: *When you say too big, how many nje* [if you can estimate] *in your class? How many students do you have?*

L48 Teacher A: *Now they are about 40.*

Earlier, he mentioned that there were four groups, which meant that there were about 11 learners per group when he used the CBS. In such a big group, some learners may not participate and may be left behind. Also, he mentioned the challenge of purchasing the equipment needed for CBS as another challenge. This is in line with his remark about the shortage of equipment for experiments to show that molten insoluble salts do conduct electricity.

Theme 4: Teaching strategies

Teacher A explained why he used various strategies during teaching:

L4 **Teacher A:** *Ok, it is question and answer, practical and discussion.*

L5 **Interviewer:** *Ok can you give a reason to why do you use those teaching strategies?*

L6 **Teacher A:** *For question and answer, that is used when trying to introduce a lesson and also trying to link a lesson to previous knowledge.*

L7 **Interviewer:** *Ok*.

L8 **Teacher A:** *And the practical part learners become, sort of hands-on the lesson. We then discuss the results of the experiment*.

His response indicated that he used a constructivist approach during lessons. He was concerned that learning a new concept has to be developed from known to unknown ideas. He also believed that learners have to be carry out practicals and then discuss the results of the experiment as the whole class, indicating that he valued social knowledge construction. The reasons show that he understood the importance of combining different teaching methods, including practical activities to accommodate the different learning styles such as audio, visual and kinaesthetic preferences. His believed that the use of CBS may be improved upon, as shown in the excerpt below:

L29 **Interviewer:** *So how do you think the use of computer simulation can be improved?*

L30 **Interviewee:** *I think that they be improved by the use of experiment and also if a big screen can be used and also where the students are watching there can be more speakers, so that all the students can be able to hear what is being said in the computer simulation.*

Teacher A seemed to lack understanding of how to use CBS in teaching; he seemed to think that learners simply sit and watch without participating. Yet, when using CBS, learners are supposed to do more work, be involved and hands-on while the teacher guides them. Nevertheless, his response shows an understanding that visualising and hands-on practical activities can be effectively combined. He also remarked that he assisted the learners while they were using the CBS during the lesson:

> *One has to move around the classroom and that the learners must be in groups to enable the teacher to move from one group to the other and stop and assist where necessary* (L32, Appendix G).

His remark shows that he was aware of the need for facilitation. His response, however, contradicted what actually happened during the lesson because he mostly used traditional methods, which limit learners' participation during a lesson. The lessons took place in the computer laboratory and he used a projector despite the fact that the computers were functional. When he was asked how he assisted learners with the misconception that insoluble salts do not conduct electricity, his response indicated that a practical was the only possibility:

L39 **Interviewer:** *So how do you assist them with this major one?*

L40 **Teacher A:** *The only way is to carry an experiment where the insoluble compound is heated, then they are allowed to see if electrolysis takes place while the compound is in the molten state.*

He mentioned earlier in the interview that there was a shortage of equipment and chemicals, so perhaps he still believed that an experiment is the best way to assist learners with this challenge. One would have expected that he would suggest CBS because he had been exposed to it at this stage. It seems that he believed that learners have to see for themselves that electrolysis really takes place, something which a simulation does not show.

Theme 5: Teachers' curricular knowledge

When he was asked what the pre-requisite knowledge for electrolysis is, he responded:

> *It is of ionic compounds, the discussion of properties of ionic compounds and also the conduction of electricity in general* (L44).

Naming the concepts required for teaching electrolysis indicated that he was aware of some of the concepts linked to electrolysis.

4.4.7 Questionnaire after using CBS

Theme 1: Advantages of CBS

Teacher A reiterated that the use of CBS enhances the learning of electrolysis as he wrote, “I want learners to actually see ions migrating to the different electrodes” (q1). Regarding the importance of CBS for learners, he further stated that:

> *It is important to learners because they are able to see ions migrating to the different electrode and also products being formed at the electrodes (q2* Appendix V*).*

The above quote indicates that he realised that CBS enables learners to visualise the migration of ions and formation of products at different electrodes. Thus, CBS improves learners’ understanding of electrolysis.

He also understood that CBS encourages learners and reinforces the concept that is being learnt, particularly through visual learning:

> *Computer simulations motivate and reinforce learners’ learning, especially those that are visual (q5).*

When he was asked how CBS contributes to lesson development, he wrote that “it contributes positively because learners’ participation in the lesson is maximised, a lot of ground is covered within a short space of time” (q9). This remark shows two more advantages that teacher A recognised in the use of CBS.

Theme 3: Challenges in using CBS

Regarding the challenges of CBS as an instructional strategy, he noted that “CBS is suitable for a small group, equipment for CBS maybe expensive for the schools to purchase” (q4). According to Teacher A, financial constraints may make it difficult to buy enough equipment as needed for small groups. This may hinder the effective use of CBS as an instructional strategy in schools.

Theme 4: Teaching strategies

Teacher A wrote that he assessed learners' understanding of electrolysis "by giving them questions and also by giving learners a test." His response once again shows that he practiced formative assessment, which is continuous in nature, that is, it is on-going. He also acknowledged that "CBS is student-centred and it can be used easily in conjunction with the teach strategies" (q7) when responding regarding the teaching procedures he used with CBS. His response shows that he was aware that using CBS is a learner-centred approach, meaning that learners have to be more engaged in the lesson. Moreover, as strategies to use to ascertain learners' understanding, he replied, "Question and answer be used because it allows students to express themselves as far as the topic is concerned" (q8). This implies that he used questions not simply for assessment, but also to give learners time to verbalise their own thoughts, which in itself enhances learning.

Theme 5: Teachers' curricular knowledge

The pre-requisite knowledge required for electrolysis according to Teacher A is "the conduction of electricity and properties of ionic compounds" (q6). This reveals his knowledge about the foundational knowledge required in electrolysis.

4.4.8 Summary of the findings of Teacher A

A summary of the different themes gained from Teacher A's data from the different instruments is presented in Table 4.3

Table 4.3: Themes identified from Teacher A using different instruments

	Advantages of CBS	Learners' difficulties in electrolysis	Challenges in using CBS	Teaching strategies	Teachers' curricular knowledge	Teachers' attitude
Q1			x	x	x	
I1	x	x	x	x	x	x
LP				x	x	
O				x	x	x
Q2	x		x	x	x	
I2	x	x	x	x	x	

Key: Q1 - questionnaire before using CBS

I1 - interview before using CBS

LP - Lesson plan

O - Observation

Q2 - Questionnaire after using CBS

I2 - Interview after using CBS

Theme 1: Advantages of CBS

The advantages that Teacher A ascribed to CBS were evident in the interviews before and after using CBS, and the questionnaire completed after using CBS. In all of the instruments he indicated that CBS enables learners to visualise the migration of ions. He noted that CBS enhances learners' understanding because learners are able to visualise the movement of ions, which they cannot do in a practical. He understood that learning is enhanced when learners are given an opportunity to visualise what they have learnt theoretically. Additionally, in the interview after using CBS, he further said that CBS enables the learners to observe the processes of electrolysis unlike in a practical, which mainly shows the end product. This shows that he realised that electrolysis is an abstract topic, thus it is important for learners to also visualise the sub microscopic chemical processes of electrolysis to help them understand the concept. Thus, he believes that CBS enhances what learners have learnt theoretically.

He also believed that CBS improves learners' interest, motivates them to learn, and increases learners' participation, suggesting that learners pay more attention when they are using CBS. Consequently, this means that CBS has a positive effect on teaching and learning because learners' participation in the lesson is maximised.

Theme 2: Learners' difficulties in electrolysis

Learners' difficulties were noted in the interview before and after using CBS. In both instruments, Teacher A noted that the major mistake that learners make is that they seem to think that electrolysis takes place only in a solution and that those ionic compounds that are insoluble cannot conduct electricity. He did not specify any other mistakes that learners make. Identifying only one learner difficulty may be an indication that his content knowledge was limited.

Theme 3: Challenges in using CBS

The interviews and the questionnaire after using CBS revealed further challenges. He noted that CBS is suitable for a small number of learners. His class had 44 learners, and he worked with four groups, which meant that there were about 11 learners in a group. Big groups may have made it difficult for him to monitor whether all of the learners were participating.

Another challenge that he mentioned was the shortage of equipment and chemicals. He further noted that it may be expensive for schools to buy the equipment required to use with CBS. Surprisingly, the school had a computer laboratory with computers, and one of his lessons was held in the computer laboratory. It thus did not seem to make sense mentioning a shortage of computers as a challenge. It is possible that the challenge was that the science department did not have access to the computer laboratory because schools are guided by policies that stipulate that the computer laboratory belongs to the ICT department.

Theme 4: Teaching strategies

All of the instruments indicated the teaching strategies that he normally used to teach electrolysis. He said that he used practicals, a discussion, and the question and answer methods to teach electrolysis. He further explained that he used practicals to enable learners to be hands-on, the discussion method to elaborate the results of an experiment, and the question and answer method to link the current lesson with the previous lesson, and for learners to express themselves. He acknowledged that CBS enhances learners' understanding since it enables learners to visualise the migration of ions, but should be used with practical experiments. He also mentioned that his teaching was influenced by the full participation of the learners, that is, the involvement of learners in the lesson.

His strong preference for practicals was observed when, even though he was given three CBSs to use, he only used one of them and still used an experiment to show the learners the macroscopic features of the processes of electrolysis such as change of colour.

He also made use of the chalkboard by writing important points on the chalkboard such as the electrolytic cell, and by using a number of examples during the lessons.

Theme 5: Teachers' curricular knowledge

Teacher A answered the questions in the first questionnaire correctly; the questions required basic content knowledge about electrolysis. In the first and second questionnaire, he also gave the pre-requisite concepts as properties of ionic compounds. He further mentioned solubility in the first questionnaire and the conduction of electricity in the second questionnaire.

His understanding of the important ideas of electrolysis was observed as he said that he intended learners to know that ionic solutions conduct electricity and that electrolysis can be used in industrial application. His focus in electrolysis seemed to be on conduction of electricity because in the first lesson an experiment was done to show that ionic substances conduct electricity. He also highlighted it as one of the reasons why it is important to teach electricity. Furthermore, when he was asked about the challenges that learners have in electrolysis, he cited conduction in insoluble salts.

However, there is a lot that is involved in electrolysis, which includes half reactions, which he did not mention in his lessons. This may be an indication that his content knowledge was limited. This assumption was affirmed in the third lesson when he taught about the electrolysis of acidified water. He could explain 'preferred', yet he kept referring to what was ‘preferred’ and also he contradicted himself when using the sodium chloride to explain the concept of electrolysis of acidified water and ended the lesson instead. Knowledge of concepts that are linked to electrolysis was observed when he referred to those topics in the second lesson, which included the reactivity series and displacement reactions.

In the beginning of each lesson he told learners what the lesson would be about, thus causing learners to focus on what is important in the lesson. He also wrote lesson objectives in the lesson plans, indicating what is important to be learnt.

Theme 6: Teachers’ attitudes

His concern in assisting learners in understanding electrolysis was observed in his efforts of borrowing equipment from the University. He also showed a positive attitude towards practicals and a negative attitude towards CBS since he chose to use only one of the three CBSs that were given to them.

The next section presents the findings of Teacher B.

4.5 The findings of Teacher B

4.5.1 Profile

Teacher B was a qualified chemistry teacher, holding a Bachelor of Science (B.Sc.). She also had a Post-Graduate Certificate in Education (PGCE). She has been teaching Chemistry for 15 years at the time of data collection. Her school is located in a semi-urban area and has a fully furnished science and computer laboratory. She had a teaching load of 20 periods, each period being 40 minutes at the time of data collection. In the science classroom that was observed there were 53 learners. Table 4.4 is a summary of Teacher B’s profile.

Table 4.4 Teacher B's profile

Aspect	Details
Gender	Female
Teacher's qualification	B.Sc. and PGCE
Teacher's experience	15 years
Number of learners in observed classroom	53
Teaching load (periods)	20

4.5.2 Findings from interview before use of CBS as an instructional strategy

Theme1: Advantages of CBS

Teacher B anticipated that CBS would improve learners' learning:

L93 Interviewer: *Ok then, have you heard of computer simulation?*

L94 Teacher B: *Yes, I have heard about them from a far.*

L95 Interviewer: *What do you know about them?*

L96 Teacher B: *Ahmm, I know that and I think I'm interested that it can bring manipulation because there certain style of learners that need to manipulate and also those are visuals, they can visualise better. Like as I have said in a practical those who have seen can recall up to a certain percentage than if you just use formal lecture.*

L97 Interviewer: *How do you think they can improve because they do practicals? Then how do you think the computer simulations can add?*

L98 Teacher B: *I think that can be a perfect idea because from my personal experience, learning is something has … pupils are shifting … technologically, they are now interested in gadgets. So if you can use them i think you can just get their hearts. I think you can just get their hearts.*(Appendix K).

In the extract above, Teacher B mentioned that she was interested in CBS because learners' understanding can be enhanced as they can learn by visualisation and manipulation. This shows that she understood that visualising enhances learners' understanding better than merely explaining concepts theoretically. She also noted that using CBS can improve learners' interest in the topic because this teaching strategy is relevant to them as they are technologically inclined and eager to use modern technology.

Theme 2: Learners' difficulties in electrolysis

Teacher B indicated that learners have difficulties with the concept of the polarity of electrodes. It seems that learners find it hard to distinguish between the cathode and the anode terminals and reactions, as well as with the migration of ions during the process of electrolysis. This was noted in the excerpt below:

> *Mhm … polarity is still an issue and identifying the ions. And they cannot imagine that ions move, you know theoretically but they don't understand. They don't show understanding that ions they do move* (L90).

The extract above is an indication that she was aware of some common difficulties in the topic of electrolysis. However, she did not explain clearly where learners experience challenges. When she was asked to give examples of the challenges in teaching electrolysis, she mentioned the following:

L71 **Interviewer:** *Ok, so eh … what are the challenges of teaching electrolysis … the challenges you have encountered, for both you as a teacher and the students.*

L72 **Interviewee:** *Ok, it is usually the … it is usually the method because pupils they learn at different … styles. Let me say different styles. So others are irritated by the noise and others they do not do well in an incooperating (*not clear) *environment. Like I said I usually have 10, and they always lack prerequisite information. And others, because of this incorporating physics a lot, and so you find that others are doing very bad in physics, so the moment you talk about current, it means that you have set them aside and also brings about charges and ions, which we do in bonding. A lot of students are challenged by ... bonding.*

L73 **Interviewer:** *Ok.*

L74 Interviewee: *And also by identifying if the substance is ionic or molecular, so the fact that this topic needs about 30% of bonding. Some learners are left there. When I move, it's the same pupil who did well in the bonding.* (Appendix K).

Ten learners per group made it the class situation difficult to handle because the class became noisy. She also mentioned that some learners struggled with electrolysis because they lacked the pre-requisite knowledge, especially those learners who had challenges in physics. She explained that some learners may have had a negative attitude towards the topic and would not make any effort. Learners are diverse, thus some may not keep up.

Theme 3: Challenges in using CBS

She mentioned two major challenges with practical work that may also make it difficult to use CBS in schools:

L54 Interviewee: *I usually have a maximum of five groups, I don't have enough equipment.*

L57 Interviewer: *Ok, I will get back to that as for the challenges maybe. You are going to expand on that. The experiments the groups, how big are the groups, you said you have five groups. How many students per group?*

L58 Interviewee: *10.*

L59 Interviewer: *10 students per group!!?*

L60 Interviewee: *Yes,e usually have high numbers.*

L61 Interviewer: *So how do you make sure that each student participate?*

L62 Teacher B: *No, it's not easy but still it outweigh having to explain.*

L63 Interviewer: *Ok.*

L64 Teacher B: *The small chance of checking or peeping through, still it makes a learner better to understand, better for the learner than denying the total practical.*

The large number of learners and a shortage of equipment were given as major challenges that may have made it difficult to introduce CBS in schools. Using CBS as an instructional strategy is a learner-centred approach. Thus, it is expected that learners have to work individually or at least in pairs and it is expected of the teacher to guide the leaners during the lesson and give individual assistance. However, with these challenges, the use of CBS as an instructional method may be compromised. For example, ten learners at one computer would be inefficient due to the inadequate participation of individual learners. However, she acknowledged the importance of doing the practicals even though there were such challenges as she noted that it is still better than not doing it at all.

Theme 4: Teaching strategies

Teacher B explained that she used formal lectures, informal lectures, discussions, and questioning to teach electrolysis but from experience, she found experiments to be more efficient. She indicated that learners found the topic difficult and abstract. She acknowledged that the learners previously approached her and told her that they did not understand electrolysis, saying;

> *We can't imagine, we do not even form a picture of what you are trying to say* (L44).

After that, she decided to do practicals and used them as another teaching strategy. She was asked how she assisted learners when doing a practical activity. Her response is noted in the extract below:

L65 **Interviewer:** *And then as a teacher how do you assist …? What is your role when the students are doing the practical activity?*

L66 **Interviewee:** *I usually do not have a lot of duties. The learners, I have discovered that they are not empty vessels. Out of the blue, I can see a student knowing everything, even operating the power supply better than myself and then I just award them as heroes, so then the others are motivated.*

L67 **Interviewer:** *So you mean you do not assist them in any way?*

L68 **Interviewee:** *I first tried, and I realised that students are not empty vessels. So my duty now is to encourage those that are not doing well in the practical. So I usually … get close to that group, but I usually use those that are … those that were able to connect* *quicker, then I encourage them to go help the others, so usually many teachers.*

L69 Interviewer: *So the other students assisting them?*

L70 Interviewee: *Yes, I usually tell them that now you are assisting the teacher. So you are a teacher assistant, and they usually do a lot and better because the students, they communicate better.*

Her response suggests that she found practical group work effective for learning. She encouraged learners to work in groups while she guided them during the lesson. Her response also shows her understanding that learners, at times, work best when they learn from each other as they relate to each other much better. The extract also indicates that she understood the Social Constructivist Theory of learning and utilised group learning; this was noted when she mentioned that learners are not empty vessels. It showed that she was aware of the importance of group learning in improving learners' understanding of concepts and thus retention is improved.

However, she also admitted that she had not found an appropriate teaching method that was suitable for all learners:

L79 Interviewer: *So how do you accommodate the differences in the learning* **|** *styles of the students?*

L80 Interviewee: *Think I've got natural short … ehh … what can I say, a shortfall something like that, because, yes to tell the truth (nje), I haven't identified a fair teaching method or strategy to accommodate all of them…*

She seemed to believe that there should be one single best teaching method.

Theme 5: Teachers' curricular knowledge

She also revealed part of her own curricular knowledge when discussing learners' difficulties. She clearly indicated that the topics of bonding and electricity provide essential prior knowledge for understanding electrolysis. She regarded the application of electrolysis as the reason why learners' have to understand the topic, which shows that her focus was on the end-product, not the chemical process of redox reactions:

L91 Interviewer: *So, what do you … why do think it is important for the learners to understand the topic of electrolysis?*

L92 Teacher B: *This is a very important topic, we have cars around; it is an application of the bumpers being electrolysed, there's coating of metal using another metal. They are interested in cars and also they get employment and also when we talk about ways to prevent rust, electroplating which is also an application and also a lot of substances that can be manufactured using this especially concentrated, it's another way of making it.*

Theme 6: Teachers' attitudes

She revealed a positive attitude and willingness to improve her teaching, as shown in the following discussion:

L37 Interviewer: *What were your reasons for changing from the formal to informal to the practical?*

L38 Teacher B: *It remained abstract for the students, they could not concretise; the marks were low, the students came and others were angry and bitter. They said we do not understand your chemistry, instead of becoming angry I decided to change this because the results to me were not equivalent to the time I was spending … the results I was getting were too low.*

The above excerpt shows that conventional teaching methods were not serving the purpose of learning. The learners could not understand what was taught and she started implementing practical work in an attempt to improve teaching and learning. She confessed that she had not found a teaching method that worked for teaching electrolysis.

Similarly, she was willing to use CBS to improve teaching; this was observed in the excerpt below:

L101 Interviewer: *Would you like to use CBS or try them out?*

L102 Teacher B: *Of course, yes.*

L103 Interviewer*:* *Ok.*

L104 Teacher B: *And I'm even excited already because I can imagine my students saying "wow". Yes, I think it can help a great deal.*

Her response shows that she believed CBS can improve learners' understanding of concepts and she acknowledged that learners would love it since today's generation is technology inclined. It was clear that she had a positive attitude towards using CBS, wanted to improve her teaching, and was also looking forward to using it.

4.5.3 Questionnaire before using CBS

Theme 3: Challenges in using CBS

She noted that one of the factors that influenced her teaching of electrolysis was learners' prior knowledge. She particularly regarded learners' understanding of bonding as a limitation:

> *Ionic bonding which is done in chapter 5, so learners who had problems had no foundation, some learners are not interested* (q5, Appendix Y).

This meant that learners who lacked an understanding of bonding struggled to understand electrolysis and thus lost interest in the lesson. She also regarded gaps in the learners' knowledge of electricity as a challenge:

> *Electricity in physics gaps in the syllabus. A huge gap is existing between the JC and O level* (q3).

Theme 4: Teaching strategies

She indicated that she used "experimentation, demonstration, discussion, questioning" (q4) to teach electrolysis. This means that she combined different teaching methods.

Theme 5: Teachers' curricular knowledge

In the pedagogical section of the questionnaire, Teacher B indicated that learners have to cover certain topics, such as chemical bonding and current, before they can understand electrolysis. This indicates that she had some knowledge of curricular saliency.

In the content section, which explored teachers' knowledge of subject matter, she made some basic mistakes in Question 1, 2 and 3, but not in 4. For example, she identified an unknown substance B as carbonate instead of sodium chloride when the products of electrolysis would be sodium and chlorine. Question 3 was admittedly difficult, and she answered incorrectly. The correct answer was molten copper sulphate using copper electrodes, not inert electrodes. So, like electrolysis for the purification of metals, the anode would be eaten away while the cathode would be coated with extra copper. These incorrect responses indicate that she lacked SMK. Nevertheless, when asked what she wanted students to know about the topic, she wrote:

> *Electrolysis, extraction of aluminium and manufacture of chlorine are some of the main ideas in this topic".* She added that *"learners need to understand electrolysis' application in electroplating, especially in the car industry (q1), (*Appendix Y).

It therefore seems that she had better knowledge of the applications than the detailed chemistry of electrolysis.

Theme 6: Teachers' attitude

When Teacher B was asked to describe factors that influenced her teaching of electrolysis, she wrote "not very confident in electricity, unable to identify concrete information" (q6). This shows her positive attitude and willingness to reveal her weaknesses in the knowledge content and the disadvantage it posed in her teaching.

4.5.4 Lesson plan

Theme 4: Teaching strategies

This section presents an analysis of the three lesson plans that she prepared for using the CBS in teaching electrolysis. The three topics covered the electrolysis of $CuSO_4$ solution, acidified water and brine.

In the first lesson, Teacher B planned to use discussion and questioning; and in the second lesson, she planned to use deductive reasoning, questioning and exposition. In the third lesson, she again indicated deductive reasoning and questioning teaching strategies. She also planned to use CBS in all three lesson plans.

Also, in the first lesson plan she planned to draw the circuit diagram on the chalkboard. This is an indication that she accommodated learners who understood better when visual representations are included in the teaching and learning process. However, she did not plan any practical demonstration together with the CBS in any of the lessons.

Theme 5: Teachers' curricular knowledge

The lesson objectives in each lesson plan stated the focus of the lesson, which revealed her own curricular knowledge to some extent. The first lesson plan indicated that learners should be able to:

- Define electrolysis;
- Identify a cathode and an anode from a circuit;
- Identify ions; and
- Describe the cathode and anode reactions. (Appendix AA)

In the second lesson plan, concerning the electrolysis of water, the following objectives were stated, that the learners should be able to:

- Write observations in the Hofmann's voltammeter (ratio of gases);
- Write the cathode and anode reactions;
- Identify ions in water. (Appendix AB).

In the third lesson plan, which had electrolysis of brine as its sub-topic, the lesson objectives were stated as learners being able to:

- Identify ions in concentrated brine solution;
- Write three uses of sodium hydroxide; and
- Write the equations on the cathode and anode. (Appendix AC)

These outcomes indicate what she considered as the main ideas in the lesson. It indicates mostly declarative knowledge, suggesting that she did not expect the learners to explain chemical processes. This may be regarded as an indication of the depth of her own understanding of the content.

4.5.5 Lesson observation

Three lessons were observed while she was teaching electrolysis using CBS. The observation guide was used by the researcher and it guided her regarding what to look for during the lesson observation. Things that were noted include how the teacher introduced the lesson, noting prior knowledge that the teacher drew on, her use of examples, her use of analogies and the introduction of CBS. Lesson delivery was also noted during the lesson, in other words, how she involved learners during the lesson, which other teaching methods were used, how she introduced the CBS during the lessons, and how she assisted learners during the lessons. Furthermore, their involvement in the lessons was noted by the questions that they asked.

4.5.5.1 Narrative

The first lesson began at 8:00 and ended at 08:40 and was held in the science laboratory. Some learners brought their laptops for the lessons and they shared willingly with those who did not have. This means that each group had a laptop. There were about ten learners in a group. The lesson was an introduction on electrolysis, focusing on the definitions of electrolysis, identifying the cathode and anode from an electrolytic circuit and identifying ions from computer simulations. The teacher started the lesson by asking learners to watch a video on introduction of electrolysis. The video was about the electrolysis of molten copper sulphate and the reactions that take place at the cathode and anode. This video took about ten minutes to watch. She used the video to capture learners' attention, as well as to lead the discussion during the lesson. After watching the video, she then involved the learners through a discussion by asking them questions such as identifying the cathode and the anode electrodes, and writing the balanced equations that took place at the cathode and the anode electrodes.

After the discussion of the video, the teacher asked learners to use the CBS, which was on the electrolysis of copper sulphate solution and learners were to write products at the electrodes and write chemical equations that took place at each electrode. While the learners were using the CBS, she moved around, making sure that all learners participated in the groups. She led a discussion after the use of CBS where she every so often referred the learners to the introductory video that they had watched.

The second lesson was also held in the science laboratory. It started at 08:00 and ended at 08:40. Again, the learners brought their laptops and shared with those who did not have. The teacher started the lesson by recapping the previous lesson, asking learners if they noted what had happened in the computer simulations that they used. She discussed the electrolysis of copper sulphate solution, asking learners what they expected to happen at the electrodes. She then asked learners which ions would be preferred between a sulphate and a hydroxide ion. She was linking the previous lesson to what was to be covered that day. Then, she introduced the lesson for the day as the electrolysis of acidified water. She let the learners do a computer simulation on the electrolysis of acidified water. While the learners were using the CBS, she moved around, asking them questions and ensuring that they were participating. Afterwards, she again involved the learners in the form of a discussion by asking questions. They then had to come up with a chemical equation at the electrodes and the overall chemical equation. She ended the lesson by asking learners to write a test on oxygen and hydrogen gas.

The third lesson was also held in the science laboratory and was on electrolysis of brine. She started the lesson by discussing the task she had given learners as homework, which was a test for hydrogen and oxygen. They also had to explain the change in *pH* at the electrodes. She was observed to be referring the learners to the CBS that was used in the previous lesson, which shows that the CBS was supposed to help the learners in their homework and in answering the question.

The CBS that was used in this lesson showed the electrolysis of a concentrated sodium chloride solution. She assisted learners in their groups while they were using the CBS. She used an analogy of melting sugar to emphasise that electrolysis can also be used in molten substances. During the lesson, she mainly used the discussion method to engage the learners, referring them to the CBS that they had used. The lesson ended with her making learners aware that there is another CBS that summarises the whole topic, which learners could observe on their own.

4.5.5.2 Observation analysis

Theme 1: Advantages of CBS

CBS improves learners' understanding of electrolysis. This happens in that it engages learners and the teacher, causing learners to question things and the teacher to think deeply about the development of the lesson. This was observed in the second lesson when a discussion occurred on deciding which gas would be collected at the electrodes, as illustrated in the extract below:

L24 **Teacher**: *Now let us look at the first example, which substance was decomposed or was there any substance that was decomposed?*

L25 **Student**: *Copper sulphate.*

L26 **Teacher:** *Is it just copper sulphate?*

L27 **Student:** *Copper (II) sulphate.*

L28 **Teacher:** *Now give me the ions that are present here … the two ions*.

L29 **Student:** *Copper and sulphate* [She then asked learners to work in their groups using the given CBS on electrolysis of copper sulphate solution to find what would be produced at the electrodes. She also moved around checking the groups].

L30 **Teacher:** *Thank you very much. Then we put copper sulphate in solution, which ions are present in the water? Two ions?*

L31 **Student**: *Hydrogen and oxygen.*

L32 **Teacher**: *Anything different?*

L33 **Student:** *Hydroxide and hydrogen.*

L34 **Teacher**: *Which one is negative and which one is positive?*

L35 **Student:** *Hydrogen is positive and hydroxide is negative.*(Appendix N).

The excerpt shows that both the learners and the teachers were engaged during the lesson. When the teacher said, "let us take it step by step", it meant that she wanted the learners to engage in deep thinking.

Theme 4: Teaching strategies

On the use of CBS as an instructional strategy, she was observed to be engaging the learners by asking them questions every so often. She was also observed going around to the groups and assisting the learners. She combined the CBS use with other teaching methods such as lecturing, questioning, and the discussion methods. For example, the following questioning occurred during the third lesson to identify the products of the electrolysis of brine:

L31 Student: *Sodium and chloride.*

L32 Teacher: *Ok, from the water?*

L33 Student: *H_2O.*

L34 Teacher: *Please guys, only talk to me. Guys at the back, only talk to me So, according to the video which ions were in the cathode? Ions in the cathode? … It's H. What's the formula $2H^+$*

L35 Student: *Hydrogen.*

L36 Teacher: *It's hydrogen gas and then in the anode? In the anode, hawu* [oh]*… In the anode it's, it's $2Cl^-$ plus 2 electrons, then you get?*

L37 Students: *Chlorine.*

L38 Teacher: *Chlorine, yes. What remains in the container then?*(Appendix O)

The excerpt above shows that Teacher B mainly used the questioning/discussion method to engage the learners. This comprises formative assessment, it is on-going, and helps learners to diagnose their strengths and weaknesses. However, it seems that learners were struggling to keep up and she did not elaborate on the learners' responses. Instead, she kept asking questions and often provided the answer herself. The questions she asked were, however, relevant.

Teacher B was observed writing key points on the chalkboard. In the first lesson, when drawing an electrolytic cell on the chalkboard, she explained that the order in the connection of apparatus is very important:

> *Now we have our electrodes here (draws on the chalkboard). The taller one is the positive. So now I want us to polarise them, which one is going to be positive? (writes on the chalkboard). So I write positive and negative here, (pointing at the electrodes), okay. My diagram is not proper, let me join it here. Guys, the order is important. So, which one is going to be our anode, our cathode? Let us say this is 1 and 2, which one will be the anode and which one will be the cathode? Raise your hand* (L36).

During the lesson, she wrote on the chalkboard what she considered as key points and also emphasised to the learners what was important. This was noted as she said that the order in the electrolytic cell is important.

Theme 5: Teachers' curricular knowledge

Her knowledge of the content seemed to lack depth. This was noted on more than one occasion. For example, in her first lesson she did not explain to the learners how the ions at the electrodes are oxidised or reduced:

L47 **Teacher**: *Yes, yes, the reactivity series. Which one is more reactive between copper and hydrogen?*

L48 **Students:** *Copper.*

L49 **Teacher**: *Who can recall the reactivity series? I will write it on the board, raise it up on the board. Now our focus is here, which one is more reactive?*

L50 **Student:** *Hydrogen.*

L51 **Teacher:** *Hydrogen is more reactive than copper? Copper. We take the one below, that is, the less reactive metal. We get that since copper was less reactive than hydrogen, copper was preferred. When we were looking at the reactions of metals, it was the opposite. We used to take the one above, the more reactive one but now the opposite occurs, we take the less reactive metal.*
Now let us look at the anode, which one is preferred, the hydroxide or the sulphate? Raise up your hands. We have two negative ions. Guys, are you following? Yes, I'm saying not all of them is going to be found here [pointing to the diagram on the boar]. Which ion is going to be found here? Yes?

Her lack of understanding was also observed in the third lesson when she said in the introduction that the lesson was going to be on molten compounds, yet the CBS was about the electrolysis of brine, which is a concentrated sodium chloride solution. She then talked about the difference between molten and dissolved compounds and then referred to brine as "sodium hydroxide" (L27). After the students used the CBS she continued:

> *For brine, what is brine? Electrolysis of a molten compound, which is brine* (L30).

However, later in the lesson, she named it correctly but without indicating that it is a concentrated solution. She then discussed the products hydrogen, chlorine and sodium hydroxide, as well as their industrial importance.

The lesson observation clearly demonstrated that Teacher B lacked an understanding in chemical processes as she even struggled with the names of the substances. It seems that she did not realise that she was making many mistakes when presenting the lessons.

Theme 6: Teachers' attitude

In the second lesson, Teacher B appreciated the correction that was indicated by the learners and thought about what she had written on the chalkboard:

L45 Teacher: *In the anode there is gaining, yes. So there is gaining of electrons. Is this oxidation or reduction?*

L46 Student: *Reduction.*

L47 Teacher: *Yes … The anode undergoes the reduction reaction. What about the cathode reaction? Let us maintain order, Student A said he saw the gaining of electrons. Where were they coming from?*

Some discussion followed before Teacher B noticed her mistake:

L53 Teacher: *Yes, its oxidation. Now I want us to come up with a reaction, the complete reaction. The last lesson we heard how this reaction is split, it split like this. What is the reaction in the cathode, which ions are involved there?*

L54 Student: *Two hydrogen ions plus two electrons.*

L55 Teacher: *Cathode please?* [some students objected, she then realised the anode reaction written on the board could be wrong]. *We are done with the anode, members please help her, are you sure? That means the other group gave me something wrong for this side. Yes, we all made a mistake, okay let us see. In the anode,* *we are going to get which gas, we'll get hydrogen, cathode we'll get hydrogen? Okay let us take it step by step. Let us look at the, what do we call this? The power supply and let us look at the terminals?*

She revealed a positive attitude when admitting and erasing her mistake from the chalkboard. Then she again engaged the learners in writing the correct half reaction.

4.5.6 Interview after using CBS

Theme 1: Advantages of CBS

Teacher B mentioned that it was her first time using CBS and that it helped the learners to understand the topic. This was noted in her response when she was asked how the use of computer simulations changed her teaching of chemistry:

> *There was visualising of this abstract concept that I have failed over the years to explain, and the learners they usually fail to understand since its abstract. This time around, they had the understanding improved since they visualised and concretised the information* (L10, Appendix L).

Her response indicates that she was aware that electrolysis is an abstract concept and accepted that she was unable to deliver it appropriately. She thus acknowledged that learning is enhanced when learners visualise what they learn theoretically. This shows that she understood that CBS enhances learners' understanding of abstract concepts.

Also, according to Teacher B, CBS generates interest for learners and causes them to pay more attention and be more alert throughout the lesson:

L25 **Interviewer:** *Ok. So what did you find exciting about the lesson, whereby this time around you were using computer simulation?*

L26 **Teacher B**: *This generation is an electronic generation and they showed interest. I think when we still used this old method. The chalk and board, I lost a lot of students. But now they were captivated throughout.*

The extract shows that Teacher B observed that CBS improves learners' participation in the lesson as the learners showed interest in the lesson as compared to when using the traditional methods of teaching. She also saw the relevance of the use of CBS to today's generation as it is a generation that uses technology.

She was also impressed by the way in which the learners enjoyed working on their own. They were self-driven and were able to assist each other:

L31 **Interviewer:** *Ok. So how did you assist the learners during, when using the computer simulation?*

L32 **Teacher B:** *Actually, I am surprised. During a normal day I usually have to assist them, but this time around not expected, they assisted each other. It was quite amazing and interesting. Yes, those who were able to follow were able to manipulate and in fact to change this, eh, what can I say, to reverse a bit because I am unable to rewind myself but the learners each time I asked a question would just go back a bit, and find things on their own.*

CBS enabled learners to take responsibility for their own learning and to support one another. Teacher B was impressed by the spontaneous learning that took place. She realised that her responsibility was to guide the learners and clarify where necessary. She also saw that manipulation helps learners to learn and understand concepts better.

Theme 2: Learners' difficulties in electrolysis

She mentioned that:

> *They usually have issues with ions, yes. Identifying ions, which today I tried to discuss with them. Yes, so that they first know the ions that are expected to be seen (L34*, Appendix L*).*

In electrolysis, it is important for learners to understand which ions are present during electrolysis at the electrodes so that they are able to come up with equations at the cathode and the anode and the overall chemical equation that has taken place. However, in this interview she mentioned only one difficulty without elaborating where exactly the learners had a challenge with the ions. This may be an indication that she had limited content knowledge of electrolysis or limited understanding of learners' difficulties.

Theme 3: Challenges in using CBS

She noted that some of the learners were not used to computers since the learners came from different backgrounds. She also mentioned a lack of facilities, which may be a challenge in using CBS as an instructional strategy:

L27 **Interviewer:** *So eh…what are the disadvantages if any of using computer simulations?*

L28 **Teacher B:** *Eh. One, I can say maybe one or two. One, maybe our school does not have the facility since it is not an urban school, so there may be scarcity of the simulations and the gadgets for using the simulations. Scarcity of the gadgets is a challenge. And then eh … two… what else did I want to say. We are talking about problems or disadvantages?*

L29 **Interviewer**: *Disadvantages.*

L30 **Teacher B:** *Ow. Disadvantages, I think, yah, I can come up with one. It is the scarcity of this. Oh, another one was that some learners are not able, are not exposed in using this gadget. So, but (ke) it's not a problem because there are group members they are assisted. (*Appendix L)

She was aware that educational background has been found to have an impact on learners' achievement or performance in schools. It impacts learners' performance and teachers' choice of instructional strategy. She also mentioned the unavailability of equipment, which seems surprising as the school had a computer laboratory. However, in this case she referred to computers for the science department. This actually meant that she did not usually have access to the school's computer centre.

The issue of having a large number of learners also came up as a challenge that may pose a threat to the efficient use of CBSs:

> *If you use the simulation, I think you must have a small class. I actually had 54 … eh … 50 to 54. And this can be the numbers were a challenge to me, it wasn't easy to attend to the groups* (L40)*.*

Thus, with this challenge, it could have problematic using CBS effectively in schools. The large numbers made it difficult for her to guide each group.

Theme 4: Teaching strategies

She mentioned that together with the computer simulations, she also used discussion and a lot of questioning:

L3 Interviewer: **…***Eh this is going to be the last interview. It's going to be eh on how you found the use of computer simulations effective or both effective during the lesson. So, the first question is what teaching strategies did you use during the last sessions in teaching electrolysis?*

L4 Teacher B: *Ok. I used computer simulation, discussion and a lot of questioning.*

She combined different teaching methods for different reasons to teach electrolysis. She also gave her reasons for using the other teaching methods together with CBS as follows:

L5 Interviewer: *So you used three teaching methods. So, give reasons for using each one of them.*

L6 Teacher B: *Simulations, they were for, for the learners. Ok, let me start by discussion. After they have started listening and viewing I went group by group to evaluate their understanding and the questioning was also for including the class, and also the evaluation of the whole class and also to provoke their thinking. The simulations were for visualising. This is best method that fit those learners that have visualising as their learning style.*

Teacher B tried to accommodate the different learning styles of learners as she was aware that some learners learn best visually. So, to make her teaching effective, she combined the computer simulations with the discussion, and the questioning teaching methods. As mentioned earlier, the other teaching methods she used had their limitations. Using the different teaching methods complimented the weakness of each with the strengths of the others. She also understood the step by step procedure of a lesson by letting learners hear, see and then letting them manipulate and apply what they had observed. She indicated that she regarded the CBS as more effective than practical experiments:

L13 Interviewer: *So, do you think the, computer simulation can eh … substitute the practical or it can be used together that is as an additional teaching method. I mean, use the methods that you have been using and then in addition use the computer simulation and then, or now you want to do away with the practical?*

L14 Teacher B: *I think I will do away with the practicals. The practical it has some shortcomings … some gaps, just a solution with … there's no change they see, there is no movements of the electrons yet this is electrolysis, we wanna see electrons. When we talk about oxidation, reduction, this usually gives me a problem and they usually fail at the end because they cannot visualise.*

In terms of assessment, she mentioned that she gave the learners a test to assess their understanding of electrolysis after using CBS:

L15 Interviewer: *So if you, when you say they usually fail … have you then given a test after using computer simulations?*

L16Teacher B: *Yes, I have given them a test.*

L17Interviewer: *And how has the performance compared to the previous years or previous group?*

L18Teacher B: *It has improved.*

The extract above shows that she believed that they improved in the test on electrolysis compared to previous years. The improvement may have been due to the use of the CBS as an additional teaching strategy.

Theme 5: Teachers' curricular knowledge

Teacher B said that she had challenges with her subject matter knowledge in electrolysis. She acknowledged that CBS assisted her in understanding the topic better:

L19 **Interviewer:** *So now, how have the use of computer simulations improved your understanding of electrolysis?*

L20 **Interviewee:** *Eh. Especially the second, second lesson, I discovered that in fact, I had issues as well, which I, after using the simulation, we, the learners they understood better and they started correcting me and I felt it was a little bit, it was some havoc because the learners, they kept on assisting me and I was not aware that I did not know the concepts, but after the learners asked a lot of questions, it was then that I gave myself time to revisit the simulation and yes, I was always wrong.*(Appendix L).

Using CBS caused her to think deeply about the topic and when the learners asked her a lot of questions, she had to think about the answers. This helped her to do more research on the topic and understand the topic. The corrections given by the learners shows that she lacked SMK. If a teacher lacks SMK, that may limit their explanations. This may have a negative effect on the understanding and performance of the learners.

Also, in terms of the pre-requisite knowledge for electrolysis, she said, "Ok, it is usually chemical bonding, where before you know you must know the ions that are involved or naming of ions still mainly, it's usually an issue but not after the simulations." Her response indicates that she knew which concepts and topics are required for electrolysis.

Theme 6: Teachers' attitude

Teacher B was concerned when learners had a number of questions to ask her, showing that her understanding of the topic was inadequate. Her realisation caused her to revisit the CBS and consult a few books. This act shows a positive attitude, that is, a willingness to learn more about the topic so that she could have a better understanding of the topic:

L20 **Teacher B:** … *it was some havoc because the learners, they kept on assisting me and I was not aware that I did not know the concepts, but after the learners asked a lot of questions, it was then that I gave my time, myself time to revisit the simulation and yes, I was always wrong.*

L21 **Interviewer:** *So, the computer simulations have actually, they also helped you*?

L22 **Teacher B:** *Yes, actually, I took the side when I read a book and understand it. I discovered in the use of simulations that I myself, there was a lot of improvement from the simulation.*

After reading from a book and revisiting the CBS, she believed that she understood the topic better.

4.5.7 Questionnaire after using CBS

Theme 1: Advantages of CBS

She showed awareness of the advantages of CBS in writing it is the "visualisation of concepts especially movement of ions, it concretises abstract concepts" (q2). She also acknowledged that "learners are interested more than they are interested on chalkboard" (q5, Appendix Z) when using CBS. She further said that "CBS make lesson plan to be quick and effective. It is difficult to prepare and get the apparatus sometimes." This means that the CBS could be used instead of practical experiments to compensate for the shortage of equipment.

Theme 3: Challenges to using CBS

Regarding challenges in terms of using CBS, she noted that "availability in the schools, some schools have access, other schools do not have" (q4). Her response shows that while schools may have computers, these may not be available/accessible for science teaching.

Theme 4: Teaching strategies

When she was asked to describe the teaching procedures that she would use with the CBS, she said that "highlighting areas of importance before and questioning after the simulations" (q7). Where she explained strategies that she would use to ascertain learners' understanding of concepts, she said that she would use "high-order questioning, discussion" (q8). This means that she was aware of the importance of directing learners to the lesson focus so that learners pay attention. She also understood the importance of eliciting learners' understanding in the form of class discussion.

Theme 6: Teachers' curricular knowledge

When she was asked to explain what she intended learners to learn in electrolysis, she wrote that it is to "draw labelled diagram of an electrolytic cell, using the terms anode and cathode, outline the manufacture of chlorine and sodium hydroxide" (q1). She further indicated that "previous knowledge, chapter of nomenclature, electricity from physics and so many concepts in one topic" (q6) were factors that influenced her teaching. She did not mention the chemical reactions at all.

4.5.8 Summary of the findings of Teacher B

A summary of the findings from Teacher B is presented in Table 4.5.

Table 4.5 Themes identified from Teacher B from the different instruments

	Advantages of CBS	Learners' difficulties in electrolysis	Challenges in using CBS	Teaching strategies	Teacher' curricular knowledge	Teacher's attitude
Q1			x	x	x	x
I1	X	X	x	x	x	x
LP				x	x	
O	X			x	x	x
Q2	X		x	x		x
I2	X	X	x	x	x	x

Key: Q1 - questionnaire before using CBS

I1 - interview before using CBS

LP - lesson plan

O - Observation

Q2 - questionnaire after using CBS

I2 - interview after using CBS

Theme 1: Advantages of CBS

Teacher B believed that using CBS to teach electrolysis holds many advantages. In the interview before using CBS, she anticipated that CBS may enhance learners' understanding of electrolysis because they would learn by manipulating and by visualising. She added that CBS can capture learners' interest since they are from the new "technological" generation, who are interested in "gadgets". Her anticipation was confirmed in the interview after the learners had used the CBS as she mentioned that learners understood much better than in previous years and she ascribed this improved understanding to visualisation. She also remarked that the learners were "captivated" as they were the "electronic generation". She added that the CBS enabled learners to be self-driven, to work independently, assisting each other and requiring minimum guidance from her. They were able to manipulate the CBS themselves and to "rewind", therefore being responsible for their own learning. In the questionnaire after using CBS, she wrote that learners could visualise the migration of ions, which the practical experiments do not show. She added that using the CBS also allowed learners to concretise abstract concepts and learners' were more interested in the lesson than when using traditional methods such as "chalkboard writing". In the final interview, she also mentioned that learners' asked many questions about oxidation and reduction, which helped her to realise her own misunderstanding. This remark showed that she realised that CBS promotes critical thinking, discussion and learning, not only for learners but also for the teacher.

Theme 2: Learners' difficulties in electrolysis

Learners' difficulties were revealed in the first questionnaire as well as in both interviews. Before using CBS, she mentioned that the learners struggled with naming the electrodes and the migration of ions during electrolysis. She added that learners had difficulties with the topic of chemical bonding, although she did not elaborate on the nature of the challenge. In the interview after using CBS, she said that learners had difficulties in identifying ions in electrolysis, but she did not elaborate on these difficulties.

Theme 3: Challenges to using CBS

The questionnaires and interview before and after using CBS all revealed similar challenges associated with using CBS to teach electrolysis. In all of the instruments, she mentioned that the large number of learners in her class was a challenge. This meant that the groups were too big and difficult to monitor, having about ten learners in a group. She noted that it made it difficult for her to guide the different groups. Consequently, some learners may not have participated in the groups and got left behind, not getting the opportunity to manipulate the CBS themselves. However, she acknowledged that using CBS with large groups would be better than not using it at all.

She also said in the first interview that some learners lacked the knowledge of physics required to understand electrolysis. These learners simply shut down when they learnt about electrolysis, especially those who were struggling in physics. This meant that some learners lost interest and did not put in any effort, thus some learners were left behind because they developed a negative attitude towards the topic.

The shortage of equipment and “gadgets” is another challenge that she mentioned. Of interest, however, is that school B has a computer laboratory. However, the computer laboratory was reserved for computer lessons and was not available to other departments. This is a policy of the school to monitor the equipment in the school. Therefore, the computer laboratories were under-utilised.

Learners’ socio- economic background was also given as a challenge as some of the learners had not been exposed to computers so they may have experienced challenges in using computers. However, to overcome that challenge, Teacher B said that learners may assist each other.

Theme 4: Teaching strategies

Teacher B indicated that she used practical work, questioning, and discussions as teaching strategies prior to the study. This was revealed in all of the instruments that were used to collect data in this study. During the lesson observation, she used questioning and discussion as teaching strategies together with the CBS. She said that she used the question and answer method to link the lesson being presented with the previous one to provoke learners' thinking and to engage them in the lesson. She further noted that practical activities enable learners to be hands-on and the CBS enables learners to visualise and manipulate. She concluded that if these are not used, the topic remains abstract for learners. However, she did not use experiments together with the CBS during the lesson observations.

In the interview before using CBS, she confessed that some years back she had been using the traditional methods of teaching, mostly the chalkboard. She later realised that the traditional methods were not good enough because the learners complained, telling her that they did not understand. Thus, she changed and began to include practicals when teaching this topic and she reported that the learners' performance improved. She mentioned that during practical work, the learners worked in groups and mostly without her assistance. This showed that she understood that learners learn better when they seek information themselves and work with others.

However, it seemed that she wanted to have one single best method that she could use to teach electrolysis. In the interview before using CBS, she said that she had not found one “best” method that she could use. After using CBS, when asked how she planned to use the CBS in future, she suggested that she would do away with the practicals and only use CBS, indicating her belief that there should be one ‘best method’. Her preference for CBS above practical experiments suggests that she was mostly concerned about the microscopic aspects of electrolysis but did not appreciate the importance of the macroscopic observable effects. The CBS should not displace any of the traditional teaching strategies, but should be combined with them to make its use more effective. She also believed that the performance of the learners improved after they had used CBS in their lessons. This belief confirms that she had been teaching the topic for years without finding an effective way to teach it with understanding.

She was also observed to be asking relevant questions in her lessons, although she sometimes did not wait for the learners to answer and kept questioning them instead. She said that she was going to use higher-order questions in the questionnaire after using CBS to elicit learners' understanding. Some of the questions she used during the lessons were indeed of a higher-order nature.

The lesson plans she intended to use in her teaching also showed the different teaching strategies that she considered using. These concurred with the teaching strategies that she said she used in the interviews and questionnaires, and what she practiced in class.

Theme 5: Teachers' curricular knowledge

Teacher B's curricular knowledge was revealed in all of the instruments that were used in different ways. In the interview and questionnaire before using CBS, she regarded the applications of electrolysis as the reason why learners should understand the topic, which shows that her focus was on the end-product, not the chemical processes involved in electrolysis. She was aware of the content of the lessons as she stated the lesson objectives in the lesson plan and questionnaire after using CBS as what she intended learners to learn in electrolysis. However, she did not indicate the chemical processes as important outcomes. She showed an understanding of curricular saliency when indicating bonding, the reactivity series and electricity as topics that link to electrolysis and which have to be covered before electrolysis.

Although she mentioned that learners have difficulties with oxidation and reduction, she did not explain it adequately during the lessons. In fact, she made some mistakes during the lesson, and the learners questioned and corrected her on it. Also, she did not give adequate explanations of how to use the reactivity series to decide which of the two ions would be reduced (or oxidized). She asked which ion would be 'preferred' and said that it is "different" from the reaction of metals without explaining what is meant by "preferred". This lack of explaining suggests that she did not have a clear understanding of it herself.

Theme 6: Teachers' attitudes

Her positive attitude was first observed in the first interview when she said that she had mainly been using traditional strategies to teach electrolysis, only to have the learners complain that they did not understand because the concept was too abstract for them. She then started to include practicals in her teaching. She also revealed a positive attitude in saying that she was excited about using CBS because it would help her to discover the most appropriate teaching strategy.

During the lesson observations, the learners kept correcting her, which made her realise that her content knowledge was limited. Thus, she went through the CBS again after class and also took the initiative to do further reading on electrolysis. This is a sign of a positive attitude, and a willingness to change from what she was familiar with, i.e. using traditional methods.

In the second interview, she also admitted that she was not aware of how much she did not know and understand regarding the concept of electrolysis. She only realised after being corrected several times by the learners, where after she took the time to do additional reading to try to understand the concept. She appreciated using the CBS and was happy that there was improvement in her own understanding of the concept, showing that she was eager and willing to learn and improve her teaching.

The next section focuses on the findings of Teacher C.

4.6 FINDINGS FROM TEACHER C

4.6.1 Profile

Teacher C was a qualified chemistry teacher who holds a Bachelor of Science (B.Sc.) with Education. She also had a Post-Graduate Certificate in Education (PGCE). She had been teaching chemistry for 14 years at the time of this study. Her school was located in an urban area and had a fully furnished science and computer laboratory. She had a teaching load of 18 periods, each period being 35 minutes during the time of data collection. In the class that was observed, there were 45 learners. Table 4.6 presents a summary of Teacher C's profile.

Table 4.6: Teacher C's profile

Aspect	Details
Gender	Female
Teacher's qualification	B.Sc. with Education
Teacher's experience	14 years
Number of learners in observed class	45
Teaching load (periods)	18

4.6.2 Findings from the interview before the use of CBS as an instructional strategy

Theme 1: Advantages of CBS

Teacher C had never used CBS in her entire teaching experience prior to this study. When asked if she knew about CBS, she responded by saying:

> *I believe it is a method of teaching whereby it helps re-enforce on this topic of electrolysis, whereby the kids see using a computer what is happening when we say probably an electron moving from this place to this place, it is computerised. It better enhances the understanding other than doing it theoretically, it's something like that* (L60, Appendix P).

The extract shows that she believed that CBS may enhance learners' understanding more than doing it theoretically because learners are able to observe the microscopic aspects of electrolysis.

Theme 3: Challenges in using CBS

Prior to the study, she did not use CBS. Some of the reasons she gave for not using it was that:

> *We are going there, but at the moment it's only that, ehm our curriculum, no, our set up, you would need access to have a computers, you would need to have the thing put up. It's not readily available to us, and over the years the theoretical part has been working very well … but like I said, the limitation of time (L*62).

One concern is that the science department did not have access to the computers in the school. Also, she was concerned that she may not have been able to finish the chemistry syllabus on time because using CBS may take a lot of teaching time.

Theme 4: Teaching strategies

When she was asked which teaching methods she uses to teach electrolysis, she responded as follows:

L16 **Teacher C**: *Ok, mainly I use the question and answer method.*

L17 **Interviewer**: *Mhhm.*

L18 **Teacher C**: *That's the first and foremost.*

L19 **Interviewer**: *Mhhm.*

L20 **Teacher C**: *Ehh! because first you have to explain to them what it is all about theoretically.*

L21 **Interviewer:** *Mhhm.*

L22 **Teacher C:** *Then you answer them, showing the concepts.*

L23 **Interviewer**: *Mhhm.*

L24 **Interviewee**: *Emm, so I basically use the question and answer method … using the textbooks, using the diagrams that I can find on the textbooks to explain the concepts theoretically.*

L25 **Interviewer**: *Ehm ... so mainly you use the question and answer method, which is, I can say, is some. Ok, why do you use, like, do you try to engage the learners by using the question and answer?*

L26 **Interviewee**: *Yes, I do try to engage with the learners, simple by, maybe by demonstrate with an example of a substance. Maybe you say sodium hydroxide in the process of electrolysis, then you explain showing…*

According to her response, she mainly used the question and answer strategy. She believed in explaining and then allowed learners to ask questions, which she would then answer. She used questions from the textbooks to ask learners and illustrated concepts by using many examples and drawings also found in the textbook.

However, she noted that the use of the question and answer method has some limitations as the learners could not visualise what she explained theoretically. This was observed when she stated that:

> *Quite frankly, initially it is not easy for them to visualise what is happening, so you have to do more examples trying to explain until they understand, and if they are really not getting it clearly, then give more examples* (L34, Appendix P).

According to her response, she was aware that understanding the topic was not easy for the learners when they had to imagine the process on a sub-microscopic scale. In an effort to help the learners understand, she used additional examples to explain this abstract concept. This meant that she understood the importance of examples and repetition in the teaching and learning process.

When asked how she assessed learners, she responded:

L48 Teacher C: *Learners' assessment mainly, always have to give them tests.*

L49 Interviewer: *That one comes at the end of the lesson, I mean during the lesson?*

L50 Teacher C: *During the lesson? Probably check on how they are participating? I normally check on their participation and I ask them at times like are you really getting the concept, are you really getting what I am explaining. I need to get feedback from them if they are following the concept as I am teaching…*

From her response it seemed that Teacher C did not prepare questions in advance to evaluate learners' understanding. In fact, it seemed that she simply asked learners if they understood or not. The tendency is that when learners are asked that kind of question, they respond by saying that they do understand, even when they do not. It was thus difficult for Teacher C to assess exactly what the learners understood or not with that kind of question. The implication is that Teacher C did not really know with what learners needed help, making it difficult to assist learners. However, she said that she needed to get feedback as she was teaching which means she was aware of the importance of formative evaluation.

Theme 5: Teachers' curricular knowledge

When asked why it is important for learners to understand the concept of electrolysis, her response was as follows:

L44 **Teacher C**: *Mhhmm, besides the obvious benefits of getting good results?*

L45 **Interviewer**: *Yes, besides that?*

L46 **Teacher C**: *Yes, it make them understand like probably in the process of electrolysis, like, whereby there is the electroplating, which makes them understand the process of substances being coated nicely with material, which is better and the obvious advantages of that concept, industrially, economically. I think it an advantage so they have an insight on how does this thing …beautiful, when they say its gold coated, how does this happen,and I think it is quite educative and*...

Her response indicates that she acknowledged the importance of understanding the macroscopic effects of electrolysis and also the industrial application thereof so that learners understand and appreciate how the products are made. She did not mention the importance of understanding the chemistry of redox reactions or the energy transfer during electrolysis.

Theme 6: Teachers' attitude

When she was asked what she regarded as important concepts in electrolysis, she did not really answer the question. Instead, she elaborated on the importance of obtaining good grades in the examinations, revealing an attitude and belief that examination results were prioritised:

L52 **Teacher C**: *Ya* [yes]*, ok, being a teacher in this field for a long time is what I had wanted somehow because you kind of like know, have an idea on how the examiners work. Unfortunately, it's more like working with the examiners because at the end we are looking for good results at the end. It's not more like something like we are grooming, what do you call this? Ehm, students who are going to be expertise, researchers in doing the electrolysis, go* *further in analysing or learning the concepts of electrolysis. It's more like channelling them to the examination.*

L53 Interviewer: *So in other words, so mainly, I don't know, you teach mainly for the exams?*

L54 Teacher C: *Mainly, mainly, mainly that's the core factor, we teach for the exams but it should be beyond that. But because of time limitations, it's not like you are producing scientist, maybe you allow them to be scientist who are going to discover or we allow them to be scientist who will discover more when they reach the university* (Appendix P).

Her response shows her orientation towards teaching science mainly for examination purposes and not for understanding. She believed that the learners would have an opportunity to explore science further at tertiary level. It seems that she was not concerned about learners who may not even reach tertiary level because they could not get good grades.

When asked why she did not use CBS, she responded by saying:

> *We are going there … given the chance and try it out, probably if we look more into it, I didn't look on to it anyway. I think I can give chance to try it out, but I would love to test if it really enhances the understanding, so that, maybe I'm thinking its time taking or maybe it's not, it actually can make my work easier. Otherwise all I'm saying is I need to look more into it. Really understand it and see how I can implement and compare the methods of teaching* (L62).

Her response revealed a positive attitude towards testing CBS and observing if it improved learners' understanding. She acknowledged that she believed CBS to be time-consuming, but that it may prove to be efficient. If it did, she could then work on finding strategies to use it with other teaching strategies. She thought that it might make her work even easier.

4.6.3 Questionnaire before using CBS

Theme 3: Challenges in using CBS

Regarding the limitations to teaching electrolysis, she wrote "equipment to carry out a simple electrolysis technique" (q5, AD). This means that she wanted the learners to do some laboratory practical work in addition to the teaching strategies that she was using. It may also mean that there would not be equipment for CBS.

Theme 4: Teaching strategies

"Question and answer and demonstration" are the teaching strategies that she said she used to teach electrolysis. This shows that she did not use a single method, she combined two or more strategies. She also wrote that she used "topic test questions and group work" (q8) to assess learners' understanding of the topic.

Theme 5: Teachers' curricular knowledge

When she responded to what she intended learners to know in electrolysis, she noted that "learners have to know the products of electrolysis, products for the anode and cathode and the electrode reactions*"* (q1). She further considered "ionic bonding and electron movement" (q3) as previous knowledge required for electrolysis. These answers indicate that she knew that these topics had to be taught before learners could do electrolysis as some of the concepts are applied in understanding electrolysis. When asked why it was important for learners to understand electrolysis, she responded, "This helps the pupils to understand the topic/concept of electrolysis."

4.6.4 Lesson plan

Theme 3: Teaching strategies

For the three lessons, she planned to use CBS as her teaching strategy but she did not use other strategies to support the CBS. In the introduction, Teacher C planned to demonstrate to the learners using CBS. For the first lesson she planned to use copper as her electrodes and copper nitrate as electrolytes. In the second lesson, she intended to demonstrate the electrolysis of acidified water. In the third lesson, she planned to teach about the electrolysis of brine.

Theme 5: Teacher' curricular knowledge

The main ideas in the lesson plans were given as lesson objectives. In the first lessons plan, the objectives were given as learners being able to:

- Describe electrolysis; and
- Draw a labelled diagram for an electrolytic cell using the terms electrode, electrolyte, anode and cathode. (Appendix AF).

In the second lesson plan, it was stated as learners being able to:

- Describe the electrolysis of dilute sulphuric acid (as essentially the electrolysis of acidified water). (Appendix AG).

In the third lesson plan, the lesson objectives were given as the learners being able to:

- Describe the electrolysis of concentrated sodium chloride solution; and
- Give an example of an industry that relies on electrolysis. (Appendix AH).

The curricular knowledge in the lesson plan was also indicated in the pre-requisite knowledge stated in each lesson plan. In the first lesson, which was on defining electrolysis, the pre-requisite knowledge was given as ionic compounds. In the second and third lessons, the pre-requisite knowledge was given as the definition of electrolysis.

4.6.5 Observation

Three lessons were observed while Teacher C was teaching electrolysis using CBS. Aspects that I noted included how the teacher introduced the lesson, how she linked prior knowledge to the new concept, her use of examples, her use of analogies, and how she used CBS in her lessons. It was also observed how she involved learners during the lesson, which other teaching methods were used, and how she assisted learners during the lessons. I lastly observed if the learners were using the CBSs that were provided; their involvement in the lessons was noted by the questions that they asked.

4.6.5.1 Short narrative

Teacher C presented all of her lessons in the science laboratory. The learners used their own laptops and they worked in groups of about five because not all of the learners had laptops. Three lessons were observed in total and each lesson lasted for 35 minutes.

The first lesson began at 08:00 and ended at 08:35. As she already completed an introductory lesson on the electrolysis of copper chloride, she started the first observed lesson by questioning the learners to give the definition of electrolysis and some examples of ionic compounds. She then informed learners that they were going to use CBS, which would enable them to visualise the processes of electrolysis. After a brief discussion, she allowed learners to work in their groups where they selected metals of their choice to use as electrodes and they also used the solution of their choice as electrolytes from the CBS to make an electrolytic cell. While the learners were working in groups, she moved around checking if the learners were engaged in the activity, which took about ten minutes. Thereafter, she facilitated a classroom discussion, focusing mainly on the purification of copper nitrate. She asked learners questions and referred them to the CBS that they were using, and wrote important points on the board such as the chemical equations at the electrodes. During the discussion, she presented an incorrect product and reaction at the cathode. The discussion continued for the remainder of the period. The lesson ended with the teacher telling learners what the next lesson would be about, i.e. the electrolysis of acidified water.

The second lesson began at 08:35 and ended at 09:10. The teacher started the lesson by recapping the previous lesson, asking learners if they remembered anything from the previous lesson. Then she told learners that the lesson would be on the electrolysis of acidified water. She allowed learners to discuss what they expected to observe in the computer simulation on the electrolysis of acidified water. She wrote important points on the chalkboard. She then allowed learners to work in their groups and emphasised that they should observe while using the CBS. She told learners to observe what was going to happen at the electrodes. She then gave learners about fifteen minutes to work in their groups while she moved around. After that, she asked learners to give feedback on what they observed. She involved learners throughout the lesson using questioning. She ended the lesson by discussing the practical application of the electrolysis of acidified water.

The third lesson began at 14:00 and ended at 14:35. She started the lesson by telling learners that they would learn about the electrolysis of brine. She discussed the electrolysis of brine in detail before allowing the learners to use the CBS. While discussing with learners, she wrote important points on the chalkboard. She then gave about fifteen minutes to allow learners to observe using the CBS. After the CBS, she facilitated a discussion about the products, but in doing so she made several mistakes, showing poor content knowledge. The lesson ended with her instructing learners to go and read about the electrolysis of molten compounds, particularly the electrolysis of aluminium oxide. She was not specific about where the learners had to get the information

4.6.5.2 Analysis of the lesson observation using CBS

Theme 1: Advantages of CBS

Teacher A explained in the first lesson that the lesson was different from the other lessons because they would use CBS:

> *In computer simulation, we will be addressing this topic in a more practical manner. You'll actually be seeing what is happening during those processes, thosedifferent processes during electrolysis. To help us understand better, I have with me here some simulations …* (L7, Appendix R).

The extract above shows that Teacher C understood that CBS enhances learners' understanding by visualisation of the electrolysis process.

Also, after the learners had used the CBS in the first lesson, Teacher C asked the learners what they observed. One of the learners responded saying:

L15Student: *We had impure copper and pure copper where there was, where in a solution of copper sulphate, the impure copper was donating electrons to the pure copper. We've seen movement of the electrons moving up the anode into the cathode part, where the mass of the impure copper was reduced and the mass of the pure copper was increasing*.

L16Teacher: *Ok, thank you. Anyone else who observed anything.*

L17Student: *To further add on that, the impurities of impure copper were settled down at the bottom of the container*

This indicates that using CBS enables the learners to observe both the micro and the macroscopic aspects, which they could observe by using an experiment where they used only chemicals.

In the third lesson, Teacher C noted that CBS helps learners, this was when she said:

> *I think by now the various computer simulations that we've been going through are helping you to understand the topic a little bit better* (L6, Appendix T).

Her comment suggests that she was aware that CBS enhances learners' understanding of electrolysis. She emphasised the value of being able to visualise the movement of electrons:

L36 Teacher:…*I don't hear you talking about the movement of electrons. Are we seeing electrons that should be moving … mmmm? Good, people, aren't we seeing electrons moving at the anode. Do we actually observe the electrons moving at the anode being donated to the anode or the cathode donating electrons to our cations.*

L37Students*: We do* (class response).

Theme 4: Teaching strategies

Teacher C used the discussion method to get feedback from learners and also wrote key points on the chalkboard. Her use of examples was observed in the second lesson where she taught about the electrolysis of acidified water after learners had used the CBS:

L20Teacher: *So I want you to look at the behaviour of such ions and I also want you to pay attention to which one of the two is preferred when they are released at the electrodes. We may start our simulation session.* [Teacher moved around the groups without disturbing the learners while learners worked in groups of five. The session took about10 minutes]. *I think I have given you* *enough time to look at thesimulations, eeeee may we please give a feedback eeee on what you observed, does anyone want to contribute to what they have seen,what is it that you have observed during the computer simulations* (silence). *Ok let me be more specific, let's look at what was happening at the anode, let's look at what was happening at the anode. What didyou observe, was there any movement, any electrons involved, yes?* (Student attempts to answer but is too soft) *speak a bit louder please.*

L21Student: *The hydroxide ion drifted to the anode where they were discharged.*

L22Teacher: *The hydroxide ion drifted towards the what, eeeee the anode, so we have the OH minus* (writes on the chalkboard) *and eeeee?*

L23Student: *To give oxygen and nitrogen plus electrons.* (Appendix S).

Teacher C guided learners when using the CBS, giving clear instructions what they had to focus on. After that, she asked relevant questions that related to the syllabus. While the discussions were on-going, she wrote important key points on the chalkboard. This was observed when she wrote the chemical equation that happened at the anode and the cathode reactions.

Theme 5: Teachers' curricular knowledge

In the first lesson, she started the lesson by revisiting the concepts taught in the previous lesson:

L7Teacher: …*Ok, can you give me examples of ionic compounds that you know? Can any one of give me any ionic compounds they know?*

L8Student: *Magnesium Oxide. Magnesium Chloride.*

L9Teacher: *Magnesium Oxide, Magnesium Chloride. Ok thank you, let's use those two examples. In magnesium oxide, which ions are we talking about, which ions are we talking about because we said these are ionic compounds which ions are we talking about? In magnesium oxide.*

L10Student: *Magnesium ion.*

L11Teacher: *One. Magnesium ion. Any other?*

L12Student: *Oxide ion.* (Appendix R).

By asking learners to give ionic compounds, it seemed that she was reminding the learners about the concept of ionic compounds because it linked to her lesson. However, she did not attempt to ask what products would form if this compound was broken down by electrolysis, showing that she did not link the new knowledge clearly to the prior knowledge.

Her knowledge of the content seemed to be limited, especially in the first lesson when she was teaching about the purification of copper when discussing what was observed at the anode:

L22Teacher: *To get the copper, which is a solid which was stuck to give the anode. Is it true? What was happening? Can you speak a little bit louder.It was copper, we had the pure copper losing an electron to form what? Copper to ion.*

L23Students: *To balance…*

L24Teacher: *To balance the equation we need two atoms of copper, which is going to lose two electrons to the anode because the anode is deficient in electrons. Do you see that?*

L25Students: Yes.

L26Teacher: *Alright, so we can use this to represent half of what was happening in t his process. Let's look at the cathode reaction…*

She revealed poor content knowledge in saying that pure copper instead of impure copper lost electrons at the anode. She also said that two copper atoms are needed, instead of each copper atom losing two electrons. When they were discussing the reaction at the cathode, she continued to make mistakes in the lesson. She did not accept the correct answer, but led the discussion to an incorrect one when they were discussing the reaction at the cathode:

L27Student: *The copper nitrate, copper nitrate was … we added ema electrons to the copper nitrate to give us copper ions.*

L28Teacher: *To give you?*

L29Student: *Copper.*

L30Teacher: *But in this case do we have copper in this case?*

L31Students: *No (Class response)*

L32Teacher: *What are we expecting to get?*

L33Students: *Oxygen.*

L34Teacher: *And what?*

L35Students: *Nitrogen.*

L36Teacher: *Nitrogen and oxygen…*

The learner answered that copper ions form at the cathode, and then corrected it to copper. However, the teacher did not accept the correct answer but indicated that nitrogen and oxygen would form, and this is incorrect. She even wrote an equation showing the production of nitrogen and oxygen and balanced it with the students, instead of $Cu^{2+} + 2e^- \longrightarrow Cu$. Overall, Teacher C showed poor content knowledge of purification of copper by electrolysis.

This episode suggested that Teacher C understood electrolysis at a superficial level. Also, in the third lesson, when explaining which ions would be preferred at the anode, she referred to concentration instead of using the reactivity series. This is observed in the extract below:

L21Teacher: *Yes, it is concentrated.*

L22Student: *So, the chloride ion and the sodium ion will be discharged first becausethe solution is concentrated, which means the water, there's less water.*

L23Teacher: *Thank you very much. This is a very good observation, this is a concentrated solution of sodium chloride so we expect to see more of the Na plus than the H plus, which is coming from the polarised water.Is it correct? We also expect to see Cl minus being discharged first or more of these than the OH from the same water because if we say is concentrated, it means the molecules of, the water that we are dealing with is in small quantity. But let's also look at, let's anticipate what is going to be going on, on the anode before we even try to investigate using simulations.*

(Appendix T).

However, in the second lesson (the electrolysis of acidified water), Teacher C demonstrated appropriate knowledge of the curriculum when discussing learners' observation at the cathode:

L38 Teacher: *As a molecule or when it has been split into two? Because in the simulation, we said we have water and this water is acidified, we were trying to give it a charge. So which one is which. Is water going to the cathode as water or as……?*

L39 Students: *Hydrogen.*

L40 Teacher: *Okay in this case your colleagues are correcting you, they are saying the hydrogen ion is the one that goes to the cathode. The reason that, it is ……?*

L41 Student*:* *Positive.*

L42 Teacher: *It is positively charged, therefore it must be attracted to the negatively charged cathode. But what happens at the cathode?*

L43 Student: *It gathers electrons (*not clear*).*

L44 Teacher: *Alright, so we are saying, hydrogen ion plus the electrons that it gains at the cathode to give us what?* (Teacher is writing the equations as learners speak)*.*

L45 Student: *Hydrogen gas.*

L46 Teacher: *Hydrogen gas, thank you, is it a balanced equation?* (Appendix S)

She led the discussion, guiding the learners towards the correct response.In her teaching, she also included the practical application of electrolysis as stated in the syllabus, this was observed in her second lesson:

L49Teacher*:* *… Do we have any practical application to this processes? Have you ever heard of any situations where electrolysis of water is done at a large scal*

L50Student: *Yes, industry.*

L51Teacher: *Where? I mean what kind of industry is that?*

L52 Student: *Industries that produce hydrogen.*

L53Teacher: *Industries that produce hydrogen, can you give examples, not names but types of industries, mmmmm?*

L54Student: *The Haber process.*

L55Teacher: *They are talking about the Haber process, production of ammonia, which is useful for?*

L56 Student*:* *Fertilizer.*

L57Teacher: *Making of fertilizer, isn't … ? Alright? What else is important in the production of eeee, I mean in this electrolysis. It also produce oxygen which can be used in various industries, steel industry and the like.*

In the discussion, she related the importance of electrolysis of acidified water to the industrial application and also related the products of electrolysis to what learners are familiar with.

4.6.6 Interview after using CBS

Theme 1: Advantages of CBS

Teacher C indicated that she found that CBS improved learners' understanding of electrolysis:

> *For a start, I would say that the students were more participating, they were interested and the, that meant a lot. If you got the attention of the students, it means that they have are so much interested to see what was really happening. Yes, so think that the use of this simulation enhanced the learning of this topic as they can easily recall it now* (L15, Appendix Q)*.*

Teacher C acknowledged that her experience showed that CBS enhanced learners' understanding of electrolysis because it enabled learners to visualise what they otherwise learnt theoretically. She also pointed out that learners were engaged and had more interest in the lessons. She thus believed that CBS improved their understanding of electrolysis.

She also noted that the performance of the learners improved, and she believes this was because the learners could relate what they learnt previously to what they saw on a microscopic level:

L20 Interviewer: *Ok, and then now how has the use of computer simulation improved your understanding and teaching of this topic?*

L21 Teacher C: *Ehm ... ok, I will start with the teaching of the topic. For the students, I will say normally you teach theoretically trying to explain how the other one is going to gain electrons and the other one is going to release electrons. It was like they are trying to picture something which they wouldn't visualise. So when I was using the theoretical method, you would really see that you are explaining to the kids and have to take it for your word but then for you to be sure that they really get what you are talking about was difficult to see.*

L22 Interviewer: *Ok.*

L23 Teacher C: *But now with the simulations, you could see them saying oh yes; Ma'am, this is what you have been talking about. You see this, there are moving electrons from this side, they are going this side and they would really see what was happening. Even the changes in mass, this side the mass is becoming smaller, this side it's gaining in mass and even voltage and everything.*

The excerpt above shows that she noted that it was difficult for learners to conceptualise what they learnt theoretically, so using the CBS enhanced learners' understanding of what they learnt theoretically because they linked what they observed to what they were learning. As a result, the learners' understanding of the concept improved because they did not have to rely only on imagination.

She mentioned that CBS may be useful in some topics in schools because they enhance learners' participation and understanding:

> *Eh. I would suppose they would be used in schools, not for all the topics, but to enforce the learning in sub-topics like electrolysis and because I would see the enthusiasms in the kids. And over the period, over the past years, if you ask some of our students, you would hear them say that the topic of electrolysis is the one that is challenging to them. But with this group, you find that the topic of electrolysis was more interesting, because I think because of the use of computer simulation* (L54, Appendix Q).

According to Teacher C, the learners were full of energy and were attentive when using CBS compared to the previous groups, which did not use them.

Theme 2: Learners' difficulties in electrolysis

When Teacher C was asked about the common mistakes that learners make in this topic, her response was:

> *Ok, generally, it's when they have to decide which one has been oxidised, which one has been reduced. Like if you give them the electrode, you have to determine where the electrons are from and where they are going to* (L40).

Teacher C's response shows that she was aware of some challenges that the learners had in electrolysis. This shows that she was aware of the challenges related to identifying the oxidation and reduction reactions, the current in the external circuit and the polarity of the cell. However, she did not mention challenges related to the ions in the solutions, and the movement of ions in the solutions. This suggested that she did not have a holistic understanding of the learners' difficulties.

Theme 3: Challenges in using CBS

The challenges she mentioned indicate that she was examination orientated, this was noted when she pointed out that CBS was time consuming:

> *The disadvantages that I would mainly see on using simulation is that it needs a lot of time. It is time consuming because to teach one or more concepts you need time, which according to our syllabus we won't be able to complete the syllabus, and students are tested on the assumption that they have completed the syllabus. The only problem I could see is that it takes a lot of time. It's a time-consuming method for teaching* (L32)*.*

She was concerned that using CBS takes time and thus it may be impossible to finish the syllabus on time before the learners at the end of the year sit for the examination. Her major concern was time, i.e. not being able to finish the syllabus on time. When it was suggested that she allow the learners to work at home at times, she highlighted another challenge, saying:

> *Ok that can be a possible option, for the students to go and do it at home, but taking into consideration that there are gadgets now to be putting on laptops to be putting on computers and so forth. Which some of them they are disadvantaged too, they don't have them* (L34, Appendix Q).

Her response revealed another challenge, the socio-economic background of the learners as some learners did not have laptops and could not afford one. Thus, it would be unfair to give learners work to do at home knowing that some do not have the necessary gadgets.

Theme 4: Teaching strategies

She mentioned the different teaching strategies that she used in teaching electrolysis in which these were combined during the lesson to make the lesson more effective:

> *We use question and answer method and then we had a practical followed by discussion of what the kids had observed in the results. Yes, and the practical was using the computer simulations which they were observing what was happening in the process of electrolysis* (L6).

She justified using the other teaching methods, showing the importance of class discussion after doing a simulation:

> *Ok, the first one was the question and answer, it was basically to link the kids with the previous knowledge about the topic which we are about to use the computer simulation on. And then the practical method was for them to see what we had talked about happening, being shown clearly the process of electrolysis. Then the last part was the discussion, to discuss the observations and link it with the theory, what we have learnt and observed* (L8).

The reasons she gave for using different teaching strategies shows that she acknowledged the importance of lesson development, that of linking what they had done theoretically, then visualising using the CBS, and then again discussing the observations in the form of a class discussion.

She combined different examples and questioning as a teaching strategy to develop understanding:

> *Basically, what we have to do as many problems as possible, and give them enough questions to keep on practising and practising until they understood the concepts and apply it in any given situation* (L42).

She enabled learners to practice by giving them many examples.

Theme 5: Teachers' curricular knowledge

When she was asked about the previous knowledge or concepts that have to be done before doing electrolysis, she said that "…normally it's eh, the reactivity series" (L44). She regarded the knowledge of concepts that are linked to electrolysis as important so that when teaching one builds from known concepts to the new concept. She affirmed this thinking in stating, "Basically, what you have to do is you have to do an introduction first where they recap on the theory that has been learnt before" (L50).

She also acknowledged that CBS also improved her own understanding electrolysis:

> *Yes, it even helped me to some extent. It led me to really think even deeper about the topic of electrolysis than I ever done before (L 24).*

Theme 6: Teachers' attitude

She acknowledged that her own learning and teaching of electrolysis was theoretical until using the CBS. After using it, she found it interesting to see what was actually happening. This remark indicated a willingness to learn and a positive attitude towards teaching:

> *Yes, it even helped me to some extent because, ehh, before as well it was theoretically shown. I learnt it theoretically and was teaching it theoretically. It was fascinating to see how the process of electrolysis go, ehm, how it was happening. And as quite interesting (L2),* Appendix Q).

When she was asked if she would recommend that CBS be introduced in schools her response was, "…So I would advocate for them. Not for the whole syllabus but maybe some topics selected topics in chemistry and physics" (L54). This indicates a positive attitude towards using CBS selectively in teaching.

4.6.7 Questionnaire after using CBS

Theme 1: Advantages of CBS

According to Teacher C, it is important for learners to use CBS because "learners are able to visualise the process, observing what changes take place practically" (q2,

Appendix AE). This shows that it was of importance to her that learners understand the process of electrolysis and that CBS could enable them to understand the content better. She further said that “it is an effective way of teaching and keeps learners actively participating” (q5). This showed that she believed that learners’ active engagement when using CBS supported their understanding.

Theme 3: Challenges in using CBS

When she was asked what the challenges of CBS were, she responded, “there is need for enough computers to cater for all the students” (q4). Although there were computers in the school, they belonged to the ICT department, thus the science department did not have access to them. In other words, the science department had to make an arrangement with the administration and ICT department to have access to the computers in the school.

She further said, “It needs more time to teach using the CBS and will be impossible to use every day and complete the syllabus on time” (q6). Her response showed that her main concern was that it would be impossible to finish the syllabus on time if CBS was used daily. Therefore, its use has to be managed so that time is not lost.

Theme 4: Teaching strategies

In terms of teaching strategies, she wrote, “Teacher demonstrated the use of CBS and discussed with the pupils then have practical as pupils use the CBS” (q7, Appendix AE). This indicated that she started lessons by showing learners how to use the CBS and discussed the topic before she let them do it themselves.

Theme 5: Teachers’ curricular knowledge

She explained that she intended the learners to know “… the process of electrolysis, the movement of the electrons change in current voltage and the mass of the electrodes” (q1). This showed knowledge of some of the outcomes envisaged. However, her response focused on the movement of electrons, but did not mention the motion of ions and chemical reactions, which suggested gaps in her own understanding.

4.6.8 Summary of the findings of Teacher C

A summary of Teacher C's findings is shown in Table 4.7.

Table 4.7: Themes identified from Teacher C from the different instruments

	Advantages of CBS	**Learners' difficulties in electrolysis**	**Challenges in using CBS**	**Teaching strategies**	**Teacher's curricular knowledge**	**Teacher's attitude**
Q1			x	x	x	
I1	x		x	x	x	x
LP			x		x	
O	x			x	x	
I2	x	X	x	x	x	x
Q2	x		x	x	x	

Theme 1: Advantages of CBS

Teachers C's views about the advantages of CBS were demonstrated in the first and last interview, in the lesson observations and in the questionnaire after using the CBS. As seen in all of the instruments, she indicated that CBS enabled learners to visualise what they learnt theoretically and therefore CBS improved their understanding of electrolysis. She also acknowledged in the interview after using CBS that the lessons were more interesting, and learners participated more as compared to previous lessons. She also noted that the CBS allowed learners to relate what they had learnt theoretically and to really think about what they were doing, the learners were full of energy and more attentive. This was indeed observed in the lessons in the discussions when she referred the learners to what they had observed. She also noted in her first lesson that the CBS would enable learners to observe what was actually happening during the process of electrolysis and she believed that seeing the process would help the learners to understand the concept better. Using CBS also stimulated the teacher to think critically, which was observed in the lesson observations when the learners asked questions.

Theme 2: Learners' difficulties in electrolysis

Learners' difficulties were discussed in the interview after using CBS. She mentioned that the learners had difficulties in deciding which electrode has been reduced/ oxidised.

Theme 3: Challenges in using CBS

This theme was observed in all of the instruments except the lesson observation. In the interview, she indicated that she was concerned that using CBS may take a lot of teaching time. According to Teacher C, this may be a problem because learners have a syllabus to finish and an examination to write and may thus not perform well in the examination if they have not finished the syllabus. Another challenge she noted was that learners may tend to then begin to do their own thing during the lesson and therefore proper guidance would be required. She also mentioned that there was a shortage of computers in the department which needed to be attended to as the computers in the computer laboratory were not accessible. She was also concerned that the socio-economic background of the learners would possibly make it impossible for learners to use CBS as some did not have their own laptops.

Theme 4: Teaching strategies

Teaching strategies were evident in all of the instruments used except the lesson plans as she did not state the teaching method that she planned to use. During the interviews, she mentioned that she mainly used the question and answer method and discussions. She further explained that she used the question and answer method to link the new lesson with the previous lesson. It was observed during the lessons that she asked learners many questions and guided the learners through the process. With the CBS, she used discussion to deliberate on the observations, linking what was visualised to theory.

During the lesson observations, Teacher C started each lesson by discussing with learners the concept to be learnt and she wrote important points on the chalkboard. After that, she told learners to start working in groups. She allowed the learners to work independently while using the CBS while she moved around assisting them when needed. Before the end of each lesson, she again had discussions with the whole class. She combined the use of CBS with the lecturing, questioning and discussion methods. She also made use of the chalkboard in her lessons where she wrote important points, such as the chemical equations at the electrodes.

Theme 5: Teachers' curricular knowledge

Regarding curricular saliency, for example, she noted in the interview before and after using CBS that ionic bonding and the reactivity series were some of the topics that she considered as necessary to be covered before electrolysis. This was an indication that she was aware of the concepts that linked to electrolysis. She indeed started the first lesson by recapping the concept of ionic bonding. However, she revealed inadequate content knowledge during the classroom discussions. In the second lesson, she did not use the reactivity series when explaining which ions would be preferred at each electrode, instead she tried to explain using concentration, which was incorrect. She also made a number of mistakes, especially in the first lesson. It was particularly noticeable when learners tried to improve an incorrect response by giving a correct one and the teacher rejected the correct answer. Unfortunately, the rest of the class agreed with the incorrect response. These episodes revealed that Teacher C had limited understanding of the process of electrolysis.

In terms of why it was important for learners to learn about electrolysis, she mentioned understanding the process of electrolysis and also its industrial applications in the questionnaire after using CBS.

Theme 6: Teachers' attitude

Her orientation towards and beliefs regarding teaching science indicated that she taught mainly for her learners to obtain good results in the examinations, as revealed in the first interview. It seemed that she was not much concerned about understanding chemistry. Before the lesson observations, she was sceptical about the use of CBS as she believed that it may take up too much time and negatively impact learners' performance in the examinations.

After using the CBS, she changed her attitude towards it and mentioned that through proper guidance, CBS may be used to improve the teaching and learning process. Thus, it she felt that it might be a good idea to introduce it in schools. She acknowledged that CBS even caused her to think deeper about the processes of electrolysis than she had ever done before, which was noted in the interview after using CBS.Table 4.8 shows a summary of the data collecting strategies which answered the research questions.

4.7 CHAPTER SUMMARY

In this chapter, the data obtained from the three participants were discussed in detail. Six themes emerged from the data. For each teacher, the data were presented per instrument according to the themes. In the next chapter, the conclusions drawn from the study will be presented, as well as recommendations for further research.

CHAPTER 5 DISCUSSION OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

5.1 INTRODUCTION

The purpose of the study was to understand teachers' use of CBS in teaching electrolysis. For me, as the researcher, to be able to fulfil the purpose of this study, it was necessary to comprehend the chemistry teachers' views in order to understand the way in which they used the CBSs that were given to them. Thus, the study attempted to answer the following research sub-questions:

- What are teachers' views on the use of CBS in teaching and learning electrolysis?
- How do teachers integrate CBS into teaching electrolysis?

The answers to the above sub-questions were utilised to answer the main question, which is:

- How can teachers' use of CBS in teaching electrolysis be understood?

Six themes emerged from the data, namely:

- The advantages of CBS;
- Learners' difficulties in electrolysis;
- Challenges in using CBS;
- Teaching strategies;
- Teachers' curricular knowledge; and
- Teachers' attitude.

This chapter begins with a discussion of how the themes relate to the theoretical framework that was used for this study. It is followed by the findings of the study presented as answers to the sub-questions, from which the main question was answered. A summary of the research process follows, discussing the purpose of the study, how the data was collected, and the sampling technique that was used to collect data. This is followed by a comparison of the findings with the existing literature, looking at how it differs or is similar to what the literature says. It is then followed by the limitations of the study, that is, the challenges that I came across which may compromise the validity of the study. This is then followed by the recommendations made in this study. Lastly, the study comes to a conclusion with an epilogue.

5.2 HOW THE EMERGING THEMES RELATE TO THE THEORETICAL FRAMEWORK

The theoretical framework models the transformation of different knowledge components into classroom practice. All of the themes emerging from the data analysis can be related to the components of the theoretical framework, as illustrated in Table 5.1. Also, most of the themes relate to the category of Topic Specific Professional Knowledge (TSPK). This is mainly because the study focused on a specific topic, that of electrolysis.

Table 5.1: How emerging themes relate to the theoretical framework

CATEGORIES IN THE THEORETICAL FRAMEWORK	THEMES IDENTIFIED	EXAMPLES
1.Teacher Professional Knowledge Bases		
a) Assessment knowledge	Theme 1: Teaching Strategies	Formative assessment during discussions.
b) Pedagogical knowledge	i) Theme 1: Advantages of CBS. ii) Theme 4: Teaching strategies.	i) Learners are able to visualise and are actively involved. ii) Previous knowledge.
c) Content knowledge	Theme 5: Teachers' curricular knowledge.	Understanding previous knowledge, e.g. redox reactions.
d) Knowledge of students	i) Theme 1: Advantages of CBS. ii) Theme 3: Challenges in using CBS.	i) Learners are eager to use technology. ii) Learners' socio-economic situation.

f) Curricular knowledge	i) Theme 5: Teachers' curricular knowledge.	Topics linked to electrolysis.
2.Topic Specific Professional Knowledge		
a) Instructional strategies	i)Theme 4: Teaching strategies.	i) CBS: visualise movement of ions, observe change in mass at the electrodes. ii) Discussion: link to previous concepts, e.g. reactivity series, elicit learners' understanding. iii) Questioning: engaging learners, assessing learners' understanding.
b) Content representations	i) Theme 5: Teachers' curricular knowledge.	i) Use of symbols. ii) Writing of ionic/half equations at the cathode and anode.
c) Students' understanding	i) Theme 2: Learners' difficulties in electrolysis	i) Identifying oxidation/reduction at electrodes.
3.Amplifiers and filters		
a) Teachers' beliefs and orientation	i) Theme 3: Challenges in using CBS. ii) Theme 6: Teachers' attitude.	i) Belief that examination is more important. ii) Willingness to change.
b) Context:	i) Theme 3: Challenges in using CBS.	i) Shortage of equipment and overcrowding in the classrooms.
4.Classroom practice		
a) Personal PCK:	i) Theme 4: Teaching strategies.	i) How the teacher integrates CBS with other teaching

		methods.
	ii) Theme 6: Teachers' attitude.	ii) Willingness to use CBS.
b) Knowledge of curriculum:	i) Theme 5: Teachers' curricular knowledge.	i) Knowledge of the topic of electrolysis.
5.Amplifiers and filters		
a) Students' beliefs	Theme 2: Learners' difficulties in electrolysis.	Regard electrolysis as difficult because it overlaps with physics.
b) Student's prior knowledge	i) Theme 2: Learners' difficulties in electrolysis.	i) Ionic bonding, reactivity series.
c) Students' behaviours	i) Theme 1: Advantages of CBS.	ii) Interest, engagement, involvement.

5.2.1 Advantages of CBS

The above theme links to a number of categories in the theoretical framework. For example, it links to the generic category of pedagogical knowledge in the Teacher Professional Knowledge Bases. This was illustrated by the teachers' views that visualisation is an efficient way of learning. The teachers revealed this pedagogical knowledge when they mentioned that CBS enables the learners to visualise the migration of electrons and ions. It also relates to the knowledge of students in Teacher Professional Knowledge Bases; teachers' beliefs and orientation towards teaching science in teacher Amplifiers and Filters; and personal PCK in Classroom Practice. The theme is also reflected in learners' behaviours in student Amplifiers and Filters because this category indicates learners' active involvement when using CBS.

5.2.2 Learners difficulties in electrolysis

According to the teachers, learners' difficulties in electrolysis included common mistakes, difficulties with specific content, and their belief that electrolysis is difficult. Therefore, the theme links with students' understanding in Topic Specific Professional Knowledge, as well as students' beliefs and prior knowledge in student Amplifiers and Filters.

5.2.3 Challenges in using CBS

Challenges in using CBS linked with the teacher Amplifiers and Filters, which contained two components, namely: teachers' beliefs and orientation, as well as context. The context refers to the challenges that may hinder the use of CBS. The challenges include the teaching environment in which chemistry teachers teach while using CBS, for example, a shortage of equipment (computers) and resources, and overcrowding. The above theme also relates to the teachers' beliefs and orientation in that a teacher may be examination orientated and thus avoid CBS as it may consume too much teaching time. The theme also relates to knowledge about learners' socio-economic background under the Teacher Professional Knowledge Bases, which may make it difficult for some learners to acquire equipment.

5.2.4 Teaching strategies

Teaching strategies link to instructional strategies, which is found within the Topic Specific Professional Knowledge. The instructional strategies relate to suitable teaching methods that may be used in teaching electrolysis and the justification for using each teaching method. The different teaching strategies include the lecture method, which may be used to introduce and summarise a lesson by stressing the main points. The questioning method may be used to involve learners and to elicit their understanding of electrolysis. Discussions were also used; these engaged learners in the lesson and supported them to take responsibility for their own learning. A chemical experiment used together with CBS can allow learners to also experience the macroscopic aspects of the process, for example, the smell of chlorine. In Topic Specific Professional Knowledge, the content representations also link with the abovementioned theme because it entails the symbols and the chemical half reactions that take place at the electrodes.

It was found that CBS was not well utilised in this study; sometimes the teachers did not even refer back to the CBS but simply carried on with the next topic. Personal PCK in Classroom Practice also relates to this theme because it shows what teachers do in class, including how they combine CBS with other teaching methods. Pedagogical knowledge in Teacher Professional Knowledge Bases also links to the teaching strategies as constructivist teaching requires the linking of electrolysis to previous concepts, such as bonding and the reactivity series.

5.2.5 Teachers' curricular knowledge

Content knowledge under the component of Teacher Professional Knowledge Bases refers to aspects of this theme. For example, teachers' basic knowledge of chemistry is implicit in their understanding of redox reactions during electrolysis. Also, Knowledge of the Curriculum within the component of Classroom Practice includes this theme, as revealed during the classroom discussions. This theme also links with Content Representations in Topic Specific Professional Knowledge as it includes the use of symbols, writing and balancing ionic equations at the electrodes.

5.2.6 Teachers' attitude

This theme was identified in teachers' beliefs about the value of CBS and willingness to change which is represented by teacher Amplifier and Filters. The theme also relates to personal PCK in Classroom Practice because it shows teachers' willingness to use CBS in their lessons in trying out a new approach.

5.3 REVISITING THE RESEARCH QUESTIONS

This section presents the conclusions drawn from the data gathered in the study. The purpose of the study was to understand how teachers use CBS in the teaching of electrolysis. It was a qualitative study that involved three chemistry teachers in three schools.

5.3.1 Conclusions pertaining to the first sub-question

The first sub-question was: What are teachers' views on the use of CBS in teaching and learning electrolysis?

5.3.1.1 Teacher A

Teacher A understood that learners have to operate both at the microscopic and macroscopic levels in order to understand electrolysis since it is an abstract topic. He believed that CBS enabled learners to observe the microscopic features of the topic such as the visualising movement of ions, but he also strongly believed that learners need to experience and observe the macroscopic features during practical experiments. In fact, he mentioned that he even borrowed equipment when there was a need. He also believed that CBS would be effective on a big screen where learners could observe the processes of electrolysis without taking a hands-on approach.

He associated the challenges that learners have in electrolysis with the conduction of electricity. He said that learners seemed to think that insoluble compounds do not conduct electricity, yet they do when in a molten state.

However, he was concerned that the appropriate use of CBS in eSwatini schools may be hindered by the large number of learners in schools and the shortage of computers in schools. Despite these challenges, he still believed that CBS enhances learners' understanding of electrolysis because learners can observe the microscopic aspects of the topic such as the movement of electrons at the electrodes. Learners normally have to use their imaginations with this concept, making it difficult for them to internalise the topic. Thus, he felt that even with these challenges, CBS can play a significant role in enhancing learners' understanding of abstract topics such as electrolysis. However, he believed that schools have to buy a big screen and speakers so that learners can hear and observe the processes. This indicates that he was of the opinion that learners need not be physically involved in manipulating the CBS. It is apparent that he thought that seeing is sufficient.

5.3.1.2 Teacher B

She usually expected the learners to memorise certain concepts of electrolysis, such as the ionic equation of the electrolysis of acidified water. She indicated that she had not found an appropriate teaching method that she could use to clearly explain the concept of electrolysis. After using CBS, she felt that she had found the 'appropriate teaching method'. This was evident when she said she would do away with practical experiments and use simulations instead.

Teacher B strongly believed in the importance of microscopic aspects in understanding electrolysis. She mentioned that CBS enables learners to observe the movement of electrons at the electrodes, which helps learners to internalise the concept of electrolysis and in the process, enhance their understanding. In addition, she also believed that CBS promotes independent learning, enables learners to be responsible for their own learning and to be critical thinkers. This was seen in her comment that she allowed the learners to work on their own and that they normally assisted each other, making them responsible for their own learning. She also said that the learners asked more questions this time around. This indicates that she believed that while they were using the CBS, questions started to formulate in their minds, causing them to think deeply about the topic.

She also understood that CBS is a learner-centred approach because it allowed learners to manipulate the simulation themselves. She also believed that using CBS is suitable for today's generation because they are familiar with technology. However, she was concerned that the appropriate use of CBS can be affected by the non-availability of equipment such as computers, overcrowding in schools, and the socio-economic background of the learners. She also believed that the lack of previous knowledge and basic concepts led to learners' negative attitude towards electrolysis. She thought that the learners had challenges in identifying ions in the solution at the electrodes. However, she did not express any views on the usefulness of CBS in supporting learners with this challenge.

5.3.1.3 Teacher C

Teacher C believed that CBS improved understanding of electrolysis for both learners and teachers. This belief was revealed when she noted that CBS allowed learners to observe the microscopic aspects of electrolysis. After using the CBS, she confessed that she thought of the topic in a way she had never done before. In other words, using CBS helped her to reflect and to think deeper about the topic. She also believed that CBS stimulated the learners to learn and helped them to link concepts with what they had learnt theoretically. She also appreciated using CBS and confessed that using CBS stimulated her to think deeply about the topic.

Initially, she was sceptical about the use of CBS as she believed CBS took a lot of teaching time and thus learners may not finish the syllabus on time, which might negatively impact their performance in the examination. However, she changed her views after using the CBS and felt that it could be used with proper guidance. She also thought that learners had difficulties in deciding which electrodes are involved in reduction and oxidation, but did not indicate any views about using CBS to address this challenge. She also felt that the appropriate use of CBS may be affected by the shortage of computers and the socio-economic background of the learners as some of the parents may not be able to afford hand held gadgets such as laptops.

5.3.2 Conclusions pertaining to the second sub-question:

How do teachers integrate CBS into teaching electrolysis?

5.3.2.1 Teacher A

Teacher A used only one of the three simulations given to him. He used the CBS in his first lesson, in isolation, towards the end of the lesson and did not ask learners questions or lead a discussion afterwards. During the lesson, he first explained electrolysis then had the learners do a practical experiment and then used the CBS in the last five minutes of the lesson. He did not demonstrate the use of CBS to the learners, he however moved around the groups while the learners were using CBS. He used the practical experiment, discussion and questioning teaching methods in the better part of the lesson. However, he could not even summarise the lesson because the time allocated for chemistry was over. In the other lessons, he predominately used the discussion and questioning methods without relating these discussions to the CBS. He only referred the learners to the CBS in the second lesson in the introduction when he referred learners to the oxidation/reduction reactions that had taken place at the electrodes. The second lesson was a discussion of the previous lesson, no new concept was learnt but the teacher was trying to link the lesson to the experiment and the CBS which was covered in the previous lesson which was on electrolysis of copper chloride solution. In the third lesson, which was on the electrolysis of acidified water, he did not use the CBS, thus there was poor integration of CBS with other teaching methods.

He also used the chalkboard and examples in his teaching to show the electrolytic cell that learners had used in the experiment. He also linked previously learnt concepts leading up to electrolysis, starting his lessons from the known and moving to the unknown. This showed that he was aware of the importance of sequencing related concepts, and told learners about the focus of the lesson. However, he did not utilise the CBS in the sequencing of the content.

5.3.2.2 Teacher B

Teacher B used all three CBSs that she was provided with in her three lessons. She integrated them with questioning and discussions into the lessons. She guided the learners in each lesson on what to observe while using the CBS and then gave them some time to use the CBS while she moved around. After which, she led the class in a discussion by asking learners relevant questions referring to the CBS that they had used. For example, she asked learners what they observed at the electrodes. She made several mistakes in the lesson and was corrected by the learners. It seems that they had a better understanding of electrolysis after they had used the CBS. For example, she was not sure of the products at the anode and the cathode in the electrolysis of acidified water. This caused her to realise that she was lacking in content knowledge and she decided to also revisit the CBS in order to improve her own understanding of electrolysis. She did not include any real practical experiment in her lessons.

In each lesson, she explained the topic to learners using the chalkboard and textbooks, and also used different examples from the textbook while making reference to the CBS. For appropriate use of the CBS, she asked relevant questions including higher-order questions. She also combined the CBS with previous knowledge. She started her lessons by recapping or discussing concepts that are linked to electrolysis. She also made learners aware of the focus of the lesson by informing them what the new lesson would be about.

During the lesson when the learners were using CBS, she moved around checking their work. After that, she led a discussion deliberating on what learners had observed while using the CBS. She made a number of mistakes, such as writing the incorrect products at the electrodes. She was, however, assisted by the learners who tried to correct her. She therefore erased what she had written on the board and accepted the learners' corrections. It appeared that she depended on the learners for the correct response. This meant that the CBS had helped the learners to understand the concept better, which she confirmed by adding that they even asked more questions. This made her realise that she was lacking in content knowledge of electrolysis. Afterwards, she revisited the CBS and she confirmed during the last interview that she had always misinterpreted the topic. This event indicates that she realised that CBS also improves teachers' content knowledge.

5.3.2.3 Teacher C

In each lesson, after the learners used the CBS, Teacher C followed it up with the questioning and discussion methods. She started each lesson by recapping then giving clear instructions on what learners had to observe while using the CBS. She then gave learners the time to use the CBS and moved around the groups checking the progress of the learners. After some time, she then facilitated discussions referring to the CBS. Thus, she combined the CBS very well with other teaching methods such as questioning, discussion and lecturing, for example, regarding what learners observed at the electrodes in the electrolysis of copper nitrate. She also used the chalkboard to write the ionic equations that the learners suggested after observing the processes of electrolysis. Thus, she combined the CBS with the use of the chalkboard.

However, she made many content related mistakes in her lessons, and she did not seem to even realise that she was making mistakes. The worst case was when she rejected a correct response from a learner and suggested an incorrect one and the whole class accepted it as truth. This was observed when she was discussing the products of the electrolysis of copper nitrate solution using copper electrodes. Her lack of content knowledge was also observed when she explained which ions would be preferred at the electrodes. She used the concept of concentration instead of the reactivity series. Thus, her lack of content knowledge seemed to impact the effective use of CBS.

5.3.3 Conclusions pertaining to the main question

The main question was: How can teachers' use of CBS in teaching electrolysis be understood? In answering this question, I explain how each teacher's unique situation, including their beliefs, contribute to the choices that ultimately determine their use of CBS in the classroom.

5.3.3.1 Teacher A

He used the CBS once in his lessons, indicating his unwillingness to integrate CBS into his teaching. He complicated the chemical experiment by using the CBS. However, he seemed to think that seeing the movement of ions and electrons is sufficient, which is probably why he used the CBS only for the first topic. His unwillingness to use CBS seemed to be based on a poor understanding of how CBS should be used. He did not think that learners should manipulate the CBS, which is why he said that for CBS to be effective there has to be a big screen that he could use to demonstrate to the learners. He made learners do a chemical experiment and that gave him the satisfaction that the learners were actively involved in doing an experiment. The use of CBS also depended on the availability of the big screen that learners could use to observe the processes of electrolysis.

He believed that CBS increases learners' interest since learners pay more attention. However, his actions proved otherwise because he did not think of using CBS to assist learners in overcoming their mistakes, even after being exposed to them. He still preferred to use experiments, which indicates that he held strong beliefs regarding the use of experiments as compared to CBS.

5.3.3.2 Teacher B

During the lesson, she allowed the learners to work on their own and manipulate the CBS because she believed that using CBS is a learner-centred approach. She believed that improved understanding of electrolysis could be achieved when learners are more engaged. She also allowed the learners to visualise the concept, then led a discussion referring to what they had observed, indicating that she believed that learning is enhanced by linking what is learnt with what has been visualised. She also started each lesson by recapping previous knowledge and referred learners to concepts that are linked to electrolysis because she believed that the effective use of CBS involves integrating it with previous knowledge.

She also believed that CBS could enhance teachers' understanding of electrolysis, which is why she went back to the CBS and did it on her own in an effort to understand the topic better.

5.3.3.3 Teacher C

Using CBS caused Teacher C to change her view if it. At first, she was sceptical about using CBS because she felt it would take a lot of teaching time. However, after using the CBS she changed her view and said that she was willing to use CBS during teaching with proper guidance. She was examination orientated and thus felt that CBS may take a lot of teaching time that should otherwise be used to complete the syllabus for exams. She combined its use with the questioning and discussion methods. Although she integrated the CBS with the questioning and discussions into her lessons, it was not very effective because of her lack of content knowledge. As a result, the learners did not benefit fully from the discussions. In one instance, she actually dismissed a correct response from a learner about the purification of copper nitrate using copper electrodes on the reaction at the electrodes. The teacher's action confused the learners because she was not able to support the CBS with a constructive discussion.

Also, she believed that using CBS is a learner-centred approach seeing as she allowed learners to work on their own in groups while she then assisted them. She also believed that CBS enhances learners and teachers' understanding of electrolysis as it enables them to observe the microscopic aspects. Also, when learners ask questions, they reflect on their content knowledge, which is why she let the learners manipulate the CBS, then afterward she linked the lesson to what the learners had observed in the CBS.

5.3.3.4 The case of the three teachers

To understand the teachers' use of CBS in teaching electrolysis, it was necessary to understand their views on using CBS and then interpret their use of CBS in terms of their views. This makes it possible to understand why they did things the way in which they did.

Teacher A did not consider CBS as a method of teaching which should lead to learners' manipulating or being hands-on with the topic. This was observed in how he used it in his lessons. He did not allow the learners to manipulate or be hands-on, thus he did not use it effectively. Even when he used the CBS, he used it in isolation at the end of the lesson and ended the lesson thereafter. He did not combine it with other teaching methods like questioning learners or leading a discussion that integrates CBS. He also advocated for a big screen where learners could observe the process of electrolysis instead of manipulating it. While Teacher B and Teacher C had an understanding that using CBS required learners to manipulate the simulated apparatus in the CBS. For example, the learners had to select the electrodes and the electrolytes. Teacher B and C realised that the role of the teacher is to guide the learners in using CBS. These teachers allowed their learners to work on their own and guided them throughout by using the questioning and discussion methods.

Teacher B and C also believed that CBS improved learners' understanding of concepts but that the teachers' role was to lead classroom discussion to reinforce learning. Teacher B revisited it when she realised that her content knowledge was lacking. After using the CBS, Teacher C also changed her views about using CBS and said that it could be used in schools with proper guidance. These two believed that learners have to be hands-on with the topic. Teacher A, alternatively, believed that learners only have to watch from a screen. Thus, all of the teachers believed that CBS enhances learners' understanding but they differed on how to use it.

5.4 TEACHERS' PCK

The teachers' lack of pedagogical knowledge about the appropriate use of CBS may lead to its ineffective use and thus may not enhance an understanding of concepts. To be used appropriately, learners have to manipulate the CBS, and teachers have to allow learners to work on their own but guide them by asking relevant questions in the form of the discussion or questioning teaching methods.

The teachers' lack of content knowledge about electrolysis also affected their appropriate use of CBS. In this regard, the teachers' lack of content knowledge obstructed the opportunity to help learners make sense of the chemical reactions shown in the CBS. However, the CBS may also help teachers to realise their own inadequate knowledge and it thus has long term benefits.

The teachers' attitudes towards CBS acted as amplifiers and filters in their use of CBS. Initially, Teacher B was particularly enthusiastic and she was also the one who had the most success in her use of CBS as she was willing to learn from her content related mistakes.

Another factor that may contribute to teachers not using CBS is that teachers in the various departments in schools work in isolation. Thus, the computers in these schools are underutilised. There is a need for schools to review their policies so as to allow teachers in the respective departments to have access to the computers so that they can use them during teaching to support all learning.

5.5 SUMMARY OF THE RESEARCH PROCESS

The purpose of the study was to understand how teachers use CBS in the teaching and learning of electrolysis. The study employed a qualitative research methodology, which entails a case study research design of three teachers teaching in two different regions in Swaziland, namely, the Manzini and Hhohho regions. Purposive and convenience sampling were used to select the study participants and these were qualified chemistry teachers with more than ten years' teaching experience.

For me to explore the teachers' use of CBS as a teaching strategy, I analysed and interpreted the teachers' views of how CBS enhances learners' understanding of electrolysis, teachers' knowledge of common mistakes in electrolysis and how they assist learners in overcoming the challenges, the challenges of using CBS as an instructional strategy, and how the challenges are overcome. I also observed how the teachers integrated the CBS into teaching electrolysis, including the other teaching strategies that they used, their reasons for using those teaching methods, the limitations of the teaching methods, how they used CBS when teaching electrolysis, and the teachers' curricular knowledge.

This study was framed by the Consensus Model for pedagogical content knowledge as a theoretical basis. This model involves the transformation of Teacher Professional Knowledge Bases and Topic Specific Professional Knowledge into Classroom Practice. The transformation is influenced by Amplifiers and Filters, which depend on teachers' beliefs, orientations and context. Ultimately, Classroom Practice influences student beliefs, prior knowledge, behaviours and ultimately, student outcomes.

The study employed questionnaires, face to face interviews, classroom observations and document analysis to gather data. The data was presented, discussed and analysed according to the themes that emerged. The data gathered was then compared with the literature related to the study.

The data gathered, presented and analysed in this study ensured that all set objectives were attained. The findings indicate that the teachers' use of CBS depended on their understanding of how CBS enhances learners' understanding. Thus, they may decide to make the learners observe or manipulate the CBS. If the teachers' understanding is limited to a view that CBS enhances learners' understanding by observing, the teacher may limit learners' experience to observing the CBS without giving them an opportunity to manipulate the CBS. Consequently, learners' opportunities to gain an understanding of electrolysis is limited. The appropriate use of CBS is to allow the learners to manipulate it under the guidance of a teacher.

The teachers were all concerned about the shortage of equipment and the large numbers of learners in their classrooms, which may impact the effective use of CBS. Otherwise, they all agreed with the literature in that CBS enhances learners' understanding of electrolysis because they allowed learners to visualise the concept and learners participated more in the learning. After using CBS, they also believed that CBS can even improve teachers' understanding of electrolysis. One of them also said that using CBS is a teaching method that is in line with today's generation because it is technologically inclined.

The findings also show that a lack of understanding of pedagogy may lead to the inappropriate use of CBS such as using it in isolation instead of combining it with other teaching methods. In this study, some of the teachers combined the CBS with other teacher methods such as the discussion and questioning methods, but one teacher used it in isolation, thus showing a lack of understanding of its use. The findings also indicate that the effective use of CBS requires teachers' knowledge of content since they are expected to link the CBS with pre-requisite knowledge, and lead appropriate discussions about the topic presented by the CBS. A lack of teachers' content knowledge may therefore influence the appropriate use of CBS. The teachers in this study linked the CBS with the previous concepts related to electrolysis, but the classroom discussions after using the CBS were inadequate.

5.6 COMPARISON OF THE FINDINGS WITH THE EXISTING LITERATURE

The findings from this study show that teachers understand that CBS enhances learners' understanding of abstract concepts. This was noted in the questionnaires, interviews, class observation and document analysis. The findings also reveal that the teachers believed that CBS improves the teaching of electrolysis.

The views of the teachers in this study concur with those of Fishwich (1995); Perkins, 1999; Jaakola and Numi (2008) and Cornwell (2010) that CBS enhances learners' understanding of concepts. Understanding is enhanced because it facilitates active learning through which learners are actively engaged in the lesson and take responsibility for the acquisition of knowledge. In addition to enhancing learners' understanding, CBS make lessons interesting for learners. In this approach, there is active learning in the class because learners are stimulated to think critically. In addition to that, CBS also enhances learners' understanding of electrolysis because it enables learners to visualise what they are not able to see during the practical activity, which is the movement of ions, and to observe the electrodes that lose and gain ions, and to observe electrodes being worn out and gaining mass. This increases learners' retention and understanding of electrolysis. Even their teaching improved because CBS enhance teachers' understanding of the topic of electrolysis.

Minner *et al.,* (2010) show that CBS has the potential of helping learners overcome their misconceptions and provides them with visual representations of sub-microscopic phenomena, which are otherwise difficult to explain. Minner, Levy and Century further concur with Garmstone and Wellman (1994) that CBS assists science teachers to use teaching strategies that are learner-centred. The literature has shown that learner-centred strategies enhance learners understanding of concepts because learners are not passive; they also contribute and feel part of the learning process. Thus, the learners do not get bored since they are involved in learning in a hands-on way. The use of CBS has to be combined with other teaching methods for it to be effective. The views of the teachers in this study also concur with the above scholars since all of the teachers combined the CBS with other teaching methods, which included discussions and the question and answer technique.

The findings from this study also show that some of the teachers still used teacher-centred methods that promote rote learning. One teacher confessed in the interview that she encouraged learners to memorise things that they had not understood because she herself had challenges with the content. Also, the teacher acknowledged that she mainly used teacher-centred methods because that is how she was taught and therefore she tended to use that kind of approach herself. Thus, the teachers' beliefs regarding teaching science influenced the teaching strategy that they used in their lessons. The views of the teachers in this study are also in agreement with Peterson (2011), who notes that some science teachers still use teacher-centred approaches in teaching science, yet this is a practical subject. Magnusson *et al.* (1999) note that science teachers' beliefs regarding teaching science influence their choice of instructional strategy. This means that some teachers may be aware of learner-centred approaches, but they prefer teacher-centred approaches because that is how they were taught themselves.

Moreover, Teacher C admitted that some of the learner-centred approaches, for example, the use of CBS, take time. Thus, instead of allowing learners to discover information on their own, she gave more and more examples. It may be inferred that this teacher used traditional approaches in her lesson as she wanted to control how much the learners learnt and the pace at which the content was learnt. This is because she was concerned with finishing the syllabus on time, as well as the performance of the learners in the exams. However, the traditional approaches allow learners to be passive and do not promote critical thinking in learners (Peterson, 2011). So, as a way of assisting learners, this teacher gave learners more and more examples.

Taber (1998) concurs with Finley *et al.* (1982) that electrolysis is also one of the most challenging topics in the chemistry syllabus for learners. The views of the teachers in this study also agree with these two scholars as one teacher noted that electrolysis is difficult and abstract for learners because the topic incorporates physics. If the learners lack understanding about current, which is covered in physics, the moment one mentions ions in electrolysis, the learners lose interest and confidence. The teacher further noted that learners have challenges with bonding, which is prerequisite knowledge for this topic. The views of the teachers in this study thus concur with those presented by Taber (1998), who argues that electrolysis is challenging for learners because of a lack of teaching aids and also because it is common in physics and chemistry, thus causing confusion for learners who did not assimilate their knowledge across physics and chemistry. Ogude and Bradley (1994) also claim that electrolysis is a challenge for learners because learners have difficulties with conduction in electrolytes, electric neutrality and terminology, as was also mentioned by the teachers in this study.

Ogude and Bradley (1994) further noted that poor management; poor teacher preparation and poor understanding of content by teachers are some of the reasons for learners' poor performance in the topic of electrolysis. The teachers' views also concur with these scholars as one of the teachers confessed that she also did not understand the topic and it was not easy for her to teach since it is abstract. The literature has also indicated that teachers' SMK influences their PCK. In other words, it is not easy to teach a topic that you do not understand yourself. The conclusions from this study also concur with those of Ahtee *et al.* (2002), who investigated teachers' conception of teaching electrolysis and their difficulties with it. Their findings showed that teachers have challenges in identifying topics that are related to electrolysis and these teachers expressed their need to read more on the topic in order to be able to understand and teach it properly.

The findings from this study also reveal that electrolysis is difficult because of a lack of teaching aids. The teachers all noted that the equipment needed to teach electrolysis is expensive and the use of CBS as an instructional strategy can be a challenge because it can be expensive. The large number of learners in class was also raised as a cause for concern, which could make the use of CBS ineffective in schools. Otherwise, they believed that CBS helps learners to understand electrolysis as they are able to visualise the concepts instead of simply learning theoretically.

Haston and Leo-Guerrro (2008) support Brownlee's (2007) findings that content knowledge is necessary for the development of PCK. Content knowledge positively influences teachers' decisions about the selection and use of teaching strategies and teaching materials. In support of this, the findings from this study also indicated that teachers' poor content knowledge obstructed their effective use of CBS.

5.7 LIMITATIONS OF THE STUDY

In conducting this study, there were a number of limitations inherent to the study. The study used a qualitative research approach, a case study design and the face-to-face interviews, observations and document analysis. I realised that there were challenges regarding the research approach, research design and each methodology used in this study as these had flaws, which were discussed in Chapter 4. For example, case studies have been criticised for not being able to generalise their findings since the sample is usually small (Maxwell, 2012). In this study, only three science teachers from three different schools participated. Since the results of the study do not represent all of the schools in eSwatini, the results of this study cannot be generalised beyond the schools that participated in this study. However, the findings may be of use in the teaching of electrolysis.

Another limitation was that the teachers were not familiar with CBS, and they may have used it differently if they had prior experience with CBS. Also, the CBS were provided to the teachers, so they were not expected to judge if the CBSs were good enough or not. If the teachers had selected their own CBS, they would be able to justify their choice of CBS stating its strengths and limitations. Further studies are recommended to explore how teachers select CBS.

5.8 RECOMMENDATIONS FOR ACTION

From the above findings, certain recommendations for action are suggested. It is recommended that teachers be informed through educational workshops regarding the value of using CBS in their teaching so that they can embrace it or be more willing to use CBS in their teaching. If they do not understand the value or the importance of using CBS in teaching, they will not use it even when they are provided with it or they may end up misusing it.

Also, it is recommended that the policies in schools be reviewed so as to maximise the accessibility of computers. This could allow teachers to make arrangements with the ICT department to use computers.

It is also recommended that teachers be guided on how much time they should spend using CBS in each topic so as to avoid losing track of time while using CBS.

It is also recommended that teachers be informed that CBS cannot replace any of the teaching methods that they normally use, but rather these have to be combined with CBS.

5.9 RECOMMENDATION FOR FURTHER STUDY

The purpose of the study was to understand how teachers use CBS in the teaching of electrolysis.

It is recommended that a study be done to investigate how teachers' familiarity with computers plays a role in the use of CBS as an instructional strategy. This will indicate if teachers' use of CBS also depends on their computer skills or not.

It is also recommended that a study be done with teachers who have used CBS as an instructional tool before. This could help researchers to understand if CBS provides correct information to the learners or not. Another study may investigate how teachers select CBSs and investigate why they select them. Moreover, researchers could discover what they regard as the advantages and disadvantage of each CBS.

5.10 EPILOGUE

The results of the eSwatini Physical Science examination from 2009 – 2016 show that the performance of learners in this subject is quite low. According to the Ministry of Education and Training report (2012), some of the challenges, particularly in the education system, include a shortage of resources such as teaching aids; insufficient teaching time for the subject; the high enrolment of learners in classrooms, teachers' lack of experience in teaching science subjects (physics and chemistry); teachers' beliefs about and attitudes towards teaching, which also influences their selection or choice of teaching strategies; teachers' specialisation in the subject, teachers' competency in Information and Communication Technology (ICT); teachers' use of ICT in teaching and learning; learners' prior knowledge and learners' socio-cultural context. It states that these factors may contribute to teachers' limited choice of teaching methods and further reduce the chances of offering individualised attention to learners. This consequently negatively affects the performance of the learners.

Also, schools have to come up with strategies for the departments in the schools to support each other and not work in isolation. This would further allow the teachers to make arrangements with the ICT department to have access to computers so that they may use them to improve teaching. Schools should also come up with strategies to support learners from different socio-economic backgrounds.

As an effort to improve the performance of learners, there is a need to use teaching techniques that enhance understanding of concepts which are learner-centred. These teaching techniques have to be interesting for learners. Teachers should be informed about the value of CBSs and trained in how to use them. This calls for teachers to be willing to use them, that is, embrace the use of CBS in their teaching mostly because the literature has shown that CBS enhances learners and teachers' understanding of concepts. However, CBS should not replace the teachers' responsibility; teachers' content knowledge and pedagogical content knowledge are prerequisites for the effective use of CBS.

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APPENDIX A

Questionnaire to be completed before observation

The purpose of this research is to find the difficulties associated with teaching of electrolysis. The information will be used for research purposes only: your responses will be treated with confidentially.

Section A: Demographic information
Table 1: Background information of participants

Name:	
Qualifications:	
Gender:	
Teaching experience:	

Section B
Curricular saliency
Describe how you would prove that hydrogen and chlorine are the gases evolved at the electrodes during the electrolysis of concentrated hydrochloric acid?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………………………………………..

2. This question involves three elements, A, B and C from the following list:
aluminium oxide carbon copper (II) oxide sulphur
sodium carbonate sodium chloride lead (II) oxide

Substance	**Appearance**	**conduction of electricity**	**molten in water**	**products at electrodes when molten** +pole -pole
A	dark grey powder	Yes	insoluble	none none
B	white crystals	Yes	Yes	chlorine sodium
C	yellow powder	No	insoluble	none none

Use the list and the table above to suggest possible identities for A, B and C.

3. Describe what you would observe on the anode and on the cathode during and after the electrolysis of copper (II) sulfate using copper electrodes.
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

4. Fill in the blanks by adding one word in each open space.

Solid sodium chloride will not conduct electricity. This is because the………………….in the crystal are not free to move. When the solid is………………….. strongly, it will…………………and it will then conduct electricity. If carbon electrodes are used in the electrolysis of molten sodium chloride,………………………is released at the anode and………………………at the cathode.

Section C
Pedagogical content knowledge

1. What do you intend students to know in this topic??
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
2. Why is it important for students to know this?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
3. What is the previous knowledge needed for electrolysis?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
4. Which teaching strategies do you use in teaching electrolysis?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
5. What are the limitations connected with teaching this topic?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
6. Describe any other factors that influence your teaching of this topic?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
7. Describe knowledge about learners that influence your teaching?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………
8. Explain strategies will you use to ascertain learners conceptions of the topics?

Source: Loughran, Mullhall and Berry (2004)……………………………………………

Questionnaire to be completed after using CBS

1. Describe what you intend students to learn in this topic by using this simulation?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

2. Explain the importance of learners to use this computer simulation?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

3. Describe what else do you know about computer simulations that students do not need to know?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

4. Describe the challenges associated with teaching using computer simulations?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

5. What knowledge can you share about CS that influence your teaching of this topic?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

6. Describe any other factors that influence your teaching of this topic?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

7. Describe teaching procedure will you use with the CBS ?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

8. Explain strategies will you use to ascertain learners conceptions of the topics?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………..

9. Explain how you the use of CBS contribute to the lesson development?
   ……………………………………………………………………………………
   ………………………………………………………..

Source: Loughran, Mullhall and Berry (2004)

APPENDIX B

The teacher interview schedule before using CBS
The use of computer-based simulations as an instructional strategy in teaching electrolytic cells

Time of interview:_____________ Duration______________
Date:____
Place____
Interviewer:__________________________________
Interviewee:__________________________________
Male / Female________________________________

Technology knowledge

1. What teaching strategies do you use in teaching electrolysis?
2. Give a reason for using each teaching strategy?
4. What are the challenges of teaching electrolysis?
5. How do you overcome the challenges?
6. Why do think it is important for learners to understand this topic?
7. How do you make the learners actively engaged during the lesson?
8. How do you assess the learner understanding during the lesson?

APPENDIX C

The teacher interview schedule after using CBS
The use of computer-based simulations as an instructional strategy in teaching electrolytic cells

Time of interview:____________ Duration_____________
Date:_____________________________________
Place_____________________________________
Interviewer:________________________________
Interviewee:________________________________
Male / Female______________________________

Technology knowledge

1. What teaching strategies do you use in teaching electrolysis?
2. Give a reason for using each teaching strategy?
3. How has the use of CBS changed your teaching of electrolysis?
4. How has the use of CBS improved your understanding of electrolysis?
5 How did you find the CBS that you used in your lesson?
6. What did you find exciting about the lesson?
7. What do you think if any, are the advantages of using CBS in teaching electrolysis?
8. Please support your response above.
9. Also give disadvantages of using CBS for the electrolysis topic if any.
10. Explain each disadvantage
11. How can the CBS that you used be improved?

Content Knowledge

12. How do you assist the learners when using computer simulations during the lesson?
13. Do you think using computer simulations benefits the learners, support your response?
14. What are the common mistakes that learners make in the topic electrolysis?
15. How do you assist the learners?
16. For the topic electrolysis, what are the pre-requisite concepts?
17. What are the challenges of teaching chemistry using CBS in your class?

Pedagogical Knowledge

18. How do you plan or write your lesson plan to accommodate the use of computer simulations?
19. How do you assist the learners during the lesson?
20. Would you suggest that computer simulations be used in schools for teaching electrolysis and other topics, please support your stand?

APPENDIX D

Observation guide

Indicator	Comments
How lesson is introduced • use of prior knowledge • referring to previous lesson • use of analogies • involvement of learners • introduction of CBS	
Lesson delivery • does teacher use examples • does teacher use analogies • any other teaching aids used • does teacher involve learners, if yes how • does teacher demonstrate CBS • does teacher assist leaners with CBS • what other teaching methods are used • how does teacher use CBS with other teaching methods	
Is the teacher confident • subject matter: allows learners to ask questions and answers confidently • in the use of CBS • assists learners in their groups • asks questions •	
CSC • Is it accurate • Is it easy to use • Does it link to the syllabus • Is it appropriate level • Content coverage	
Learners • Are they using CBS • Are they asking questions • Are they answering correctly the worksheet	

APPENDIX E

Chemistry section of syllabus showing subtopics in electrolysis

All learners should be able to:

1. Describe electrolysis

2. Draw a labelled circuit diagram for an electrolytic cell using the terms electrode, electrolyte, anode and cathode

3. Describe the electrode products formed in the electrolysis of copper chloride between inert electrodes

4. Describe electrolysis in terms of the ions present and reactions at the electrodes in examples given.

5. State the general principle that metals or hydrogen are formed at the negative electrode and that oxygen or halogens are formed at the positive electrolyte

6. Outline the manufacture of chlorine and sodium hydroxide from concentrated sodium chloride

7. Describe the electrolysis of dilute sulphuric

8. Construct equations for the electrode reactions in the manufacture of aluminium, chlorine and sodium hydroxide

9. Describe the process of electroplating

APPENDIX F

TEACHER A FIRST INTERVIEW

DATE: VENUE: SCHOOL A HIGH SCIENCE PREP ROOM
DURATION: 20mins

I would like to thank you for accepting to take part in this interview. Please feel free to say anything. Remember the views expressed here are only going to be used for this study and there are no wrong answers. Also, you do not have to say who you are because only the ideas and not your name are important.

	Themes	**Comments**
L1 Interviewer: Good morning and thank you very much for allowing me to use you to take part in the study. As I explained to you before, the study is on the use of computer simulations as a teaching method. Ehh hopefully computers will be introduced in the coming years whereby they will be used in assisting or helping students to understand complex concepts. So are you ready for the interview so that we can start. **L2 Teacher A**: Yes mam I'm ready.		
L3 Interviewer: Please raise your voice a bit because I am recording. What teaching strategies do you use in teaching electrolysis? **L4 Interviewee**: Ok we <u>use practicals and also we use computer simulation.</u> **L5 Teacher A**: Wow	Teaching strategies	Names the Teaching strategies as practicals & computer simulations

L6 Teacher A: But we normally use that at the end of the lesson. **L7 Interviewer**: Ok. So you know about computer simulation? **L8 Teacher A**: Yes mam. **L9 Interviewer**: Wow I'm impressed why,what are your reasons for using the two? You use mainly the two methods. **L10 Teacher**: Yes **L11 Interviewer**: So what are your reasons for using the two methods that is the practical activity and the computer simulations? Ok if you may start with the practical activity, why do you, do you use it? **L12 Teacher A**: The practical activity is for students to be involved on the topic, because electrolysis is about the passing of electricity through solutions and also molten ionic substances. **L13 Interviewer**: Mhm **L14 Teacher A**: So when doing the practical, we make the solutions so the learners will do, for example the electrolysis of copper chloride whereby the learners are able to see the gas being given off at the anode, and also at the cathode the students actually see copper being coated on the carbon electrode, that is the air, cathode.	Teaching strategies Teaching strategies	States at which section of the lesson he uses computer simulations, seems to misunderstand CB since learners use it at the end, yet it is expected that CBS be integrated in the lesson and leaners do some manipulation. Practical-believes students' involvement have to see gas being given off and the coating at the cathode live…appreciates macroscopic values

L15 Interviewer: Ok alright so from your experience what is the limitation, with the use of practical activity, meaning what is it that the use of practicals cannot ehh,or limit the student in understanding the topic. What is it they cannot or what is it they have to imagine or what is the limitation of the use of practical activities. **L16 Teacher A**: Actually I see there are no limitations, it's just that the students have to do chemical bonding, that is ionic bonding. So from ionic bonding the students are able to compare ionic equations ehm ionic compounds and covalent compounds. So one, when looking at the properties of ionic equations is that ionic compounds conduct electricity, so once the student have done after the student have looked at ionic properties they are able to appreciate the fact that ionic solutions conduct electricity and also molten ionic compounds. So when we, after having done ionic bonding then we move on to electrolysis. And electrolysis is all about passing electricity through solutions and molten ionic compounds. **L17 Interviewer**: Ok **L18 Teacher A:** So, the practical part that is on solutions, that one the students are able to see what is formed at the electrodes. Ehm maybe the limitation could be how do you show a student that a molten substance can conduct electricity because we do not have enough equipment to demonstrate or to carry out practicals on the passing out of electricity between molten substances mam. So maybe that could be the limitation.	Teachers' curricular knowledge Challenges to using CBS	Thus no limitation with practicals states the previous knowledge for understanding of electrolysis Shortage of equipment

L19 Interviewer: Ok **L20 Teacher A:** In-availability of chemical, chemicals on equipment of ionic solutions. **L21 Teacher A**: And then you also mentioned computer simulations, how does the computer simulation help or what gap does it try to fill for the students to understand a concept of electrolysis? Or does it improve? **L22 Teacher A:** Ok, ok it sort of improve maybe on what has been learnt **L23 Interviewer:** How does it improve? **L24 Teacher A:** .in the computer simulation the students are able to see the ions actually migrating to the different electrodes. But when you are carrying out the practical you do not actually see the ions migrating to the different electrodes, but comparing with computer simulations the students are able to see that. Or maybe another is that learners during the practicals only do, at the different…[not clear] with computer simulation they can see the migration of ions and also what is formed when the bonding takes place.	Challenges to using CBS Advantages of CBS	Shortage of chemicals Enhance learners' understanding Learners are able to see migration of ions to the electrodes
L25 Interviewer: Ok, so that way it helps to improve the understanding? **L26 Teacher A:** Yes, the understanding of the concept. **L27 Interviewer:** Ok, ok. So from your teaching experience what are the prerequisite for electrolysis, what are the the prerequisite concepts for students to understand? **L28 Teacher A:** Ok, it is electricity and, the properties of ionic compounds and, also solubility, and ofcourse melting.	Teacher's curricular knowledge	Names the pre requisite concepts for electrolysis: Electricity, properties of ionic compounds, solubility and melting
L29 Interviewer: Ok, so what are the common misconceptions that students make **L30 Teacher A:** Ok students, one of the the misconceptions they make is that insoluble salts do no conduct electricity. Whereas, ok then we may have insoluble salts but the insoluble salts conduct electricity when they are in the molten state, and that requires the salts to be heated first. So then once they are in the molten state then they can conduct electricity.	Learners' difficulties in electrolysis	Some learners think insoluble salts do no conduct electricity
L31 Interviewer: That's the misconceptions they make? **L32 ITeacher A:** Yes **L33 Interviewer:** Ok and how do you assist them in overcoming that misconception?	Challenges to using CBS	

L34 Teacher A: Ok because at the school we do not have enough equipment for carrying out that so we normally do we borrow some of the equipment from the university. And if that is not possible that part of experiment we can see it in computer simulations.	Challenges to using CBS	Shortage of equipment
L35 Interviewer: So you said you aslo use practicals, so usually how many students do you have in a group? **L36 Teacher A:** On average its about six. **L37 Interviewer:** So how do you make sure that make sure that each student participate, how do you assist the student during the practical? **L38 ITeacher A:** Mhm, I move around from one group to the next. And at a time you find that you do the practicals with the groups of four. **L39 Interviewer:** Ok. **L40 ITeacher A:** So with the four groups as a teacher I can have enough time, I have enough time to move from one group to another.	Teaching strategies	
L41 Interviewer: Ok, and then also…ehm why do you think it is important for learners to understand the topic of electrolysis? **L42 Teacher A:** Ok, it is that important so that students should be able to know that it is not only metals that conduct electricity, and also solutions can conduct electricity. and also the industrial application of electricity is also important because it addresses some of local issues.	Teacher' curricular knowledge	For understanding of the concepts that link with electrolysis eg electricity Industrial application
L43 Interviewer: Ok, so ehh, how do you assess learner's understanding during the lesson? **L44 Teacher A:** Ok, by asking questions and also by giving them work which they will do while in class, then also give them homework, quiz and tests.	Teaching strategies	Use of formative evaluation
L45 Interviewer: Ok, maybe I was supposed to ask this one first. What is your teaching experience? **L6 Teacher A:** Mine is 24 years. **L47Interviewer:** Of teaching electrolysis, of chemistry? **L48 Teacher A:** Yes **L49 Interviewer:** So also you say you use computer simulation, so where do you get the computer simulation? **L50 Teacher A:** The University of Swaziland at the faculty of education.		

L51 Interviewer: By the faculty of education? **L52 Teacher A:** Yes in time **L53 Interviewer:** And you have to pay or its free of charge? **L54 ITeacher A:** You have to pay. **L55 Interviewer:** So do you recommend that teachers use the computer simulations? **L56 Teacher A:** Yes because <u>the learners become more interested </u>with, <u>when you show them that is what is applied</u>. The attention they give.	Advantages of CBS	Leaners become more interested Believes in demonstration (showing them)
L57 Interviewer: So in most cases do you, are the students hands on when they use the practical sorry I mean the computer simulations or you demonstrate? **L58 Teacher A:** I <u>demonstrate.</u> **L59 Interviewer:** Ok, you know thank you very much for giving us time for doing this interview, so we are going to continue with the classroom observation. **L60 Teacher A:** Ok, you are welcome.	Teaching strategies	He seems to misunderstand CBS. He believes in demonstration not allowing learners to be hands on

APPENDIX G

TEACHER A LAST INTERVIEW

I would like to thank you once again for accepting to take part in this interview. Please feel free to say anything. Remember the views expressed here are only going to be used for this study and there are no wrong answers. Also, you do not have to say who you are because only the ideas and not your name are important.

DATE: **VENUE: SCHOOL A HIGH SCIENCE PREP ROOM** **DURATION: 20mins**

	Theme	**Comments**
L1 **Interviewer:** Good afternoon sir. **L2** **Teacher A:** Good after noon.		
L3 **Interviewer:** Thank you once again Mr for honouring this, for participating in this interview. Guess this will be the last interview. So without wasting your time can we start? The first question will be what teaching strategies do you use in teaching electrolysis? **L4** **Teacher A:** Ok, it is question and answer, practical and discussion.	Teaching strategies	Names the different teaching strategies as the question and answer, practical and discussion
L5 **Interviewer:** Ok can you give a reason to why do you use those teaching strategies? **L6** **Teacher A:** For question and answer, that is used when trying to introduce a lesson and also trying to link a lesson to previous knowledge. **L7** **Interviewer:** Ok. **L8** **Teacher A:** And the practical part learners become, sort of hands on	Teaching strategies	Understands the importance of combining different TS: Q&A-introduce new lesson and links with previous lesson

the lesson. We then discuss the results of the experiment.		Practical- learners hands on Discussion
L9 **Interviewer:** Ok, what was the reason? Ok, how has the use of computer simulation changed your teaching of electrolysis that is the topic? **L10** **Teacher A:** What we noticed is that the learners became more involved in the lessons. Most of them, even those learners who before did not ask questions were, asked. Ok more questions were asked by the learners which is something that did not happen before. **L11** **Interviewer:** Ok. so do you think the use of computer simulation improved the learner's understanding of the topic? **L12** **Teacher A:** Yes, yes of course? **L13** **Interviewer:** Ok, how do you think it improves their understanding? **L14** **Teacher A:** In the computer simulations more things were explained **L15** **Interviewer:** Ehm? **L16** **Teacher A:** And the learners they actually saw ions migrating to the different electrodes?	Advantages of CBS Advantages of CBS	Promotes critical thinking as learners ask more questions Learners were more involved Learners are able to visualise migration of ions to the electrodes
L17 **Interviewer:** Ehm? **L18** **Teacher A:** Eh in a practical we only see what is being produced in the, at the electrodes.	Teaching strategies	Specifief that practical enable one to see what is produced at the electrodes

L19 **Interviewer:** So how did you find the computer simulations that you used in your lessons? You say they were good? How did you find them? **L20** **Teacher A:** They were good because they covered, the computer based simulation, I found that they good were because one; in the…in a practical the learners only see what is being produced but when using the computer simulation, they see the migration of the ions to the different electrodes and they are also able to see what is being produced at the electrode. With the computer based simulations a lot of ground is being covered with a short space of time. And the learners they get to understand some of the concepts. **L21** **Interviewer:** So do you think there are any advantages and what do you think are, what are the advantages of using the CBS in teaching electrolysis? **L22** **Teacher A:** There are advantages like I said. **L23** **Interviewer:** Eh. **L24** **Teacher A:** Learners get to see the actual movement of ions and also they see what is being produced at the electrodes. And another thing in the computer simulations, they explain more things which some have already seen during praticals or heard from the teacher, so that enforces what a student have to learn.	Advantages of CBS Advantages of CBS	Leaners only see what is produced in a practical, however he acknowledges that learners also see migration of ions and what is produced at the electodes. Also a lot of ground covered within a short time Highlights the advantages of CBS
L25 **Interviewer:** So do you think there are any disadvantages of using computer simulation? **L26** **Teacher A:** I think one disadvantage is that it is sort of suitable for a small group of learners. **L27** **Interviewer:** Ok, why do you say it is suitable for a small group?	Challenges to using CBS	Suitable for a smaller group
L28 **Teacher A:** If the group is small, all the learners are able to see what is happening in the computer simulation and if all of them want to ask some questions all of them get a chance to express that question.	Teaching strategies	Believes that CBS is to be demonstrated to learners

L29 **Interviewer:** So how do you think the use of computer simulation can be improved? **L30** **Teacher A:** I think that they can be improved by the use of experiment and also if a big screen can be used and also where the students are watching there can be more speakers, so that all the students can be able to hear what is being said in the computer simulation.	Teaching strategies	Believes that leaners may manipulate by doing an experiment. Also believes that practicals should be used together with CBS
L31 **Interviewer:** Ok, so now how do you assist the learners when using the computer simulation during the lesson? **L32** **Teacher A:** Ok, one the teacher has to move around the room and also the learners must be in groups so a teacher can move from one group to the other. And maybe also at certain points the teacher can be able to stop and assist where necessary.	Teaching strategies	Guides learners
L33 **Interviewer:** So can you give the common mistake that learners make in the topic of electrolysis? **L34** **Teacher A:** One common mistake they did is that they think electrolysis can only take place.	Learners' difficulties	they think electrolysis can only take place in solution
only in solution, some ionic compounds are not soluble and they think those they… those ionic compounds which are insoluble, … the learners, think that they cannot conduct electricity. **L35** **Interviewer:** Oh, ok. **L36** **Teacher A:** But they…all ionic compounds conduct electricity in solution or in molten state. Those ones soluble they have to be heated first so that they are in a liquid state. .		

L37 **Interviewer:** So how do you assist them in overcoming those mistake or those challenges? **L38** **Teacher A:** Eh. I can… ok…that is a major mistake but they are…maybe you may find that they are also…they are mistakes but too minor. They can be easily corrected. **L39** **Interviewer:** So how do you assist them with this major one? **L40** **Teacher A:** The <u>only way is to carry an experiment where the insoluble compound is heated, then they are allowed to see if electrolysis takes place while the compound is in the molten state.</u> **L41** **So** **L42** **Interviewee:** For example, Two iodine because in the experiment we actually see one of the electrodes, iodine fumes being given off. **L43** **Interviewer:** Ok. so for the topic of electrolysis what are the prerequisite, which concepts the students need to understand in this topic? **L44** **Interviewee:** It is of ionic…the discussion of properties of ionic compounds and also…	Teaching strategies	Make learners to carry out an experiment
L45 Interviewer: so what are the challenges of teaching electrolysis using CBS? **L46** **Teacher A:** <u>You,.. the challenges maybe our classes are too big and maybe that the equipment which is used in the computer simulation may be a little bit expensive for the school to purchase them.</u> **L47** **Interviewer:** When you say too big how many nje in your class? How many students do you have? **L48** **Teacher A:** Now they are about 40. **L49** **Interviewer:** Ok. So if I may ask since you said it helps them, the use of computer simulation. Have you compared the marks, have you given a test where you compared the marks for the students for the different groups whereby this group used the computer simulation and maybe the previous groups that did not use the computer simulation? **L50** **Teacher A:** Ok. I tried to compare last year's results and of course of the test where the test included electrolysis and the test that the marks were	Challenges to using CBS	Large class sizes Shortage of equipment

better for this year than last year. **L51 Interviewer:** Ok. **L52 Teacher A:** So I thought maybe the computer based simulation helped a lot. **L53 Interviewer:** Ok. So would you recommend it is introduced in schools? **L54 Teacher A:** Yes. **L55 Interviewee:** So how do you plan or write your lesson plan to accommodate the use computer simulation **L56 Teacher A:** Eh. In the lesson plan? **L57 Interviewer:** Ehm. **L58 Teacher A:** Ok. Before we did not include CBS in the teaching but now I included it. **L59 Interviewer:** Ok. And you allocate it some time? **L60 Teacher A:** Yes of course **L61 Interviewer:** Ok. I think that is about all in this interview. So thank you very much for taking part in the study and definitely the report of everything if you are interested.		

APPENDIX H

TEACHER A Lesson observation 1
Computer simulation on electrolysis

	Themes	Comments
L1Teacher: Morning class. What we are going to look at today is electrolysis. Well start by you giving me the properties of ionic compounds, all the properties of ionic compounds. **L2Student A:** They conduct electricity in molten state (teacher writes responses on the board). **L3Student B:** Ionic compounds have strong ionic bonds (teacher writes on the board). **L4Student C:** They are solid at room temperature (teacher writes responses on the board) **L5Student D:** They consists of negative and positive ions (teacher writes responses on the board).	Teacher's curricular knowledge	Tells learners what they are going to learn about Writes key points on the board Links new lesson to previous knowledge
L6Teacher: I think these properties are now more than enough. Okay our interest will be on the first property. Ionic compounds conduct electricity when in molten state, is that all? Or also in solution. So ionic compounds are expected to conduct electricity when in molten state and when in solution. Why is it possible for ionic compounds to conduct electricity when in solution or in molten state? **L7Student:** They have free moving electrons. **L8Teacher:** Okay we are talking about ionic compounds in solution or in molten state. You are saying electrons are free to move around? What is free to move in solutions? Is it ions or electrons? **L9Class response:** Ions	Teacher' curricular knowledge	Links new lesson to previous knowledge

L10Teacher: So there is free movement of ions in solutions or molten state. The ions are the ones that conduct the electricity. electrolysis is the process by which current is passed through a solution or when substance is in molten state. So what I have here is a solution of copper (II) chloride. Chemical formula is $CuCl_2$ (writes on the board), if this substance is dissolved in water, it dissociates to its ions. So the ions are copper two and two chloride ions. So the solution is soluble in water, thus split into copper ions and chloride ions. Okay please form your groups. each group has its copper chloride solution. So this is the solution. [learners moved to their groups and did the experiment using chemicals collected from their teacher,] [after some time, he demonstrates] So these are the carbon rods (dips rods into copper chloride solution). So what happens to each rod.	Teaching strategies	Teacher calls learners in groups and demonstrates that copper chloride solution conducts electricity (experiment)
L11Student: There is a change of colour in this one (pointing to the one that has changed colour). **L12Teacher:** What colour is it? **L13Student:** It is brown. **L14Teacher:** Okay go back to your seats. (teacher draws diagram of the electrolytic cell on the board). This is a circuit and this is a solution. (pointing to the diagram on the board). The bulb is part of the circuit. Then you have these two carbon rods which are called electrodes. Then you have the positive and the negative side of the circuit. In this circuit, there are three cells. The electrode on the negative side is called the cathode and the one on the positive side is called the anode. Then in this solution what type of ions are there?	Teaching strategies	Shows by drawing on the chalkboard a diagrammatic representation of an electrolytic cell
L15Student: Chloride and copper ions **L16Teacher:** So what did you see at the anode? **L17Student:** Gas bubbles. **L18Teacher:** What about the cathode? **L19Student:** The rod changed to brown.		

L20Teacher: Okay in your groups use the computer simulation on electrolysis and select the different metals of your choice as electrodes and select a solution of your choice to use with each metals. Make your observations. **L21Teacher:** We'll end here for today.	Teaching strategies	

APPENDIX I

TEACHER A LESSON 2

No CBS was used, but the lesson was on the discussion of electrolysis of copper chloride solution and copper sulphate solution which was done in the previous lesson where learners used a CBS

L1Teacher: Good morning. I hope all of us were able to see what was happening in the computer simulation of electrolysis. In the computer simulation, electrolysis was defined and I think the definition is the same as the one I gave you. So electrolysis is the passing of electric current through a solution and in molten state. Molten state of <u>copper (II) chloride</u> breaks up to two types of ions. In the molten state, the liquid you have only two ions. In solution you have copper (II) and chloride ions and of course there are other ions. The other ions are hydrogen and hydroxide ions. So you have two electrodes, what are they?	Teacher' curricular knowledge Teaching strategies	Refers learners to the previous lesson Use of examples Question and answer/ discussion
L2Class response: Anode and cathode. **L3Teacher:** In the anode, it's the chloride ions which move to the cathode since its negative and where the copper (II) ions go to. So what happens at the electrode? <u>You remember at the video, we said that at the anode oxidation takes place then at the cathode reduction takes place.</u> So if reduction takes place it means two molecules of chloride ions at a time loose electrons to form chlorine. The electrons travel through the electrodes through the cells to the cathode and they are picked up by the copper ions. <u>What I think you should note is that, at the anode two chloride ions at a time loose two electrons. I think you saw chlorine bubbles being liberated at the anode even during the experiment we carried out. For copper (II) chloride to conduct electricity, the copper (II) chloride must be in molten state that means it</u> has to be heated so that it melts. For copper (II) chloride to be in solution, the salt is simply dissolved in water. This is what happens in the two electrodes, that is, the anode and the cathode. <u>The experiment in the lab was on electrolysing copper (II) chloride. Then the terms used in electrolysis, you have</u> electrolysis, then	Teaching strategies Teaching strategies	refers learners to the CBS uses copper chloride solution as an example combines the CBS with experiment in his teaching refers learners to the experiment he did, uses these two in his teaching

you have electrodes. There are two types of electrodes and these are anode and …. **L4Class response:** Cathode.		
L5Teacher: Then you also have what is referred to as an electrolyte. So electrolyte can be in two forms, solution or molten state. Then you also have what is referred to as the electrolytic cell. What is it?...okay the process of passing current through a solution or molten state. We call that electrolysis. Then electrolytic cell is everything involved in the carrying out of electrolysis. So we have copper (II) chloride, its very easy to understand what is going on with it. <u>But when you electrolyse a solution, for example, copper (II) sulphate, you would expect copper two ions to migrate to the anode. So what happens at the electrodes?</u> **L6Student:** Copper is deposited at the cathode. **L7Teacher:** What about the anode? **L8Student:** A gas will be given off. **L9Teacher:** Where is the gas coming from? So here copper (II) ions and sulphate ions, since this is dissolved in water. Some of the water will be converted to hydrogen ion and also hydroxide ions. So the positive ions migrate to the cathode and the negative ions migrate to the anode. Here we are going to have a sulphate and hydroxide ions [pointing to the chalkboard] and here we are going to have copper and hydrogen ions. Then how is this electrode going to choose between the two? What criteria will be used?	Teacher's curricular knowledge Teaching strategies	Uses another example also covered in CBS
L10Student: <u>Reactivity series</u> **L11Teacher:** Then at the top we have the most reactive and at the bottom the least reactive. The cathode will prefer which ions. **L12Student:** Copper ions. **L13Teacher**: Why? **L14Student**: Copper ion is more reactive than hydrogen.	Teacher's curricular knowledge	Previous knowledge

L15Teacher: Hydrogen is somewhere here, which means hydrogen is more reactive than copper. Okay its true that cathode will prefer copper ions than hydrogen ions. Okay at the anode and cathode, the most preferred ions are the least reactive. Do you get that? It's the least reactive substances which are preferred at the 2 electrodes. For this electrode, copper is preferred because it is less reactive than the hydrogen ion. So it is going to be reduced or oxidised? If you loose electrons that is oxidation and if you gain electrons , that is reduction. So copper ions will gain two electrons. Here are two ions, sulphate and hydroxide ions. The anode will prefer the hydroxide ions. So one hydroxide ion will loose one electron. But at a time, four hydroxide ions loose four electrons to form a molecule of oxygen and two molecules of water and this is an atom. Then the anode, here are two ions, sulphate ions and hydroxide ions. The sulphate ions is more reactive than the hydroxide ions, so the anode will prefer the hydroxide ions. So one hydroxide ion is going to loose one electron. At a time, four hydroxide loose four electrons to form a molecule of oxygen and molecule of water. So this oxygen is going to be liberated at the anode. You will see that by gas bubbles. At the cathode, it will be deposited with a brown substance to show that what is produced is copper. So in electrolysis, the least reactive metal is preferred. But in displacement reactions, the most reactive metal is preferred. More reactive metals cannot displace least reactive metals. So in electrolysis, we use the electrolysis series not the reactivity series. However, if you use the reactivity series, don't forget that the least reactive metal is preferred. Any questions? We are going to end here for today. Next time well look at the electrolysis of water.	Teacher' curricular knowledge Teacher's curricular knowledge	Tells the learners a rule without explaining why the least reactive metal is preferred Doesn't explain why the least reactive is preferred Links to previous concept of displacement reactions Emphasizes, the main point

APPENDIX J

TEACHER A LESSON 3

CBS on electrolysis of acidified water was provided but was not used

L1Teacher: Good morning. Today we are going to learn about electrolysis of water. Water is a covalent compound. So covalent compounds do not conduct electricity unless other substances are added to it. so to electrolyse water sulphuric acid is added (teacher writes on the board). So if few particles of sulphuric acid is added, the water then will conduct electricity. So what ions are you going to find in the acidified water because adding small amount of an acid to water we call that acidified water. From the ions that going to be found from the sulphuric acid, we get one molecule of sulphuric acid , we get two hydrogen ion and a sulphate ion. Then, this makes water to happen, it means some of the water come from the hydrogen ion and the hydroxide ion, this is what will happen, if you look at this, [points to the chalkboard] positive ions will be the hydrogen ions. From the sulphuric acid you get hydrogen ions, from the water you also get hydrogen ions. So these ions will migrate to the cathode. Then, hence the anode, that is, where the sulphate ion and hydroxide ions will migrate to. Then the anode is going to prefer the hydroxide ion because they are less reactive than the sulphate ion. So what will happen is this, four hydroxide ions are going to loose four electrons to form one molecule of oxygen and two molecules of water. So that is the electrolysis of acidified water. The water is being acidified by sulphuric acid. Then another example could be sodium chloride. If you dissolve sodium chloride in water, what are the ions are you going to have? Sodium chloride dissolved in water [pauses, waiting for students' responses]. …positive ions, *kutoba yini?* (what is it going to be?).	Teacher' curricular knowledge Teaching strategies Teaching strategies Teaching strategies	Tells learners what lesson will be on, lesson focus Uses the chalkboard, uses an example Uses another example

L2Student: Sodium ions **L3Teacher:** Sodium chloride, so this going to split to sodium ions and chloride ions (writes on the board, Na^+ and Cl^-). So what is going to be formed at the anode, cathode? So if you look at the reactivity series, which amongst the two is more reactive, sodium or hydrogen? **L4Student:** Sodium. **L5Teacher:** Sodium is more reactive than hydrogen, so the cathode will prefer the cathode would prefer the hydrogen. So what will you see at the cathode? **L6Student:** Bubbles. **L7Teacher:** So at the cathode, you will see bubbles, what will happen at the anode? So this chlorine (pointing to the board) is more reactive than a hydroxide ion, sorry, hydroxide is more reactive than chlorine. Which means if the hydroxide is less reactive than the chloride ions, so the hydroxide ions, which is more reactive between the two, the problem I have now, I am not sure which ion is more reactive but I will give you this as a homework. The homework is, which amongst the two ions is more reactive?	Teacher' curricular knowledge Teacher's curricular knowledge	Links lesson to the reactivity series, concepts that link with electrolysis Limited, not sure
L8Student: Chlorine is more reactive. **L9Teacher:** So this is the ion that will be preferred. If that is the case, what will happen at the anode? At the anode the hydroxide ions are preferred, what would you see at the anode….(pause) what would you see at the anode? We are going to stop here for today.	Teacher' curricular knowledge	Accepts learners' response yet he's not sure and does not guide learners in getting the correct answer, instead ends the lesson leaving learners in a state of uncertainity.

APPENDIX K

TEACHER B FIRST INTERVIEW

I would like to thank you for accepting to take part in this interview. Please feel free to say anything. Remember the views expressed here are only going to be used for this study and there are no wrong answers. Also, you do not have to say who you are because only the ideas and not your name are important.

DATE: VENUE: SCHOOL B SCIENCE PREP ROOM DURATION: 20mins

L1 **Interviewer:** Goodmorning Mrs… **L2** **Teacher B:** Morning, morning mam. **L3** **Interviewer:** Mhm…thank you very much for allowing me to use you to take part in the study. As I explained to you before, the study is on the use of computer simulations as a teaching strategy. So the interview is one of the instruments I am going to use to collect the data and already we have done one which is a questioner. So after the interview we are going to have some observations. So without wasting any time….are you ready for the interview? **L4** **Teacher B:** Yes I'm ready. **L5** **Interviewer:** I would appreciate maybe if you raise your voice a bit because I am recording. **L6** **Interviewee:** Ok **L7** **Teacher B:** So the first question will be…ehh… For how long have you been teaching chemistry? You are a teacher, a qualified one. Will start from there. **L8** **Teacher B:** Yes **L9** **Interviewer:** For how long have you been teaching chemistry?		

L10 **Teacher B:** Ok, ten years, after my education, but certificate. But before that I was a contracted teacher for five years. **L11** **Interviewer:** Ok **L12** **Teacher B:** So I think I can say roughly 15 years. **L13** **Interviewer:** Wow, you have a lot of experience. **L14** **Teacher B:** Yes **L15** **Interviewer:** So have you been teaching chemistry? **L16** **Teacher B:** Yes…yes. It's my major, there is no year that I haven't taught chemistry. **L17** **Interviewer:** Ok. So we can say you have 13 years of teaching chemistry? **L18** **Teacher B:** Yes **L19** **Interviewer:** Of which electrolysis is one of the topics you have been teaching? **L20** **Teacher B:** Yes we can say 15 years. **L21** **Interviewer:** Ok **L22** **Teacher B:** Yes		
L23 **Interviewer:** So what teaching strategies do you use in teaching electrolysis? This topic is mainly electrolysis. **L24** **Interviewee:** Electrolysis?...Ok… Earlier on I tried informal lecture, formal lecture, discussion and so dispensatory but through experience…I have…I usually am dealing with it using experiments. **L25** **Interviewer:** Ok **L26** **Teacher B:** Yes, and demonstrations. **L27** **Interviewer:** Alright…. So what do you mean by informal and what do you mean by formal? **L28** **Teacher B:** Informal lecture I think is not where I stand formal there and talk most of the time, so it is informal because they also support…they also help me in reading and answering the questions. Or maybe I can correct myself and say it is questioning. **L29** **Interviewer:** Ok.	‘ Teaching strategies Teaching strategies	She names the different teaching strategies she uses to teach electrolysis She engages learners through questioning in a form of discussion

L30 **Teacher B:** Yes. **L31** **Interviewer:** Ok, ok?… so have you been using questioning? **L32** **Teacher B:** Yes. **L33** **Interviewer:** Question and answer? **L34** **Teacher B:** Yes, yes. **L35** **Interviewer:** So what do you mean by formal? Because earlier on you said you have been using the informal. So what were you?... now that you have explained the informal, what do you mean by the formal then? **L36** **Teacher B:** The formal I think I refer to the indigenous method used for teaching me, the teacher I used to impart. The knowledge, knowledge and we were behaving passively even after education, my education certificate. It became difficult for me to apply or to change to my previous method even if… though I knew now that it have to be student centred , but I think it remained teacher centred for some time. It is not easy for me to move from theory to practical. **L37** **Interviewer:** So what were your reasons from changing from the formal to informal, to the practical?	Teacher' attitude	She is aware of the learner centred approaches thus was willing to change from teacher centred a practice she had been using to learner centred
L38 **Teacher B:** It remained abstract… it remained abstract for the students…., they could not concretise, the marks were low. So then I started asking a few questions. And the students…they came, and others were angry and bitter. They say we do not understand your chemistry. So they started shouting at me. And then one day, I began…ehh.. instead of becoming angry I decided to change this because the results to me were not just equivalent to the time we or rather proportional to the time I was spending to the results that I was getting because they were just too low. **L39** **Interviewer:** Ok. **L40** **Teacher B:** Yes. **L41** **Interviewer:** Ok… so the results you were getting were….was it at the end of the year or you mean during the formative… I mean like tests or was it at the end? **L42** **Teacher B:** From formative to the final assessment, to the final	Teaching strategies and teacher' attitude	She points to the limitation of the traditional method of teaching, her willingness to change the teaching strategies shows her attitude, that is she was concerned that the learners were not doing well.

exam. And yes they were frustrating because I thought there was something wrong with the students. **L43** **Interviewer:** Ok. **L44** **Teacher B:** Yes, but others were brave enough to open up we can't imagine, we do not even form a picture of what you are trying to say.		
L45 **Interviewer:** Ok, alright. So now with the change…you said you are now using the practical? **L46** **Teacher B:** Yes. **L47** **Interviewer:** So do you see any improvement? **L48** **Teacher B:** Yes, there's a lot of improvement.	Teaching strategies	
L49 **Interviewer:** In what way? **L50** **Teacher B:** They can identify the direction of the flow of electricity, they can label the electrodes nicely, and if I use the questions from their concise, and practical approach to chemistry, the inservice textbook that we are using, they can answer the questions independently. **L51** **Interviewer:** So now you are happy with their performance? **L52** **Teacher B:** Yes I am happy because if we were collecting oxygen. I am greatly helped by following the activities in the textbook. After doing the experiment, you do not have anything to explain they can answer the questions well. Which means that the experiments…the practicals they help a great deal. **L53** **Interviewer:** Ok. Having said you use practical…practical activity, does it mean that each student is working on his/her own or they are working in groups?	Teaching strategies Teaching strategies	She observes an improvent when learners do practicals as well while learning electrolysis in addition to questioning/ discussion method. She also uses textbook as her teaching strategy

L54 **Teacher B:** I usually have a maximum of 5 groups, I don't have enough equipment. **L55** **Interviewer:** Mmhm? **L56** **Teacher B:** Yes, so I usually encourage them to move from one group to the next. Especially I highlight the groups that are having the direction because we also have some problems from the materials that we are using like for the power supply. **L57** **Interviewer:** Ok, I will get back to that as for the challenges maybe. You are going to expand on that. The experiments the groups, how big are the groups, you said you have five groups. How many students per group? **L58** **Teacher B:** 10 **L59** **Interviewer:** 10 students per group!!? **L60** **Teacher B:** Yes we usually have high numbers	Challenges to using CBS Challenges to using CBS	Shortage of equipment because of the large number of learners Large number of learners, makes it difficult to give individual attention

L61 **Interviewer:** So how do you make sure that each student participate?		
L62 **Teacher B:** No, it's not easy but still it outweigh having to explain.		
L63 **Interviewer:** Ok.		
L64 **Teacher B:** The small chance of checking or peeping through still it makes a learner better to understand, better for the learner than denying the total practical.	Teaching strategies	Acknowledges the use of practicals because learners can visualise
L65 **Interviewer:** And then as a teacher how do you assist them? What is your role when the students are doing the practical activity?		
L66 **Teacher B:** I usually do not have a lot of duties. The learners I have discovered that they are not empty vessels. Out of the blue I can see a student knowing everything, even operating the power supply better than myself and then I just award them as heroes, so then the others are motivated.	Teaching strategies	Shows that she believes in the constructivism theory, where learners have to make meaning from what they learn
L67 **Interviewer:** So you mean you do not assist them in any way?		
L68 **Teacher B:** I first tried, and I realised that students are not empty vessels. So my duty now is to encourage those that are not doing well the practical. So I usually…get close to that group, but I usually use those that are…those that were able to connect quicker, then I encourage them to go help the others, so usually many teachers.		

L71 **Interviewer:** Ok, so eh, what are the challenges of teaching electrolysis…the challenges you have encountered, for both you as a teacher and the students. **L72** **Teacher B:** Ok, it is usually the…it is usually the method because pupils they learn at different…styles. Let me say different styles. So others are irritated by the noise and others they do not do well in a cooperating environment. Like I said I usually have 10, and they always lack prerequisite information. And others, because of this incorporative physics a lot, and so you find that others are doing very bad in physics, so the moment you talk about current, it means that you have set them aside. And also brings about charges and ions which we do in bonding. A lot of students are challenged by...bonding . **L73** **Interviewer:** Ok. **L74** **Teacher B:** And also by identifying if the substance is ionic or molecular, so the fact that this topic needs about 30% of bonding. Some learners are left there. When I move, it's the same pupil who did well in the bonding.	Challenges to using CBS Teacher'curricular knowledge Learners' difficulties in electrolysis Teacher' curricular knowledge Teacher' curricular knowledge and learners' difficulties	She gives challenges as, learners lack pre-requisite knowledge, learners have different learning styles, thus don't learn well in a big group because they may be destructed by noise and mentions the abstraviness of the topic Some learners don't put an effort thus they don't cope when the topic becomes more abstract

. **L75** **Interviewer:** Ok. **L76** **Teacher B:** Yes. **L77** **Interviewer:** So, that refers to the students. About you then what are the challenges that you have with teaching, or maybe should I rephrase and say isn't there another teaching method you would have to use, but maybe even the practical activity, maybe would you have used other methods but because of the challenges you are facing, now you are only forced to use only the practical activity. What are the challenges of the practical activity? **L78** **Teacher B:** Well I have realised that I fail to just choose one method that will arouse the interest for all of them. The method that most of them will be interested will be eh…actively involved. Since I said that only a few they become the heroes, the others then they stop partaking, so I think groups only allows those extroverts to learn and the introverts are left behind because they cannot…,those type of personality, they don't like winning or arguiments so they end up shouting and they start doing other business. **L79** **Interviewer:** So how do you accommodate the differences in the learning styles of the students? **L80** **Teacher B:** think I've got natural short…ehh…what can I say…a short fall something like that because, yes…to tell the truth nje, I havnt identified a fair teaching method or strategy to accommodate all of them. This is still evident worksheets and to tests, and of course to the exams they still get others. **L81** **Interviewer:** Ok, but …ok. Why …why you want to have just one teaching method because you realised that they are of different learning styles?	Teaching strategies Challenges to using CBS	The large numbers lead to shortage of equipment which lead to large numbers in a group Limitation of the teaching strategies that she uses and the learners' attitude to learn

L82 **Teacher B:** As I said, I think I am not that creative unless I take it and go and research. **L83** **Interviewer:** So what are the, how do you try to meet the challenges which the students face like you mentioned that you have realised that the students have a challenge with bonding and yet it is prerequisite and even the other challenges, like which others? **L84** **Teacher B:** Physics? **L85** **Interviewer:** Yes being most incoperative physics. So how do you try to accommodate or to meet to overcome that challenge? **L86** **Teacher B:** I usually,for the physics part I usually wait for the colleague in physics to first cover electricity. **L87** **Interviewer:** Ok. **L88** **Teacher B** For my part, which is the bonding I usually try to, not even try to, I usually refer like I start reminding them the key concepts.	Teacher' attitude Teacher' curricular knowledge Teacher' curricular knowledge	She knows her weakness and knows how she can work on her limitation She is aware of curricular saliency and the importance of linking new concept with previous knoweldge
L89 **Interviewer:** So what are the common misconceptions which students make? Common mistakes which they make, which prevent them from understanding electrolysis? **L90** **Teacher B:** Mhm…polarity is still an issue and identifying the ions. And they cannot imagine that ions move, you know theoretically but they don't understand. They don't show understanding that ions they do move	Learners' difficulties in electrolysis	It appears like learners have a challenge with naming the electrodes and the migration of ions during electrolysis

L91 **Interviewer:** So what do you…why do think it is important for the learners to understand the topic of electrolysis? **L92** **Teacher B:** This is a very important topic, <u>we have cars around, it is an application of the bumpers being electrolised, there's coating of metal using another metal. They are interested in cars and also they to get employment and also when we talk about ways to prevent rust, electroplating which is also made an application and also a lot of substances they can be manufactured using this especially concentrated s, it's another way of making it.</u>	Teacher's curricular knowledge	Reagards the application of electrolysis as the reason why learners have to understand the topic, which shows that focus is on the end-product not the process
L93 **Interviewer:** Ok then have you heard of computer simulation? **L94** **Teacher B:** Yes I have heard about them from afar. **L95** **Interviewer:** What do you know about them? **L96** **Teacher B:** <u>Ahmm, I know that and I think I'm interested that it can bring manipulation because there certain style of learners that need to manipulate and also those are visuals, they can visualise better. Like as I have said in a practical those who have seen can recall up to a certain percentage than if you just use formal lecture.</u> **L97** **Interviewer:** How do you think they can improve because they do practicals? Then how do you think the computer simulations can add? **L98** **Teacher B:** I think that can be a perfect idea because from my personel experience, learning is something has…<u>pupils are shifting…technologically, they are now interested in gadgets. So if you can use them i think you can just get their hearts. I think you can just get their hearts.</u>	Advantages of CBS Advantages of CBS	She mentions that it allows learners to manipulate, can help learners to visualise, can cover the limitation of the traditional teaching methods Can improve learners' interest, also relevant to the learners because they are technology inclined

L99 **Interviewer:** So why don't you use them in your teaching strategy? **L100** **Teacher B:** We haven't thought about it or even discussed them as a department, we just, I don't even know what my colleagues are thinking about it, I don't even have an idea. **L101** **Interviewer:** Would you like to use them or try them out? **L102** **Teacher B:** Of course yes. **L103** **Interviewer:** Ok. **L104** **Teacher B:** And I'm even excited already because I can imagine my students saying wow. Yes I think it can help a great deal.	Teacher' attitude	Willingness to use CBS and is even excited about it
L105 **Interviewer:** So as of now how do you assess learner's understanding of the topic electrolysis. **L106** **Teacher B:** Lack…I lack evaluating the practical. Yes it's the practical skill that I should have marks for, but I don't have the clue and tool for getting the practical or evaluating their practical efforts. I only specialise on theory. **L107** **Interviewer:** Ok, what are your reasons for not assessing them practically? **L108** **Teacher B:** I don't have know, I just entered the school, I haven't seen one doing it, even seen the HOD yourself, even the HOD herself. **L109** **Interviewer:** You know thank you very much for giving us the opportunity for conducting this interview. And I hope and believe we are still going to work together well and learn from each other with the study. **L110** **Teacher B** So you are saying you are going to help me with the simulations? **L111** **Interviewer:** Yes. **L112** **Teacher B:** Wow I'm looking forward to it. It should be exciting **L113** **Interviewer:** It is exciting and I'm sure the students will love it. So thank you very much.	Teaching strategies Teacher' attitude	Learners are not assessed in the practicals Looking forward to the use of CBS

APPENDIX L

TEACHER B INTERVIEW AFTER USE OF CBS

I would like to thank you once again for accepting to take part in this second interview. Please feel free to say anything. Remember the views expressed here are only going to be used for this study and there are no wrong answers. Also, you do not have to say who you are because only the ideas and not your name are important.

DATE: VENUE: SCHOOL B HIGH SCIENCE PREP ROOM DURATION: 20mins

	Themes	**Comments**
L1 **Interviewer:** Good morning. **L2** **Teacher B:** Morning Mam. **L3** **Interviewer:** Thank you very much once again for…ehh making time for this interview. Eh this is going to be the last interview. It's going to be eh… on how you found the use of computer simulations…effective or both effective during the lesson. So the first question is what teaching strategies did you use during the last sessions in teaching electrolysis? **L4** **Teacher B:** Ok. I used computer simulation…also discussion and a lot of questioning. **L5** **Interviewer:** So you used three teaching methods. So give reasons for using each one of them.	Teaching strategies	CBS, discussion and questioning
L6 **Teacher B:** simulations they were for…for the learners… Ok, let me start by discussion. After they have… started listening and viewing I went group by group to evaluate their understanding and the questioning was also for including the class. And also the evaluation of the whole class and also to provoke their thinking. The simulations were	Advavantage of CBS	Group facilitation, whole class discussion, questioning Identifies that CBS benefits

for visualising. There are the best method that fit those learners that have visualising as their learning style.		learners because they are able to visusalsie, especially those who are visual
L7 **Interviewer:** So what… was it your first time to use computer simulation in your class? **L8** **Teacher B:** Yes it was my first time. **L9** **Interviewer:** So how did the use of computer simulation change your teaching of electrolysis? **L10** **Teacher B:** It's…there was visualising of this abstract concepts that I have failed over the years to explain, and the learners they usually fail to understand since it's abstract. This time around they had the understanding improved since they visualised and concretised the information. **L11** **Interviewer:** So before you use computer simulation which teaching method did you use to teach this topic?	Advantages of CBS	Learners were able to visualise, thus enhanced learner' understanding of electrolysis which she considers to be abstract and was unable to teach appropriately
L12 **Teacher B:** I usually use eh… practical methods, the experiments and discussion. **L13** **Interviewer:** So do you think the, computer simulation can eh… substitute the practical or it can be used together that is as an additional teaching method. I mean use the methods that you have been using and then in addition use the computer simulation and then, or now you want to do away with the practical? **L14** **Teacher B:** I think I will do away with the practicals. The practical it has some shortcomings…some gaps, just a solution with…there's no change they see, there is no movements of the electrons yet this is electrolysis, we wanna see electrons. When we talk about oxidation, reduction this usually gives me a problem and they usually fail at the end because they cannot visualise.	Teaching strategies	Before using CBS, she used practical, discussion She considers to omit practicals in future. She does not appreciate the macroscopic, values only the microscopic at this stage
L15 **Interviewer:** So if you…when you say they usually fail…have you given them a test after using computer simulation?		

L16 **Teacher B:** Yes I have given them a test. **L17** **Interviewer:** And how has the performance compared to the previous years or previous group? **L18** **Teacher B:** it has improved, when I did a calculation it was around 57% increase. I have, we usually both failed. I failed to explain and they failed to understand. Usually there is no formation of new concepts, there is no concretisation. They always remained abstract. They usually assisted me…there is one question where we expect them to cram, but this time I did not ask them to cram but they were able to write the equation from the cathode and anode especially the one for water the OH.	Teacher' curricular knowledge	She believes CBS enhance understanding, helped her in teaching with understanding, simplified electrolysis to an understandable concept
L19 **Interviewer:** So now how have the use of computer simulations improved your understanding of electrolysis? **L20** **TeacherB:** Eh. especially the second…second lesson I discovered that I, in fact I had issues as well which I after the, using the simulation we, the learners they understood better and they started correcting me and I felt it was a little bit, it was some havoc because the learners they kept on assisting me and I was not aware that I did not know the concepts but after the learners asked a lot of questions it was then that I gave my time, my self-time to revisit the simulation and yes I was always wrong. **L21** **Interviewer:** So the computer simulations have actually, they also helped you? **L22** **Teacher B:** Yes, actually I took the side when I read a book and understand it. I discovered in the use of simulations that I myself there was a lot of improvement from the simulation.	Teacher's attitude Teacher' attitude	Teacher admits that she previously misunderstood some content. She accepted learners' ideas and improved on knowledge, She took initiation to investigate on her own.
L23 **Interviewer:** Ok. The next question is how did you find the computer simulation that you used in your lesson. The ones that you used how you find them, in your assessment? Were they good, were they not good? How did you find them?		

L24 **Teacher B:** They were all good, just that the one for the second lesson with…our syllabus did not take that approach. They chose another approach, from the approach. But after I have eh…the learners have read from themselves. I discovered in the test that actually, the root we are taking is the most difficult route. The ones in the simulations there were different from our syllabus but they showed well the concept. Yes. **L25** **Interviewer:** Ok. So what did you find exciting about the lesson, whereby this time around you were using computer simulation.		
L26 **Teacher B:** This generation is an electronic generation and they showed interest. I think when we still used this old method, the chalk and board I lose a lot of students. But now they were captivated throughout and I guess they saw that once you are busy with others you literally see how you have missed instantly but when I am talking and they usually start getting busy with their personal stuff.	Advantage of CBS	New generation computer literate, able to learn because they are able to use computer and interest simulated**.**
L27 **Interviewer:** So eh…what are the disadvantages if any of using computer simulations? **L28** **Teacher B:** Eh. One I can say maybe one or two. One may be our school does not have the facility since it is not an urban school, so there may be scarcity of the simulations and the gadgets also for using the simulations. Scarcity of the gadgets. And then eh….two….what else did I want to say. We are talking about problems or disadvantages? **L29** **Interviewer:** Disadvantages. **L30** **Teacher B:** Ow. Disadvantages, I think yah I can come up with one. It is the scarcity of this. Ow yah another one was that some learners are not able, are not exposed in using this. So, but ke it's not a problem because there are group members they are assisted.	Challanges to using CBS Challenges to using CBS Learners' difficulties in electrolysis	Shortage of equipment Some students not exposed to technology, but they assist each other
L31 **Interviewer:** Ok. So how did you assist the learners during when using the computer simulation?		

L32 **Teacher B:** Actually I am surprised. During a normal day I usually have to assist them, but this time around not expected, they assisted each other. It was quite amazing and interesting. Yes those who were able to follow were able to manipulate and in fact to change this, eh what can I say, to reverse a bit because I am unable to rewind myself but the learners each time I asked a question would just go back a bit, and find things on their own.	Teaching strategies	Facilited group learners take responsibility for their own learning goes back to clarify, spontaneous learning
L33 **Interviewer:** So what are the common mistakes that learners make in the teaching of electrolysis? **L34** **Teacher B:** They usually have issues with ions, yes. Identifying ions which today I tried to discuss with them. Yes, so that they first know the ions that are expected to be seen.	Learners' difficulties in electrolysis	Focuses on naming of ions
L35 **Interviewer:** So for the topic of electrolysis what are the prerequisite concepts that are required for them to understand the topic? **L36** **Teacher B:** Ok. it is usually chemical bonding, where before you know you must know the ions that are involved or I guess the ions eh…naming of ions still mainly, it's usually an issue but not after the simulations.	Learners' difficulties in electrolysis And teacher's pre-requisite knowledge	She focuses on naming of ions. Does not mention oxidatuion/ reduction microscopic process
L37 **Interviewer:** So are there any challenges? Maybe we have discussed this one I think, in teaching chemistry using computer simulation. I think we had…I think we had. **L38** **Teacher B:** No we talked about disadvantages. **L39** **Interviewer:** Yes what are the challenges? **L40** **Teacher B:** If you use the simulation I think you must have a small class. I actually had 54, eh, 50 to 54. And this can be the numbers were a challenge to me, it wasn't easy to attend to the groups. **L41** **Interviewer:** Eh, ok. **L42** **Teacher B:** Yes. **L43** **Interviewer:** So now that you are using computer simulation	Challenges to using CBS	Large number of learners

how do you plan your lesson plan to accommodate the use? **L44 Teacher B:** It would be better for me if I use this in a computer so that I can refer to it that I can refer to that. And what can be…what can I say, the person looking at me can be able to look up well. **L45 Interviewer:** Ok. Do you have a projector in your school, in your department? **L46 Teacher B:** Yes we do. **L47 Interviewer:** So did you use it? **L48 Teacher B:** No I didn't think eh. The problem was with myself. I didn't think of it that way. I wanted them to first visualise and then manipulate eh…they manipulated the things without one. So there was less assistance as I said earlier, I was actually monitoring. **L49 Interviewer:** So would you suggest that computer simulation be introduced in schools for teaching.	Teaching strategies	She referred to manipulate in the first interview and also practiced it in class. She realises the value of learners' manipulating
L50 Teacher B: Uh definitely yes. Looking at the interest and the classroom management is no longer a hassle because you know that you will get disturbed if you look at your friend and you will miss out. **L51 Interviewer:** So do you think the use of computer simulation enhances the students understanding of the concept? **L52 Teacher B:** I think yes. And I was just thinking that these days it's a relavent. Yes this…is the other method that we are using that they are irrelevant to, the current generation. Yes. **L53 Interviewer:** Ok. Thank you very much, we have come to the end of our interview and thank you very much for cooperating with me. **L54 Teacher B:** It's my pleasure.	Advantages of CBS	It is relevant Promotes interests

APPENDIX M

TEACHER B LESSON 1

Learners watched a video showing electrolysis of molten ionic compounds and ionic compounds in solution. Molten copper sulphate was used as an example. The learners were then asked to use a CBS using copper sulphate solution to state what would be produced at the electrodes.

L1Teacher: Morning class. **L2Students:** Morning mam. **L3Teacher:** Today im going to introduce a new topic to you which is electrolysis. So you are going to learn by listening to that computer simulation that is in your gadgets. At the end im going to ask you some questions. You normally listen without any visualising, today its going to be an advantage because you are going to listen and see, okay. Let us all start…[learnerss begin in their groups, each group has a laptop and there are about ten learners in a group]. [After using CBS] **L4Teacher:** So together we are going to get an idea of how much we got from this computer simulation. Yes we are first going to define electrolysis. First question, what is electrolysis? Raise up your hands.	Teaching strategies	The students are watching the video on introduction of electrolysis using molten copper sulphate. She now asks learners after watching the video
L5Student: I think electrolysis is an electric current that break up an ionic compound to form an element **L6Teacher:** Guys do you agree? **L7Class response:** No. **L8Teacher:** which word do you want eliminated? **L9Student:** I think he should have said electric current is used to….. **L10Teacher:** Please guys help her. **L11Student:** Where electric current is used to decompose ionic compounds **L12Teacher:** Thank you guys for the attempts. So this team they have joined their efforts to come with an explanation. They are saying that electric current is used to decompose ionic compounds. Okay did you pick	Teaching strategies	She uses assessment for learning to elicit learners understanding of electrolysis

another word which has the same meaning as the ionic compound? They sometimes refer to it as ….mmmm? who captured the word? The two electrodes that were used, what are they called? **L13Student:** Anode and cathode. **L14Teacher:** What is the nature of the electrodes? ..the material used to make the electrodes? **L15Student:** Graphite, yes it is inert.		
L16Teacher: It has to be made from a substance that is inert, meaning nonreactive. Others can be metal and others non-metal. In the example which metal was used? **L17Student:** Platinum **L18Teacher:** Okay between the cathode and the anode, which one is the positive electrode and which one is the negative electrode? Raise up your hands. **L19Student:** An anode is the positive electrode. **L20Teache**r: Which ions do you expect to see, anions or cations? **L21Student:** The anions because it is positive. **L22Teacher:** Then which ions do you expect to see here (pointing to an electrode)? **L23Student:** Cations.	Teaching strategies	She improves learners' responses by making some additions to what learners say
L24Teacher: <u>Now let us look at the first example, which substance was decomposed or was there any substance that was decomposed?</u> **L25Student**: Copper sulphate. **L26Teacher:** Is it just copper sulphate? **L27Student:** Copper (II) sulphate **L28Teacher:** Now give me the ions that are present here…the two ions. **L29Student:** <u>Copper and sulphate.</u> [She then asks learners to work in their groups using the given CBS on electrolysis of copper sulphate solution to find what will be produced at the electrodes, she moves around checking the groups] .	Teaching strategies	She does not correct learners, it is confusion whether its copper metal or copper ion and if its sulphate ion

L30Teacher: Thank you very much. Then we put copper sulphate in solution, which ions are present in the water? two ions? **L31Student**: Hydrogen and oxygen. **L32Teacher**: Anything different? **L33Student:** Hydroxide and hydrogen. **L34Teacher**: Which one is negative and which one is positive? **L35Student:** Hydrogen is positive and hydroxide is negative. **L36Teacher:** Now we have our electrodes here, (draws on the board). The taller one is the positive, so now I want us to polarise them, which one is going to be positive? (writes on the board). So I write positive and negative here, okay. My diagram is not proper, let me join it here. guys the order is important. So which one is going to be our anode our cathode? Let us say this is 1 and 2, which one will be the anode and which one will be the cathode? Raise your hand.	Teaching strategies Teacher's curricular knowledge	Doesn't state how the ions come from, and its confusion whether she is referring to hygroden gas or hygrogen ion. Also states that that the order is important but does not say what is the order she is referring to
L37Student: Two. **L38Teacher:** Is that true? **L39Class response**: Yes. **L40Teacher:** Yes, two will be the anode. And which one will be the cathode? **L41Student:** One. **L42Teacher:** Yes, one will be the cathode,ok. since copper sulphate is in solution, there are ions there of the 2 ions of water and also ions of 2 copper(II) sulphate. Now we have two positive ions as it is shown here and two negative ions, so between these two, copper ions and hydrogen ion which one is going to be found in the cathode. Raise up your hand **L43Student:** The copper. **L44Teacher**: Are you sure? **L45Student**: Yes. **L46Teacher**: We have two positives, so now copper will be found in the cathode? How did you choose, how do you know that its copper (II) instead of hydrogen? How do you predict, we usually go to the what…raise up	Teaching strategies	Question and answer/ discussion

your voice, I can see you have something to say.		
L46Student: The reactivity series. **L47Teacher**: Yes, yes, the reactivity series. Which one is more reactive between copper and hydrogen? **L48Students:** Copper. **L49Teacher**: Who can recall the reactivity series, I will write it on the board, raise it up on the board, now our focus is here, which one is more reactive. **L50Student:** Hydrogen **L51Teacher:** hydrogen is more reactive than copper? Copper. We take the one below, that is, the less reactive metal. We get that since copper was less reactive than hydrogen, copper was preferred. When we were looking at the reactions of metals, it was the opposite. We used to take the one above, the more reactive one, but now the opposite occurs, we take the less reactive metal. Now let us look at the anode, which one is preferred, the hydroxide or the sulphate, raise up your hands. We have two negative ions guys, are you following? Yes im saying not all of them is going to be found here (pointing to the diagram on the board). Which ion is going to be found here? Yes? **L52Student:** Hydroxide. **L53Teacher:** Yes. Which is more reactive between sulphate and hydroxide? **L54Student:** Sulphate. **L55Teacher:** Yes sulphate was above, and which one is preferred? **L56Student:** Hydroxide. **L57Teacher:** Yes we take the one below. Which gas is going to come out?	Teacher' curricular knowledge	The reactivity series She doesn't explain why the opposite applies in electrolysis,i.e. by explaining that the ion of the more reactive element stays in the solution
L58Student: Oxygen. **L59Teacher:** Now we have to write the equation, so its going to be OH, how many of these, can I have someone who will read it correctly **L60Student:** (Reads the equation). **L61Teacher:** So our lesson for today ends here, we are going to continue		

next time.		

APPENDIX N

TEACHER B LESSON 2

The CBS that was used was on electrolysis of acidified water

L1Teacher: Morning guys. Before we continue with our topic of electrolysis, I want us to recapture what we did from the last lesson. The last period, what were we talking about. Raise up your hands, anything guys? **L2Student:** Electrolysis of copper. **L3Teacher:** Was it electrolysis of copper? I guess it was a solution, please guys raise your hands. **L4Student**: Its copper solution. **L5Teacher:** It cant be copper only. There have to be a negative ion. **L6Student:** It was copper (II) sulphate.	Teacher' curricula knowledge Teaching strategies	Recapping of the previous lesson Question and answer
L7Teacher: Yes, then we made a solution. What was the total number of ions we had, give me the four ions that came up from that solution. Let us first split it, from the copper sulphate solution, how many ions were there? **L8Student:** Two. **L9Teacher:** Name them? **L10Student:** Copper and sulphate. **L11Teacher:** Who can give me the formula, raise your hands guys, yes? **L12Student:** CU2plus [teacher writes on the board, Cu^{2+}].	Teaching strategies Teaching strategies	Question and answer
L13Teacher: Yes thank you very much, and for the sulphate formula. **L14Student:** $SO4^{2-}$ negative two [teacher writes on the board, SO_4^{2-}]. **L15Teacher:** Yes thank you very much, then the two ions from water.	Teaching strategies	Writes on the board important points
L16Student: Hydrogen. **L17Teacher**: Yes, what is the formula.		

L18Student: H plus (teacher writes H^+). **L19Teacher:** Good and the other one. **L20Student**: Hydroxide, formula is OH. **L21Teacher:** Now we have two positive and negative ions. Which one is found in the cathode? Student: Copper. **L22Teacher**: Yes, then the anode which one will be found between sulphate and hydroxide, which one moved to the anode? **L23Student:** Hydroxide. **L24Teacher:** Yes. Which gas was evolved in the anode?		
L25Student: Oxygen. **[she was recapping from the pevoius from the previous lesson up to here. New lesson begins here].** **L26Teacher:** yes. <u>So today guys we are going to talk about electrolysis of acidified water</u>. I will repeat, we are going to talk about electrolysis of acidified water. how many substances are there?	Teaching strategies	Emphasis main topic for the day
L27Student: 2 **L28Teacher:** We talk of water and an acid. okay, how many ions do you expect to have? **L29Student:** I think its three. **L30Teacher:** Oh okay, can you name the three? **L31Student:** The two will be from water and the other from acid. **L32Teacher:** Another one, how many do you expect to have? **L33Student:** Four.	Teaching strategies	
L34Teacher: So now the answer is between three and four. We are going to observe from the computer simulation. I want to give you some key things you should come up with. We will see if its three or four. <u>Now I want you to see the apparatus we shall use in your computers. I also want you to observe the ratios at which the gases will</u>	Teaching strategies	She leaves it hanging, doesn't state whether there will be 3 or 4 ions, but tells leaners to note the ratio of the gases that will be evolved

be liberated, im not sure if the gases will be liberated at the same pace. So I think one will be faster and have a higher volume. At the end you are expected to have ratios of the gases that are evolved. Are we ready, let us begin. [learners work in their groups while teacher facilitates, exercise takes about ten minutes.]		
[After using CBS, teacher uses discussion method to engage learners] **L35Teacher:** From the computer simulation, what is name of the acid, guys talk to me and I want all the groups to participate. So we have got water and what is the name of the acid? you don't see the acid, so we ignore the name of the acid. we ignore the acid because we acidify so that we give the ions a boosts. The name of the acid doesn't matter. So that the ions can start moving. What are the ions present in water? **L36Student:** hydrogen and hydroxide.	Teaching strategies	Doesn't guide learners on proper naming of ions. One may confuse hydrogen gas with the ion
L37Teacher: What is the name of the apparatus that is used? …both of these now are gases, so we can just see bubbles in the beaker and can't differentiate. The apparatus is called [not clear]. I guess in physics you discuss about it and iam sure it's the gas one. So I am going to ask you some questions. What are the names of the gases that are liberated at the anode? **L38Student**: Oxygen. **L39Teacher:** Is that true class? **L40Students:** Yes. **L41Teacher:** And the name of, no let us write the equation, the anode reaction? What is happening at the anode? What did you see? Let us consider the observation, what did you see? **L42Student:** Water receive electrons electrons. **L43Teacher:** Are you talking about receiving or gaining of electrons **L44Student:** Gaining. **L45Teacher:** In the anode there is gaining, yes. So there is gaining of electrons. Is this oxidation or reduction?	Teaching strategies	She refers learners to the CBS that the learners were using

L46Student: Reduction.		
L47Teacher: Yes. Okay there is this thing that is used in the computer simulation, there is an oil rig. It's is used to help you to understand. So when there is gaining of electrons, we call it reduction. The anode undergoes the reduction reaction. What about the cathode reaction? Let us maintain order, student A said he saw the gaining of electrons. Where were they coming from? **L48Student:** They are part of the cathode. **L49Teacher:** Do you mean to tell me that cathode is loosing? **L50Student:** Yes. **L51Teacher:** Yes there is loss of electrons, and what do we call a reaction where there is loss of reaction? **L52Student:** Oxidation. **L53Teacher:** Yes, its oxidation. Now I want us to come up with a reaction, the complete reaction. The last lesson we heard how this reaction is split, it split like this. What is the reaction in the cathode, which ions are involved there? **L54Student:** Two hydrogen ions plus two electrons.	Teaching strategies	Its confusing to say the anode undergoes a reaction, language used is ambigous Learner gives incorrect response, and teacher accepts it and is now asking about the cathode
Teacher: Cathode please? [writes on the board the incorrect response, then somestudents in class grumble, she now realises the response could be wrong]We are done with the anode, members please help her, are you sure? That means the other group gave me something wrong for this side.Yes we all made a mistake, okay let us see. In the anode, we are going to get which gas, we'll get hydrogen, cathode we'll get hydrogen? Okay let us take it step by step. Let us look at the, what do		She then goes through through it again, ie reaction at the cathode

we call this? The power supply and let us look at the terminals? The red one, is it positive or negative,mmmm? **L55Student:** Red is positive and black is negative. **L56Teacher:** So now which is our cathode? Which electrode is connected to the positive terminal of the battery? **L57Student:** It's the anode. **L58Teacher:** Anode. So which gas are we going to get in the anode? **L59Student:** Oxygen. **L60Teacher**: And in the cathode? **L61Student**: Hydrogen. **L62Teacher:** Now let us write our equations for our reactions. The one that is going to yield two oxygen its this one. 2 H plus electrons. You are lost. Okay let us check, oh okay they have used a reverse reaction, thank you for making me aware. Let us use this one, thank you for clarifying. I was a bit confused as well. One last question, state the volume proportion of these gases, what is the ration of hydrogen to oxygen? Can you observe it? it is in the galvanometer? **L63Student:** Two is to one.	Teacher' curricular knowledge	Teacher was confused, doesn't give learners the correct equations but leaves it hanging, but changes focus and asks about the proportions of the volume
Teacher: Thank you very much. Then which one is two and which is one? **Student**: One is in the anode, the hydrogen in the cathode there is double the volume and there is oxygen. **Teacher**: Good and that is their ratio. Okay for the homework, you are going to describe a test for hydrogen and a test for oxygen. One last question, explain why the ph of water surrounding the anode decreases and the ph in the cathode increases? Okay, we'll end here, not unless someone has a question. Okay we have come to the end of the lesson.		Acknowledges that it's the correct proportion but does not explain why. She also does not link the homework to the lesson

APPENDIX O

TEACHER B LESSON 3
CBS was on electrolysis of brine

L1 **Teacher:** Morning. **L2** **Students:** Morning. **L3** **Teacher:** How are you today? **L4** **Students:** Fine.		
L5 **Teacher:** Ok, ah. Today our main objective we're going to look at molten electrolysis. Electrolysis of molten…electrolysis of molten compounds. Ok. before this, before that I'm going to ask questions about… Yes I know some have submitted but then we… I marked but I also want you guys to…let us discuss it. For the sake of those who did not get it well. What is the test for hydrogen?	Teaching strategies	Does not specify which molten compounds in the introduction
L6 **Student:** Insert a lighted split. **L7** **Teacher:** Please raise your voice. **L8** **Student:** Insert a lighted split. **L9** **Teacher:** You insert a… glowing or lighted? **L10** **Student:** Lighted. **L11** **Teacher:** Continue Mr. **L12** **Student:** Insert a lighted split into the test tube containing hydrogen and it will make a pop sound with hydrogen.	Teaching strategies	Starts lesson by recapping from previous lesson but does not state that these were the gases there evolved in yesterday's lesson
L13 **Teacher:** Yes thank you very much. We use a lighted split and it burns with a pop sound. Then Sibeko what is the test for oxygen? Describe the test for hydrogen. Yes we insert a glowing split in. **L14** **Student:** In a test tube… oxygen then the… it will relight. **L15** **Teacher:** Ok, what are you going to see? **L16** **Student:** Relight.		

L17 **Teacher:** Oh it relights? **L18** **Students:** Yes. **L19** **Teacher:** So oxygen relights a glowing split. Then the last question was, explain… explain why the pH of water surrounding the anode decreases. What was happening in the anode? Was hydrogen moving in or getting away from it? hydrogen was? According to the CBS, was hydrogen coming to the… yesterday's CBS? **L20** **Student:** Yes… it was moving to the anode. **L21** **Teacher:** It was moving to the…? What was coming to the anode, what was coming to the anode?		
L22 **Student:** ….ions. **L23** **Teacher:** Ok let us make… make our discussion simple hydrogen was found in the cathode. It means that in the cathode there was more hydrogen. Do you expect the pH to increase or decrease in the cathode? I'm saying in the cathode there was hydrogen. Do you expect eh…this one to have a high pH or a low pH? **L24** **Students:** Low. **L25** **Teacher:** Low pH. So the pH was low in the…? **L26** **Student:** Cathode.		
L27 **Teacher:** Yes, it was low in the cathode and it was the pH, here because hydrogen was not, was moving away. Now I can… down. Ok. pupils are making noise. So at a, at an increase in the cathode. They say explain why there was an increase in the cathode, the pH. It means… before that, there was lot of hydrogen in the cathode, so low pH because it was acidic, but then this as they were changed into a gas, it means they were moving away to the atmosphere. So now the pH increases. It became alkaline, it became more alkaline. And then in the anode we saw that there was $2HO + O^2$ now the pH decrease because there were a lot of hydrogens that were coming towards it. Ok. The formation of the water. **[she the focuses on today's lesson]**	Teacher's curricular knowledge	The new lesson begins here. She considers brine as sodium hydroxide instead of concentrated sodium chloride

Now let us look at what we are going to do today. What's the difference between a solution and a molten compound? If you've got a… We are goimg to talk about brine which <u>is sodium hydroxide, ok</u>. When you have got sodium hydroxide in solution what does… what has occurred to the sodium hydroxide pellets, if it is in solution? If we have this. Let me just say what is the difference between these two? What's the difference? Let us call this one, let us call this two. In two, what has occurred? In two what has happened? You have no idea. This one was dissolved in water. <u>People at the back, this one was dissolved in water…eh and this one it was heated directly. At home when there's no tea, if people they lack tea bags they just heat the…the sugar then they are to get molten, so if you heat directly without adding water. So there can be two options of working a beverage…</u> If you add water to the sugar you call it umtanya angitsi? And then, or else you heat the sugar now when it is a bread solid we call it molten. So now the first day when we were looking at the electrolysis we looked at copper sulphate in a solution, we added water. But today water is not added so this is heated directly…heated directly. So in your… Oh, please get ready to switch on the video that is in your gadgets I want us to see. So I'm just giving you a clue so that you can note. Ok are you ready? **[students work in their groups using CBSon electrolysis of brine].**	Teaching strategies	solution Teacher tries to explain the difference between solution and molten using sugar Relates learners to a situation they are familiar with Teacher moves around checking learners in their groups. Activity takes about ten minutes
L28 **Students:** Yes. **L29** **Teacher:** 1, 2, 3 go. …Minie? **L30** **Teacher:** For brine, what is brine? Electrolysis of a molten compound which is brine. Ok we said that when we only try to burn the sugar you then see some water angitsi? Yes, ok brine is… what is the name of the ionic compound that is called brine? Sodium chloride. Please guys switch off so that you can pay attention<u>. I wanna see what…how much you have captured ok. So do you all agree this is the brine then now we make our connection. I know you have got a better one from your books, you've got a better one from your books ok. Then which one is the</u>	Teacher' curricular knowledge	Defines brine incorrectly, she says its sodium chloride instead of concentrated sodium chloride in solution

anode and which one is the cathode. We have done it earlier as we said. Ok so how many ions do you have now? From the sodium chloride, the ions are…? **L31** **Student:** Sodium and chloride. **L32** **Teacher:** Ok, from the water? **L33** **Student:** H2O **L34** **Teacher:** Please guys only talk to me. Guys at the back only talk to me. So according to the video which ions were in the cathode? Ions in the cathode? …It's H. What's the formula $2H^+$? **L35** **Student:** Hydrogen . **L36** **Teacher:** It's hydrogen gas and then in the anode? In the anode, hawu… In the anode it's, it's $2Cl^-$ plus 2 electrons then you get **L37** **Students:** Chlorine. **L38** **Teacher:** Chlorine, yes. What remains in the container then? **L39** **Students:** Sodium.		Student gives ions as sodium instead of sodium ion. This maybe confusing to learners. She doesn't guide learners that H^+ gets reduced to hydrogen gas, but asks about the products at the anode. Even in the response that learners give her, she accepts it instead of guiding learners that chloride ion is oxidixed to chlorine gas
L40 Teacher: What remains in the container? **L41** **Student:** Sodium. **L42** **Teacher:** Sodium, we only… Please make a follow up. We only used two. Which are the two ions that we were using. We used…which other one did we also use? How many are remaining… how many are remaining? **L43** **Student:** There are two. **L45** **Teacher:** Which ones are remaining? Sodium hydroxide. So it means that the third product that we have now, the sodium hydroxide we have is going to remain here. And all of them are equally important, and all of them are equally important…and all of them are equally important. Ok yes. Now I'm going to ask you some questions. We are saying all of them are equally important or these have got major uses. Uses of hydrogen? Sibeko? **L46** **Student:** Fuel. **L47** **Teacher:** As a fuel for what? Hydrogen fuel rockets, fuel for	Teacher'curricular knowledge	Misconception of where the hydroxide and hydrogen ions come from if its molten sodium chloride. Also doesn't explain that Na^+ and OH^- remain in solution and then become NaOH

rockets what else? Fuel for rockets or hydrogenation of…freezing of margarine. Manufacturing margarine. Ya while they wait for it to solidify. If I say hydrogenation, yes margarine. **L48** **Student:** Margarine. **L49** **Teacher:** And then uses of chlorine **L50** **Student:** Bleach **L51** **Teacher:** Bleach for bleaching and…? **L52** **Student:** Sterilising. **L53** **Teacher:** Sterilisation, gives microorganisms on the water sterify… Let me just say sterilisation. Kill microbes, harmful microbes in water for drinking or swimming. And then the uses of sodium hydroxide. Please eh. Please revisit the video for the last part of it. Capture just anode all of them. **L54** **Student:** Sodium. **L55** **Teacher:** Sodium hydroxide… making for? **L56** **Student:** Soap. **L57** **Teacher:** Please what are you saying? **L58** **Student:** Forming bleach. **L59** **Teacher:** Not the chlorine… eh both of them? **L60** **Students:** Yes **L61** **Teacher:** Oh!! Making bleach, making bleach…. Then Mandisa? **L62** **Student:** Used in making soap and paper manufacturing **L63** **Teacher:** Soap and …? **L64** **Student:** Paper manufacturing. **L65** **Teacher:** And paper manufacturing. So it means now we can predict the pH of the soap, If they say they use sodium hydroxide. Who can predict the pH. Alkaline or acidic? **L66** **Student:** Alkaline. **L67** **Teacher:** Any other use for sodium hydroxide? **L68** **Students:** None. **L69** **Teacher:** Ok this is the end of the lesson. You have seen different types of electrolysis. Copper2, sulphate ions eh… electrolysis of water,	Teacher's curricular knowledge	Doesn't emphasis electrolysis of brine to the industrial manufacture of the products. Also doesn't state whether the sodium is molten or in solution. Thus learners not given true definition of brine

electrolysis of concentrated sodium chloride. Ok any questions, any questions? Ok you are expected to… there's another video in your gadgets for the summary, for the summary. So you are going to read it at your spare time and if you come across you can come to me or the class to discuss it. Ok thank you very much guys.		from the lesson introduction

APPENDIX P

TEACHER C FIRST INTERVIEW (BEFORE USING CBS)

DATE: **VENUE: SCHOOL C SCIENCE PREP ROOM** **DURATION: 20mins**

L1 **Interviewer:** Eehh_ good day Mrs… **L2** **Teacher C**: Yes good day Mam, how are you? **L3** **Interviewer**: Am fine thanks how are? **L4** **Teacher C**: Wonderful Mam. **L5** **Interviewer**: Thank you very much for taking part in the study. As I have mentioned earlier on, the study is on the use of computer simulations as a teaching strategy. So the interview is part of the instruments which I'm going to use to collect the data. **L6** **Teacher C**: Ok Mam. **L7** **Interviewer**: Yes, so the first question, are you ready for the first question? **L8** **Teacher C**: Yes I am. **L9** **Interviewer**: So what teaching methods do you use in teaching electrolysis? Maybe before I begin that one, for how long have you been teaching electrolysis? **L10** **Teacher C**: Well Eeh.. experience? **L11** **Interviewer**: Yes? **L12** **Teacher C**: More than ten years now. **L13** **Interviewer**: OK. **L14** **Teacher C**: Yes..more than 10 yes. I think maybe 12 or 13 years I've been teaching this topic of electrolysis.		
L15 **Interviewer**: Ok alright. So, what teaching strategies have you been using in teaching electrolysis? **L16** **Teacher C**: Ok, mainly <u>I use the question and answer method</u> **L17** **Interviewer**: Mhhm?	Teaching strategies	Question and answer method

L18 **Teacher C**: That's the first and foremost. **L19** **Interviewer**: Mhhm.		
L20 **Teacher C**: Ehh.. because first you have to explain to them what it is all about theoretically. **L21** **Interviewer**: Mhhm? **L22** **Teacher C**: Then you answer to them, ..showing…. the concepts. **L23** **Interviewer**: Mhhm. **L24** **Teacher C**: Emm..So I basically use the question and answer method,… using the textbooks, using the diagrams that I can find on the textbooks to explain the concepts theoretically.	Teaching strategies teaching strategies	Gives information first to learners and then allow learners to ask questions and explain/ clarify their questions Uses textbooks and diagrams in textbook
L25 **Interviewer**: Ehm, so mainly you use the question and answer method, which is, I can say, is some OK. Why do you use, like….do you try to engage the learners by using the question and answer? **L26** **Teacher C**: Yes I do try to engage with the learners, simple by, maybe by demonstrate with an example of a substance. Maybe you say Sodium Hydroxide in the process of electrolysis, then you explain showing,.there's the electrode, this is what is going to happen, this is going to move from here to here, you explain the concept of the electrons moving from one electrode to the next . **L27** **Interviewer**: Using.., what do you use to explain, the concept? **L28** **Teacher C**: The concept?.. I use diagrams.. draw them on the board, or I use the diagram on paper on the diagrams in the textbook. **L29** **Interviewer**: Ok, so you rely mostly in the textbook? **L30** **Teacher C**: On the textbook.	Teaching strategies Teaching strategies	Uses examples to clarify concepts to enhance learners' understanding Explains content by using examples, diagrams, textbook
L31 **Interviewer:** So you don't use maybe some kind of practicals **L32** **Teacher C**: Not realy, we don't do practicals because of the apparatus that is required. And looking at the syllabus the way they structure it,.though it would be more effective if I can do the practicals, but the availability of the apparatus that I need to set up and all that is not available.	Challenges to using CBS	Shortage of apparatus

L33 **Interviewer**: Ok. So if I may ask, by using the using that kind of teaching method, that is the Question-Answer method. How do you find the level of understanding? Are you happy with the level of understanding of the students? **L34** **Teacher C**: Quite frankly, initially it is not easy for them to visualise what is happening, so you have to do more examples trying to explain until they understand, and if they are really not getting it clearly then give more examples. Now you have more examples, you can see they are following and applying the concepts in the more examples that are coming, but it takes more examples that I have to give. **L35** **Interviewer**: Ok, I don't know if it's the same or they are similar. If I may ask what are the challenges of teaching electrolysis? **L36** **Teacher C**: The challenges of teaching electrolysis is just like almost that similar to the practicality part of it. We do not have readily set apparatus whereby they can do the practical part of it to show them.	Teaching strategies Challenges to using CBS	Learners are not able to visualise with the question and answer method Uses many examples to clarify concepts Shortage of equipment
L37 **Interviewer**: Ohw it's the syllabus it's mainly the theory part. **L38** **Teacher C**: Yes its mainly the..Yes.. there is no section where they ask them experimentally design this or something like that. It's more like its asking them like… The process of electrolysis, how does it happen? You can explain that theoretically.		
L39 **Interviewer**: Ok, ok.. so concerning the challenges, how do you overcome the challenges? **L40** **Teacher C**: Mmmhhhmm…. The challenges mainly it's doing more examples, they verify using the examples, just trying to find how a question can come up in electrolysis then you do lots of examples until maybe they have more like got the concept in their system practically in a way but they have done it theoretically. Hope it's coming up Ok. **L41** **Interviewer**: No its ok. So ehm.. on that if it was not for the syllabus and shortage of equipment, do you have in mind of other teaching strategies you can use if you were not limited by the syllabus or if you were not limited by the shortage of equipment which you feel as a teacher can help in the	Challenges to using CBS	Gives more examples, gives learners practice and prepares learners for examination

understanding of the topic? **L42** **Teacher C**: Yes… I think the discovery method whereby..ehm..Ok… the other thing I didn't talk about why not teach it like that is because of the syllabus of course and time factor. On the syllabus it's that they try to cover a lot of things within a short period of time. And so anything that you feel like is not specified by the syllabus you tend to push it aside. But given the time it would be quite nice for the kids to discover themselves. Let them discover what the process of electrolysis is, play around with all the apparatus, trying to see what's really happening and all those things we give them, to say these are the results we get after electrolysis. So it would be really nice for the kids to discover what really is electrolysis, how does it happens, does electrolysis occur or it doesn't, and… something like that.	Teaching strategies Challenges to using CBS	Discovery method: takes time Choice of teaching stratey influenced by the syllabus and the shortage of equipment
L43 **Interviewer**: Ok, so..ehm.. from your teaching experience why do you think it is important for learners to understand the topic of electrolysis? **L44** **Teacher C**: Mhhmm.. besides the obvious benefits of getting good results? **L45** **Interviewer**: Yes besides that? **L46** **Teacher C**: <u>Yes it make them understand like probably in the process of electrolysis..like.. whereby there is the electroplating which makes them understand…the process of substances being coated nicely with material which is better and the obvious advantages of that concept, industrially, economically. I think it an advantage so they have an insight on how does this thing beautiful, when they say its gold coated, how does this happen, and I think it is quite educative and…</u>	Teacher' attitude Teacher's curricular knowledge	Teaches for good grades Values learners' understanding of the content and the application of electrolysis For industrial and economical reasons
L47 **Interviewer**: Ok, then ehm.. how do you assess the learners understand during the lesson, the formative assessment, during the lesson and also..ok besides ….. yah… if I may pose there? **L48** **Teacher C**: Learners assessment mainly, <u>always have to assist with test, besides the test or end of topics assessments whereby you give them questions.</u>	Teaching strategies	Tests and assignement

L49 **Interviewer**: Yeah that one comes at the end of lesson. I mean during the lesson **L50** **Teacher C**: During the lesson?.. probably check on how they are participating, owhh, yes, I normally check on their participation, and I have to ask them at times like are you really getting the concept, are you really getting what I'm explaining. I need to get feedback from them if they are following the concept as I'm teaching, if not like,..,...ask them…relate to them…ask on the every part explained...or something like that.		
L51 **Interviewer**: So,so, so do you know the important concepts. I mean like what you have to emphasise on while you are teaching, like the main ideas which you have to emphasise,which you have to make sure the students understood? **L52** **Teacher C**: Ya, ok, being a teacher in this field for a long time is what I had wanted somehow because you kind of like know…have an idea on how the examiners work. Unfortunately it's more like working with the examiners because at the end we are looking for good results at the end. It's not more like something like we are grooming, what do you call this? Ehm, students who are going to be expertise, researchers in doing the electrolysis, go further in analysing or or learning the concepts of electrolysis. Its more like channelling them to the examination. **L53** **Interviewer**: So in other words, so mainly, I don't know, you teach mainly for the exams? **L54** **Teacher C**: Mainly, mainly, mainly that's the core factor, we teach for the exams but it should be beyond that. But because of time limitations its not like you are producing scientist maybe you allow them to be scientist who are going to discover or we allow them to be scientist who will discover more when they reach the University. So at this stage the is no time given to further explore.	Teacher' attitude Teacher' attitude	Her orientation to teaching is for learners to get good grades Teach for examination
L55 **Interviewer**: Are you… are you saying.. ok… You teach… it's not mainly for the understanding but you teach for the exams?		

L56 **Teacher C**: No it is for understanding because if you haven't really understood now you can't pass the examination. What I was trying to say was like ehm.. for some other instances…I don't know which…its method of teaching so that like.. ehm.. the kids discover themselves. They discover the concept and then they conclude. They experiment to do experiments. What I'm saying is that when I teach the kids the primary goal is for them to pass that stage of the examination. Its not like for them to explore… to be doing more experiments and take some time discover some things. Its not that. Its like learning that electrolysis is this process. Its like actually you are limited to say you know maybe the electrolysis of sulphuric acid, or aqueous sodium 277luoride. So its more like its limited, its guided, so its not like you can explore the other…..an come up with something and discover something	Teacher' attitude	Teaches for examination and is limited by the syllabus
L57 **Interviewer**: Ok. Have you heard about computer simulation? **L58** **Teacher C**: Yes I have heard about them. **L59** **Interviewer**: And what's your…what do you think about them…Ok what do you consider them to be and what do you….OK maybe 1 question at a time…what is your understanding of computer simulations? **L60** **Teacher C**: Ehhm, in short, because of set up to have the probability of us having time to implement, the method of teaching using computer simulation… I believe it is a method of teaching whereby it helps re-enforce on this topic of electrolysis…whereby the kids really see using a computer what is happening when we say probably an electron moving from this place to this place. And then it is computerised, it better enhances the understanding other than doing it theoretically. Something like that.	Advantages of CBS	Enable learners to visualise migration of ions enhances learners' understanding of electrolysis
L61 **Interviewer**: So why don't you use them in your school…in your teaching? **L62** **Teacher C**: We are going there, but at the moment its only that…ehm..our curriculum…no what that,.. our set up you would need access		Willingness of using CBS Can make her work easier

to have a computers, you would need to have the thing..put up. Its not readily available to us. And over the years the theoretical part have been working very well and students have been passing very well, and, given the chance and try it out, probably if we look more in to it, I didn't look on to it anyway. I think I can give chance to try it out, but like I said the limitation of time, but I would love to test if it really enhances the understanding… so that, maybe I'm thinking its time taking or maybe its not , it actually can make my work easier.. Otherwise all I'm saying is I need to look more into it. Really understand it and see how I can implement and compare the methods of teaching.	Challenges to using CBS Teacher' attitude	Willingness to understand CBS it and implement it Unavailability of computers Takes time
L63 **Interviewer**: Ok, you know thank you very much for your time and….and I hope… to observe you while you are teaching the topic. I can provide you with the computer simulations. And you do have a computer lab? **L64** **Teacher C**: Yes we do have a computer lab, its only that I need to strategies or schedule the computer group cause it's not like we are the specific group but I think can get time for schedule. But I think it can be done.		

APPENDIX Q

TEACHER C LAST INTERVIEW

I would like to thank you for accepting to take part in this interview. Please feel free to say anything. Remember the views expressed here are only going to be used for this study and there are no wrong answers. Also, you do not have to say who you are because only the ideas and not your name are important.

DATE: **VENUE: SCHOOL C HIGH SCIENCE PREP ROOM** **DURATION: 20mins**

L1 **Interviewer:** Good morning once again Miss. **L2** **Teacher C:** Yes morning Mam. **L3** **Interviewer:** I'm good. So this is the last part of the research which we going to do. And thank you very much for taking part in the study. **L4** **Teacher C:** You are welcome. **L5** **Interviewer:** So I'm just going to do… to ask you a few questions after you have used your computer simulations. So what teaching strategies did you use in teaching electrolysis? **L6** **Teacher C:** We use question and answer method and then we had a practical followed by discussion of what the kids had observed in the results. Yes and the practical was using the computer simulations which they were observing what was happening in the process of electrolysis.	Teaching strategies	Question and answer, practical ie CBS and discussion
L7 **Interviewer:** Ok, so can you give me a reason for using each of the teaching strategies or teaching methods that you used? **L8** **Teacher C:** Ok, the first one was the question and answer, it was basically to link the kids with the previous knowledge about the topic which we are about to use the computer simulation on. And then the practical method was for them to see what we had talked about happening, being shown clearly the	Teaching strategies	Q&A: linking with previous knowledge CBS: visualise what had been learnt about process of electrolysis Discussion: deliberate on

process of electrolysis. Then the last part was the discussion, to discuss the observations and link it with the theory, what we have learnt and observed. **L9 Interviewer:** So can you define clearly what do you mean by the practicals. Do you mean the practical whereby the use of chemicals or the use of computer simulation or you use both. **L10 Teacher C:** Ok it was mainly computer simulation… whereby pupils were selecting the voltage and the electrode on those computer simulations. Observing what was happening while electrolysis was taking place. **L11 Interviewer:** So do you use the practicals using the chemicals with this group or you only used computer simulations? **L12 Teacher C:** For this group we only used computer simulations, for only this lesson. But previously we had done using the chemicals. **L13 Interviewer:** So which means you have used all? **L14 Teacher C:** Yes we have used both of them.	Teaching strategies Teaching strategies	observations and link with theory How the CBS was used, the learners were hands-on Combined with a practical which was done earlier
L15 Interviewer: For a start I would say that the students were more participating, they were interested and that meant a lot. If you got the attention of the students it means that they have are so much interested to see what was really happening. Yes so I think that the use of these simulations enhanced the learning of this topic as they can easily recall it now. **L16 Interviewer:** Why do you think it was easy for them to recall? **L17 Teacher C:** As we did the discussions of the topic, most…all of them had something to say. They participated. Even the questions on topic in test, to follow up on the topic. The questions where electrolysis came up, I could see they could answer them without any much difficult. **L18 Interviewer:** Ok, ehm..can you compare the performance of this group with the performance of the previous group. Do you think it was better or it was the same? **L19 Teacher C:** Definitely I can say it was better because they could answer questions easily. The topic questions on electrolysis they have got a better understanding. They can even analyse better and give an answer that is closely meaningful, related to the…you can see that they are relating to what they saw	Advantages of CBS Advantages of CBS	More participating More interested learners visualised the process of electrolysis CBS enhanced learners' undersatnding learners had something to say, ie learner engagement Learners visualise Enables learners to visualise

on the simulations.		
L15 **Interviewer:** For a start I would say that the students were more participating, they were interested and the.. that meant a lot. If you got the attention of the students it means that they have are so much interested to see what was really happening. Yes so I think that the use of these simulations enhanced the learning of this topic as they can easily recall it now. **L16** **Interviewer:** Why do you think it was easy for them to recall? **L17** **Teacher C:** As we did the discussions of the topic, most…all of them had something to say. They participated. Even the questions on topic in test, to follow up on the topic. The questions where electrolysis came up, I could see they could answer them without any much difficult. **L18** **Interviewer:** Ok, ehm..can you compare the performance of this group with the performance of the previous group. Do you think it was better or it was the same? **L19** **Teacher C:** Definitely I can say it was better because they could answer questions easily. The topic questions on electrolysis they have got a better understanding. They can even analyse better and give an answer that is closely meaningful, they are relating to what they saw on the simulations.	Advantages of CBS	More interest More engaged Visualise
L20 **Interviewer:** Ok, and then now, how has the use of computer simulation improved your understanding and teaching of this topic? **L21** **Teacher C:** Ehm..ok I will start with the teaching of the topic. For the students I will say normally you teach theoretically trying to explain how the other one is going to gain electrons and the other one is going to release electrons. It was like they are trying to picture something which they wouldn't visualise. So when I was using the theoretical method you would really see that you are explaining to the kids and have to take it for your word but then for you to be sure that they really get what you are talking about was difficult to see. **L22** **Interviewer:** Ok **L23** **Teacher C:** But now with the simulations you could see them saying 'oh yes Mam this is what you have been talking about. You see this, there are	Advantages of CBS	**Learners visualise and relate what is learnt theoretically, migration of ions and the physical**

moving electrons from this side, they are going this side and they would really see what was happening. Even the changes in mass, this side the mass is becoming smaller, this side its gaining in mass and even voltage and everything.		**changes eg change in mass**
Interviewee: Ok. And then did they help in your understanding of the topic, the computer simulation. **L24** **Teacher C:** Yes, it even helped me to some extent because…ehh…Before as well it was theoretically shown. I learnt it theoretically, and was teaching it theoretically. It was fascinating to see how the process of electrolysis go…ehm.. how it was happening. And was quite interesting, It led me to really think even deeper about the topic of electrolysis than I ever done before	Advantages of CBS Teacher' attitude	Interesting, visualisation of the process Self-reflection
L25 **Interviewer:** Ok, so how did you find the computer simulation that you used in your lessons. How did you find them? Were they sending the correct information? How did you find them? **L26** **Teacher C:** I would say they were quite relevant and they really showed what we had theoretically and I would say that they are quite a useful way of teaching **L27** **Interviewer:** So what do you think if any, are the advantages of using computer simulation in teaching? **L28** **Teacher C:** The advantages of computer simulation is the…about the students? **L29** **Interviewer:** Yes **L30** **Teacher C:** The level of participation for the students. The students are so interested, its not like you keep the students, you keep the students awake, you keep them participating to really see what's happening and there is a positive learning taking place	Advantages of CBS	More interesting, more participation, positive learning
L31 **Interviewer:** And what do you think if any are the disadvantages? **L32** **Teacher C:** The disadvantages that I would mainly see on using simulation, is that it needs a lot of time. It is time consuming because to do one or more concepts you need time, which according to our syllabus we won't be	Challenges to using CBS	Time consuming Some students don't have laptops (shortage of

able to complete the syllabus, and students are tested on the assumption that they have completed the syllabus. The only problem I could see is that it takes a lot of time. It's a time consuming method for teaching. **L33** **Interviewer:** Don't you think that can be overcome by allowing them to work on their own at home since they can take the simulation home. **L34** **Teacher C:** Ok, that can be possible option, for the students to go and do it at home but taking into consideration that there are gadgets now to be putting on laptops to be putting on computers and so forth. Which some of them they are disadvantaged to, they don't have them.	Challenges to using CBS	equipment) Socio- economic background
L35 **Interviewer:** Ok,…ok. So, ok. Now coming to the contents, how do you assist learners when using computer simulation during the lesson? **L36** **Teacher C:** Normally we provide the relevant simulation with the topic that you want to do. Like I provide them with the simulation with the topic that we were doing. They had to download them and try to use the simulations when they are properly ready.		
L37 **Interviewer:** Ehm. So what are the common mistakes that has been made in the topic of electrolysis? **L38** **Teacher C:** Ok. With the use of simulations or? **L39** **Interviewer:** No in general. **L40** **Teacher C:** Ok, generally it's when they have to decide which one has been oxidised, which one has been reduced. Like if you give them the electrode you have to determine where the electrons are from and where they are going to and also generally calculating the electrode potential during electrolysis.	Learners' difficulties in electrolysis	Deciding which electrode has been oxidised and which one has been reduced
L41 **Interviewer:** Ok. So how do you assist the students in overcoming those challenges? **L42** **Teacher C:** Basically what we have to do as many problems as	Teaching strategies	Makes learners to practice

possible, and give them enough questions to keep on practising and practising until they understood the concepts and apply it in any given situation.		by giving them many questions
L43 **Interviewer:** So what is a pre-requisite knowledge or process which you have to cover before eh this topic? **L44** **Teacher C:** Ehh normally it's eh, the reactivity series **L45** **Interviewer:** Mh. **L46** **Teacher C:** Yah.	Teacher' curricualar knowledge	Previous concepts that link with electrolysis
L47 **Interviewer:** So what are the challenges of teaching chemistry using computer simulations, or what were the challenges of teaching electrolysis using computer simulations. Were there any, if so, what were the challenges? **L48** **Teaher C:** Ehh, I wouldn't they were challenges as such, but only that the students were so interested that the students were trying other things.eh... trying their own methods. To really discover more, playing with simulation now while you are giving other instructions. But I would say it was for their own good because they were trying to get further.		
L49 **Interviewer:** Ok. So how do you plan or write your lesson plan to accommodate the use of computer simulations? **L50** **Teacher C:** Ok…eh. Basically what you have to do is you have to do an introduction first where they recap on the theory that has been learnt before. **L51Interviewer:** Mh. **L52** **Teacher C:** And then you now introduce to say that what we learnt theoretically we are going to be using computer simulations to try to visualise and see what is really happening. Like we learnt, it is really what has happened. **L53** **Interviewer:** So would you suggest that computer simulations be introduced in schools for teaching electrolysis, and if not, which ever, would you support your stand. **L54** **Teacher C:** Eh. I would suppose they would be used in schools not for all the topics but to enforce the learning in subtopics like electrolysis and because I would see the enthusiasms in the kids. And over the period…over the	Teacher' curricular knowledge Advantages of CBS	Lesson development of the lesson start from the previous lesson Acknowledges that CBS enforce learnerning

past years, if you ask some of our students, you would hear them say that the topic of electrolysis is the one that is challenging to them. But with this group you find that the topic of electrolysis was more interesting, because I think because of the use of computer simulation. So I would advocate for them. Not for the whole syllabus but maybe some topics selected topics in chemistry and physics.	Teacher' attitude	Willingness to use CBS
L55 **Interviewer:** So would you say that electrolysis is one of the most challenging to them? Why do you think it is challenging to them. Or what reasons did they give? **L56** **Teacher C:** Eh, I think because, like I said before they had to know which one have been oxidised and which one have been reduced in the setup. **L57** **Interviewer:** So in other words you are saying it's abstract for them? **L58** **Teacher C:** Eh… in a way. **L59** **Interviewer:** Ok, alright. So thank you very much you know, for all your time and we have come to the end of the interview. Thank you very much.		

APPENDIX R

First lesson for Teacher C
Introduction of electrolysis (purification of cuppe nitrate using copper electrodes)

L1Teacher: How are you? **L2Student:** We are fine. **L3Teacher:** <u>Today we are going to look at the topic electrolysis.</u> Ehh… as we discussed. last time. In the new topic we will be dealing with electrolysis and today we are going to introduce the topic, but first of all I would like to ask you, if anyone of you know what the process of electrolysis is all about. Does anyone know what the process of electrolysis is? Anyone? Yes? **L4Student:** I think electrolysis is the breaking down of ion compounds….. **L5Teacher:** Ok thank you. Can you speak a little bit louder. **L6Student**: I think electrolysis is the breaking down of ionic compounds using electricity to form elements. **L7Teacher**: *Ok she says it's the breaking down of ionic compounds using electricity to form the constituents elements. Are we all in agreement with that? Alright. So we are going to be looking at how this electrolical… electrolysis goes about. To help us achieve that goal, we're going to use a new method that we are introducing, or we are trying to introduce in the schools which is computer simulation. In computer simulation we will be addressing this topic in a more practical manner.*	Teacher's knowledge of curriculum	Teacher informs learners what lesson will be about Repeats to reinforce To see what actually

You'll actually be seeing what is happening during those processes, those different processes during electrolysis. To help us understand better I have with me here some simulations that I have prepared. First of all we have to look the definition of electrolysis here, where it is defined as electrolysis, uses electricity to break down ionic compounds like she said. Ok, can you give me examples of ionic compounds that you know. Can any one of give me any ionic compounds they know. **L8Student:** Magnesium Oxide. Magnesium Chloride. **L9Teacher:** Magnesium Oxide, Magnesium Chloride. Ok thank you let's use those two examples. In magnesium oxide which ions are we talking about, which ions are we talking about because we said these are ionic compounds which ions are we talking about? In magnesium oxide. **L10Student:** Magnesium ion. **L11Teacher:** One .Magnesium ion any other? **L12Student:** Oxide ion. **L13Teacher:** Oxide ion. Ok may we now refer to our electrodes please. Lets do the simulation on the introduction of electrolysis. And I will give you ten minutes to do the simulations and will take it up from there. (She left the learners and went out for about five minutes, then she moved around checking each group, then she went to the front desk). **L14Teacher:** Alright may we settle down please. May we settle down please, okay in our discussion we said we should look at the computer simulations and observe what was going to happen. One of the computer simulations that we looked at was the electrolysis of eeee cooper nitrates, copper two nitrates using	Advantges of CBS Teaching strategies Teaching strategies Teaching strategy Teaching strategies	happens Questioning, asks. Helps learners understand uses previous knowledge to assist learners to understand electrolysis Asks learners to identify ions from example. Does not follow up on product for electrolysis of molten MgO or $MgCl_2$ Uses copper nitrate electrolyte and copper

copper electrodes. Ok alright. I want you to give me a feedback on what you observed during the computer simulations. Is anyone willing to maybe briefly tell us what they observed? Anyone. Anyone. Any observations please, eh? (No response). Some computer simulations in order for us to understand electrolysis a little bit better in the first simulation we used copper electrodes and copper nitrate as our electrolyte. Would you give me a feedback on what you observed during those simulations. Anyone who observed something, anything. Yes? **L15 Student:** We had impure copper and pure copper where there was, where in a solution of copper sulphate, the impure copper was donating electrons to the pure copper. We've seen movement of the electrons moving up the anode into the cathode part, where the mass of the impure copper was reduced and the mass of the pure copper was increasing. **L16Teacher:** Ok thank you. Anyone else who observed anything. **L17Student:** To further add on that the impurities of impure copper were settled down at the bottom of the container. **L18Teacher:** Alright. So from ehh, from what we discussed what is it that we can say about electrolysis. We have seen that indeed it is necessary to use electricity. Without switching on the switch, nothing was happening. When you switched on it means now the electrical energy is the one being used to decompose the electrolyte. In this case the electrolyte had two	Teaching strategies Advantages of SBS Teacher' curriculum knowledge	electrodes as examples Discussion, finds out from learners what they oserved Learners were able to observe the mascropic changes such as change in mass in the electrodes. They were also able to see the movement of electrons and impurities settling at the bottom. She also noted electrolysis requires energy input Asks about of ions

ions, it had copper ions and nitrate ions, ok. Where did the copper ions go? To which electrode did they go? The one with the cathode. What about the nitrate ions?		
L19Students: They went to the the anode.		
L20Teacher: They went to the anode. Ok, alright. So can we write the equations of what was happening at the anode. Let's talk about the anode reaction. (Writes on the board the ionic reaction as the learners speak). What was the anode reaction? Can someone give us the anode reaction. At the anode we said there were copper ions, what happened to them? Mmmm? (not clear) an electron to get what?	Teacher's knowledge of curriculum	Teacher asks questions that relate to the syllabus and writes important points on the board
L21Students: Copper		
L22Teacher: To get the copper which is a solid which was stuck to give the anode. Is it true? What was happening? Can you speak a little bit louder. It was copper, we had the pure copper losing an electron to form what? copper two ion.	Teacher's knowledge of curriculum	Mistakes: 1she said pure instead of impure copper lost electrons
L23Students: To balance…		2says that two copper atoms is needed but actually each copper atom looses 2 electrons
L24Teacher: to balance the equation we need two atoms of copper which is going to lose two electrons to the anode because the anode is deficient in electrons. Do you see that?		
L25Students: Yes.		
L26Teacher: Alright, so we can use this to represent half of		

what was happening in this process. Let's look at the cathode reaction now. What do you think happened at the cathode? Mhhh? What do you think happened at the cathode?mmmm? **L27Student:** The copper nitrate, copper nitrate was… we added ema-electrones to the copper nitrate to give us copper ions. **L28Teacher:** To give you? **L29Student:** Copper. **L30Teacher:** But in this case do we have copper in this case? **L31Students:** No (Class response). **L32Teacher:** What are we expecting to get? **L33Students:** Oxygen. **L34Teacher:** And what? **L35Students:** Nitrogen. **L36Teacher:** Nitrogen and oxygen. Ok do this balance. **L37Students:** No. **L38Teacher:** How can we balance the equation? Is it balanced? You should lose two electrons. Ok, alright. In the next session we are going to be looking at more of these computer simulations. To be specific I want you to go and look at the	Teacher's knowledge of curriculum Teacher' knowledge of curriculum	Teacher guides the learners as they respond Learner answers that copper ions form at the cathode, then corrects it to copper atoms. However, teacher doesn't accept that answer but guides to that nitrogen and oxygen would form, this is incorrect. Thus teacher shows poor content knowledge of purification of Cu^{2+} she wrote equation showing Production of nitrogen and oxygen and balanced it with the

electrolysis of acidified water and then we will discuss after the computer simulation. Thank you. That's the end of today's session, we will meet next time.	Teaching strategies	students, which was incorrect. Instead of $Cu^{2+} + 2^{e}- \longrightarrow Cu$

APPENDIX S

Second lesson for Teacher C

Electrolysis of acidified water

L1Teacher C: Good morning. **L2 Students:** Good morning. **L3Teacher:** How are you? **L4Students:** We are fine **(chorus response)** **L5Teacher C:** I am fine too, alright. We are still continuing with our lesson, I mean our topic on electrolysis, in the previous lesson we talked about electrolysis in general, whereby we were looking at the definition and we looked at some computer simulation to demonstrate what electrolysis is all about. Maybe just a quick re-cap on what we discussed yesterday, can anyone remember from the previous session, (silence for some time).	Teacher's knowledge of curriculum	Links new lesson with previous lesson, but the same question is asked as in the first lesson. she doesn't ask about the new content,i.e purification that was learnt

L6Teacher: Bhekizwe? **L7Student:** I remember the definition of electrolysis, saying that, electrolysis is is the breaking down of ionic compounds using electricity to form elements. **L8Teacher:** Thank you, are we all in agreement? **L9Stdents:** Yes (class response). **L10Teacher:** Alright, eeeee, today I want to look at , <u>to look at the the electrolysis of a</u> <u>acidified water, okay</u>? <u>Why does, why do we need to use acidified water, if I may ask, why is it necessary for us to use, for the water to be acidified, why not just electrolysis of water? Anyone? Yes?</u> **L11Student**: It contains ions. **L12Teacher**: Ions, so what is wrong with pure water? **L13Student**: It is a molecule, it doesn't have ions. **L14Teacher:** <u>Eee, pure water is not a good conductor of electricity because it does not possess ions. So,when we acidify, we are facilitating the conduction of electricity</u> <u>through the electrolyte</u>. Alright, eeeeeh I have eeee on	Teacher' knowledge of curriculum Teacher's knowledge of curriculum	Makes learners to think about the need of using a conducting liquid Explain the importance of ions to conduct electricity

your laptops a computer simulation on the electrolysis of acidified water, but before we get into detail, or before we observe what really happens can we just give some ypothesis. In other words, what do we think, what do you expect to get from these simulations when we switch on electricity, it passes through water what are we expecting to see? In this section, what are we expecting to see? (silence……..class? what is it that you are expecting to see? **L15Student**: Hydrogen ion will drift towards the cathode. **L16Teacher:** The hydrogen ions will drift towards that cathode because they are positively charged, that is a reasonable assumption, anyone else with something else, different? (…..Silence). **L17Student:** The hydroxide ion will move towards the anode. **L18Teacher:** (He write on the board learner' s response) the hydroxide ion moving to the anode, alright, because the anode is positively charged, it will get the negatively charged hydroxide ions, okay. So I will allow you to go through the simulation, I want the emphasis to be on what is	Teacher' knowledge of curriculum Teaching strategy Teacher's knowledge of curriculum	Guides learners on what to observe A discussion of what learners anticipate to observe Guides the learners by explaining why the hydroxide ion moves towards the anode and guides them on what to observe at the electrodes. Now she focuses their attention Teacher moves around while learners work in their groups

happening on the two electrodes, I also want you to think about the fact that you may have more than one cation or one anion, in this case we have OH negative, what other ions do we have, that is negatively charged? Yes? **L19Student:** A sulphate ion. **L20Teacher**: So I want you to look at the behaviour of such ions and I also want you to pay attention to which one of the two is preferred when they are released at the electrodes. We may start our simulation session. (Teacher moves around the groups without disturbing the learners, while learners work in groups of five. The session takes about 10 minutes). I think I have given you enough time to look at the simulations, eeeee may we please give a feedback eeee on what you observed, does anyone want to contribute to what they have seen, what is it that you have observed during the computer simulations, (silence). Ok let me be more specific, let's look at what was happening at the anode, let's look at what was happening at the anode. What did you observe, was there any movement, any electrons involved, yes? (student attempts to answer but is too soft,) speak a bit louder please. **L21Student:** The hydroxide ion drifted to the anode where they were discharged.	Teaching strategies Teaching strategies	Teacher leads discussion by asking relevant questions Questioning about observation, writing important equations on the board

L22Teacher: The hydroxide ion drifted towards the what, eeeee the anode, so we have the OH minus, (writes on the chalkboard) and eeeee. **L23Student:** To give oxygen and nitrogen plus electrons. **L24Teacher:** Right, so you now giving us the equation. (writes on the chalkboard). The OH gives us electrons plus oxygen plus water, is this a balanced equation? **L25Studnets:** No **L26 Teacher:** May we balance it, how many hydroxide ions do we need? **L27Student**: Four. **L28Teacher**: Four, So this becomes what? **L29Student:** Two. **L30Teacher**: Two. Is it balanced now? **L31Student:** Yes (class response). **L32Teacher:** Except for the electrons , we must also have four electrons, ok. Any other observation that you noticed, any other, yes?	Teaching strategies Teacher' knowledge of curriculum	$4OH^- \longrightarrow 2H_20 + O_2 + 4e^-$ Teacher elaborates on learners' response

L33Student: I think the process that happened at the anode is the oxidation process. **L34Teacher:** Yes, he is saying, this process that happened at the anode is a typical oxidation process, why is that? Because electrons are lost. So we can also define oxidation as the loss of electrons. Thank you very much for that contribution. What about at the cathode, was there anything happening there at the cathode while the simulation was in session? Did you observe anything, (silence) Siphamandla? Zakhele, sorry? **L35Student:** The oxygen gains electrons, letting water gains electrons. **L36Teacher:** Water gains electrons? **L37Student:** Yes. **L38Teacher**: as a molecule or when it has been split into two? Because in the simulation, we said we have water and this water is acidified, we were trying to give it a charge. So which one is which. Is water going to the cathode as water or as……? **L39Students:** Hydrogen. **L40Teacher**: okay in this case your colleagues are	Teacher's curriculum knowledge Teaching strategies	Questioning, guides towards correct process

correcting you they are saying the hydrogen ion is the one that goes to the cathode. The reason being that, it is ……? **L41Student:** Positive. **L42Teacher**: It is positively charged, therefore it must be attracted to the negatively charged cathode. But what happens at the cathode? **L43Student:** It gathers electrons (not clear). **L44Teacher**: Alright, so we are saying, hydrogen ion plus the electrons that it gains at the cathode to give us what? (teacher is writing the equations as learners speak). **L45Student**: Hydrogen gas. **L46Teacher:** hydrogen gas, thank you is it a balanced equation? **L47Students:** No (class response). **L48Teacher**: Lets try and balance it. **L49 Teacher:** 2 here, 2 there, it is now balanced. Alright. Do we have any practical application to this processes? Have you ever heard of any situations where electrolysis of water is done at a large scale?	Teacher' knowledge of curriculum	Relates importance of electrolysis of acidified water to the industrial application

L50Student: Yes, Industry. **Line51Teacher**: Where? I mean what kind of industry is that? **Line 52 Student:** Industries that produce hydrogen. **Line 53Teacher:** Industries that produce hydrogen, can you give examples, not names but types of industries, mmmmm? **Line 54Student**: The Haber process. **Line 55Teacher:** They are talking about the Haber process, production of ammonia which is useful for? **Line56 Student**: Fertilizer. **Line57Teacher:** Making of fertilizer, isn't ? alright? What else is important in the production of eeee, I mean in this electrolysis. It also produce oxygen which can be used in various industries, steel industry and the like. Okay. Alright, do you have any questions on what you have observed during this simulation, is there anything that you need to ask? Any questions, okay in the interest of time, we'll have to close this session for today. We'll meet next time.	Teacher's knowledge of curriculum	Relates products of electrolysis to what learners are familiar with industrial process

APPENDIX T

Lesson three: lesson on electrolysis of brine

L1Teacher: Good afternoon. **L2Students:** Afternoon (class response). **L3Teacher:** How are you? **L4Students:** We are fine. **L5Teacher:** I'm fine too. **L6Teacher:** Ok, today we are still continuing with our electrolysis. <u>I think by now the various computer simulations that we've been going through are helping you to understand the topic a little bit better. Today we are going to look at the electrolysis of brine</u>. Is there anyone in class who knows what brine is? What are we referring to when we saying the electrolysis of brine.	**Advantages of CBS** **Teacher's knowledge of curriculum**	**Use of CBS enhance understanding** **Informs learners what lesson will be about**

L6Student: Brine is the concentrated solution of sodium chloride.		
L7Teacher: Alright, brine is a concentrated solution of sodium chloride, ok. it's a concentrated solution of sodium chloride. I believe by now we all know that concentration has or contributes to which of the ions is discharged first in the event that we have two ions going to the same aaaanode or cathode. Now what are the ions that are involved in concentrated sodium chloride. Can we list the ions? Yes?	**Teacher' knowledge of curriculum**	**Explains which ions is preferred using the concentration concept** **Not correct**
L8Student: Chloride ion		
L9Teacher: We have chloride ion, Cl minus. Yes?		
L10Student: Sodium ion.	**Teaching strategy**	
L11Teacher: We also have sodium ion Na plus, what else? Yes.		**Question and answer**
L12Student: Hydrogen ion.		
L13Teacher: Hydrogen ion?		
L14Student: Hydroxide ion.		
L15Teacher: Hydroxide ion. So we now have		

two negatively charged ions which are also referred to as anions because they go to the anode. We also have two positively charged ions which are the cations, alright. Now what do you think happens if we are to pass electricity through this kind of electrolysis. What are we expecting to observe when we try to electrolyse brine. Now the issue of concentration must be taken into consideration. Any, anyone? **L16Student:** The hydroxide ion and the oxygen ion will be transferred. **L17Teacher:** She thinks the hydroxide ion, did you say the hydroxide ion? **L18Student:** Mhhm, cela kushintja. (can I please change)? **L19Teacher:** You are allowed to change it's Ok. You can speak. **L20Student:** The solution is concentrated right? **L21Teacher:** Yes it is concentrated. **L22Student:** So the chloride ion and the <u>sodium ion</u> will be discharged first because the solution is concentrated which means the water, there's	**Teaching strategy**	**Questioning and discussion**

less water. **L23Teacher:** Thank you very much. This is a very good observation, this is a concentrated solution of sodium chloride so we expect to see more of the Na plus than the H plus which is coming from the polarised water. is it correct? We also expect to see Cl minus being discharged first or more of these than the OH from the same water because if we say it is concentrated it means the molecules of, the water that we are dealing with is in small quantity. But let's also look at, let's anticipate what is going to be going on, on the anode before we even try to investigate using simulations. What are we expecting see happening at the anode. Yes? **L24Student:** The chloride ion and the hydroxide ion will go to the anode, where the chloride ion will be discharged first. **L25Teacher:** The chloride ion will be discharged first, which means it is going to lose it's electrons to the anode and in the process it becomes chlorine gas, ok. is this equation balanced?	**Teacher' knowledge of curriculum**	**Incorrect response by learner** **Incorrect explanation, teacher explains using the concept of concentration why the ions are preferred. She should refer to reactivity not concentration**

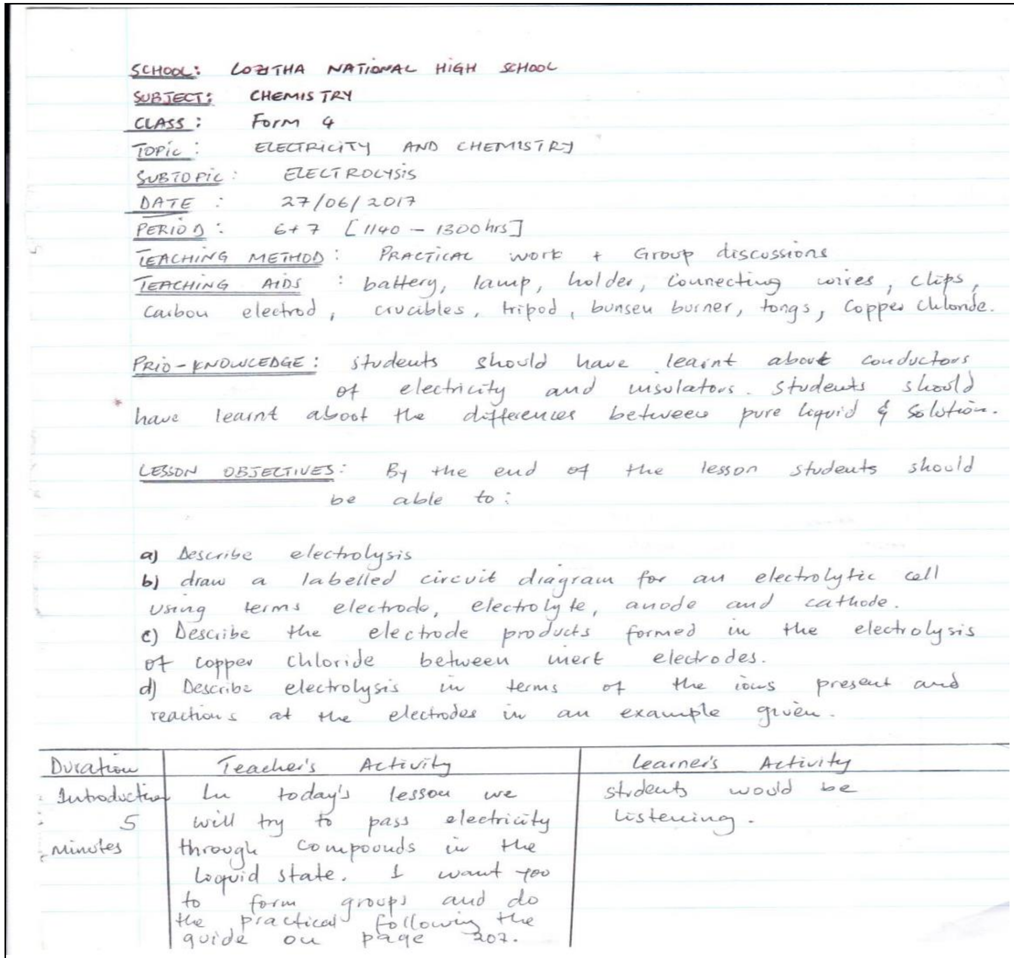
L26Students: No **L27Teacher:** How can we balance this equation? Put a two there and a two there, ok. What about the cathode reaction. We said in the cathode it is the sodium that is released first. But what are the, what is the chemical equation involved? Na plus, plus an electron to get what? Sodium which is a salt. Is this balanced? **L28Students:** Yes. **L29Teacher:** Yes it is. It is balanced. Ok so boys and girls I want us again to investigate using the computer simulation whether our predictions are going to come through or not. I will give you about 15 minutes to investigate, then you give me a feedback. **L30Teacher:** Ok class I have given you more than 15 minutes to look at the electrolysis of brine using computer simulation. We had made some aaaaaa predictions , now I want to get a feedback on whether our predictions came true. In the first prediction we said the anode reaction is supposed to be having…..Do you still remember what we predicted on. We said what,	**Teacher's knowledge of curriculum**	**Inocorrect, it has to be chlorine gas instead of chloride ion** **Incorrect: Hydrogen gas forms at the cathode. NaOH remains in solution and is precipated for**

the anode must have aaa? **L31Students:** Chloride ion. **L32Teacher:** A chloride ion which we said is going to lose an electron to the anode which is an affinity for electrons to give what, to give chlorine gas. From our computer simulations did we see that? **L33Students**: Yes (class response). **L34Teacher:** What is it, what really happened? Ok this has been confirmed, so what about the cathode reaction. <u>We anticipated that at the cathode we are going to have the sodium ion gaining an electron to form sodium salt. Is it what we came across?</u> **L35Students:** Yes **L36Teacher**: Correct. What else did we observe during the computer simulation? <u>I don't hear you talking about the movement of electrons. Are we seeing electrons that should be moving. ….mmmm? Good</u> <u>people aren't we seeing electrons moving at the anode. Do we actually observe the electrons moving at the anode being donated to the anode or the cathode</u>	 **Teacher's knowledge of curriculum**	**industrial use. she says sodium is a salt, she probably thinks about the NaoH salt remaining in solution** **Explains oxidation correctly**

donating electrons to our cations. **L37Students:** We do (class response). **L38Teacher:** What if our sodium chloride solution was actually dilute? Because in aqueous solution it is dilute are we, do we expect to see any changes if we are to use dilute sodium chloride. What sort of changes? Do we still have chlorine being released at the anode? Yes? **L39Students:** Yes. **L40Teacher:** So that's not a change so it means it still behave in the same manner. What about at the cathode? **L41Student:** There won't be a change. **L42Teacher:** There won't be a change, so basically it is the same process. Okay, good people I want you to go and look at electrolysis further. Specifically now I would want you to look at cases where we have molten compounds. Since we said it is the breaking down of ionic compounds, we must also look molten compounds not always aqueous compounds. Why do we have to look at molten	**Teacher's knowledge of curriculum**	**Learners also agree with incorrect explanation** **Enable learners to visualise the microscopic aspects such as the movement of electrons**

compounds, what does melting do to the ions? When we melt the compounds we are freeing the ions not the electrons. **L43Student:** We want to get the electrons. **L44Teacher**: We are actually freeing the ions not the electrons. Ok, so this is your homework, go and look at the electrolysis of aluminium oxide. It is used to extract aluminium from its oxide and I'll get the feedback in the next session. Thank you very much for attending this session, have a good day. **L45Students:** Thank you.	**Advantages of CBS** **Teaching strategies**	**Contradicts herself, she said erlier the concentration has no effect on products** **New example, homework**

APPENDIX U



SCHOOL: LOZITHA NATIONAL HIGH SCHOOL
SUBJECT: CHEMISTRY
CLASS: Form 4
TOPIC: ELECTRICITY AND CHEMISTRY
SUBTOPIC: ELECTROLYSIS
DATE: 27/06/2017
PERIOD: 6+7 [1140 – 1300hrs]
TEACHING METHOD: PRACTICAL work + Group discussions
TEACHING AIDS: battery, lamp, holder, connecting wires, clips, carbon electrod, crucibles, tripod, bunsen burner, tongs, copper chloride.

PRIO-KNOWLEDGE: students should have learnt about conductors of electricity and insulators. students should have learnt about the differences between pure liquid & solution.

LESSON OBJECTIVES: By the end of the lesson students should be able to:

a) Describe electrolysis
b) draw a labelled circuit diagram for an electrolytic cell using terms electrode, electrolyte, anode and cathode.
c) Describe the electrode products formed in the electrolysis of copper chloride between inert electrodes.
d) Describe electrolysis in terms of the ions present and reactions at the electrodes in an example given.

Duration	Teacher's Activity	Learner's Activity
Introduction 5 Minutes	In today's lesson we will try to pass electricity through compounds in the liquid state. I want you to form groups and do the practical following the guide on page 207.	students would be listening.

Teaching strategies	**Practical work and group discussion**	**States the TM as practical work & group discussion**
Teachers' curricular knowlegde	**States the previous knowledge**	**Gives prior knowledge as electricity and insulators, pure liquid and solution**
Teacher' curricular knowledge	**Gives lesson objectives**	**States the focus of the lesson**

Duration	Teachers Activity	Learners Activity
lesson development 30 minutes	Teacher distribute the guidelines for the practical and ask groups to pick a group leader to come get the apparatus	students would be receiving the guidelines and the leader would be collecting the apparatus
	Guideline: 1. Set the apparatus as shown in the figure below	students would assemble the apparatus. students would be following the guideline carrying out the procedure.

2. Make out a table for your results like the table below

Substance	conduction state	Observation on Anode	cathode

3. half fill a crucible with Copper chloride and gently heat it.
4. Set up the circuit as shown above, and keep the substance molten.
5. Record your observations.

Teaching strategies	Experimental	experiment

Duration	Teacher's Activity	Learners Activity
	Teacher ask's what happens during electrolysis?	Student answer clorine gas is formed at the anode and copper metal @ the cathode. molten lithium chloride contai two kinds of ion Cu^{2+} and Cl
	Teacher elaborates: When the circuit is completed electrons from the power supply go to the cathode and make it − charged. hence the overall effect is that electrons are continually removed from the cathode and an equal number are fed in at the anode, from which they return to the d.c source and complete the circuit. NOTE: Electrons do not actually pass through the liquid, they appear to do so and complete the circuit.	students take notes
Conclusion 5	In this process the ions act as electrons carriers and are chemically changed in the process and these can be summarised by equations at cathode: at the anode:	

	Teacher's curricular knowledge	Discussion of content	
(handwritten lesson plan above)	**Teacher's curricular knowledge**	**Discussion of content**	

APPENDIX V

Questionnaire to be completed after using CBS 1. Describe what you intend students to learn in this topic by using this simulation? Want the learners to actually see ions migrating to the different electrodes 2. Explain the importance of learners to use this computer simulation? It is important to learners because they are able to see ions migrating to the different electrodes and also products being form at the electrodes 3. Describe what else do you know about computer simulations that students do not need to know? Learners do not need to know how the computer Based Simulation is set-up 4. Describe the challenges associated with teaching using computer simulations? Computer Based Simulation is suitable for a small group. Equipment used maybe expensive for the school to purchase 5. What knowledge can you share about CS that influence your teaching of this topic? Computer Based Simulation ~~is suitable~~ motivate and reinforces learners' learning especially those learners who are visual 6. Describe any other factors that influence your teaching of this topic? Other factors maybe pre-knowledge e.g. conduction of electricity and properties of ionic compounds 7. Describe teaching procedure will you use with the CBS ? Computer Based Simulation is student centred and it can be used easily ~~on~~ used ~~with other~~ in conjuction with other teach strategies 8. Explain strategies will you use to ascertain learners conceptions of the topics? Question and answer can be used because it allows learners to express themselves as far as the topic is concerned 9. Explain how you the use of CBS contribute to the lesson development? It contributes positively because learners' participation in the lesson is maximised A lot of ground is covered within a short space of time Source: Loughran, Mullhall and Berry (2004) 37	**1.Advantages of CBS** **2.Advantages of CBS** **4.Challenges to using CBS** **5.Advantages of CBS** **6.teacher curricular knowledge** **8. teaching strategies** **9.advntage of CBS**	**1learners see ions** **2learners are able to visualise ions** **4. small group, equipment expensive** **5. motivate, reinforce** **6.Previous knowledge: conduction of electricity and properties of ionic compounds** **8. question and answe** **9maximise participation**	**1.Learners see ions migrate** **2.Learners see ions migrate** **4.Large numbers and equipment is expensive** **5.motivate** **6.Gives pre-requisite knowledge** **8. question and answer**

	Teaching strategy **Teaching strategy**		

APPENDIX W

Questionnaire to be completed before observation

The purpose of this research is to find the difficulties associated with teaching of electrolysis. The information will be used for research purposes only: your responses will be treated with confidentially.

Section A: Demographic information
Table 1: Background information of participants

Name:	
Qualifications:	BSc & PGCE
Gender:	MALE
Teaching experience:	24 years

Section B

Curricular saliency
Describe how you would prove that hydrogen and chlorine are the gases evolved at the electrodes during the electrolysis of concentrated hydrochloric acid?
For hydrogen use a lighted splint, it burns with a pop sound ie hydrogen. For chlorine, it bleaches moist blue and red litmus paper

2. This question involves three elements, A, B and C from the following list:
aluminium oxide, carbon, copper (II) oxide, sulphur, sodium carbonate, sodium chloride, lead (II) oxide

Substance	appearance	conduction of electricity	molten in water	products at electrodes when molten +pole	-pole
A	dark grey powder	Yes	insoluble	none	none
B	white crystals	Yes	yes	chlorine	sodium
C	yellow powder	No	insoluble	none	none

Use the list and the table above to suggest possible identities for A, B and C.
C - Carbon B - Sodium Chloride C - Sulfur

3. Describe what you would observe on the anode and on the cathode during and after the electrolysis of copper (II) sulfate using copper electrodes.
Copper metal will be coated on the cathode and hydrogen at the anode

2

Teachers' curricular knowledge	**Content knowledge**	

4. Fill in the blanks by adding one word in each open space. Solid sodium chloride will not conduct electricity. This is because the…IONS……in the crystal are not free to move. When the solid is…heated……… strongly, it will…melt……….and it will then conduct electricity. If carbon electrodes are used in the electrolysis of molten sodium chloride,…Chlorine……….is released at the anode and…hydrogen…….at the cathode. **Section C** **Pedagogical content knowledge** 1. What do you intend students to know in this topic?? - that ionic solutions conducts electricity - electrolysis can be used as a separating technique - industrial application of electrolysis - electroplating and its use in extraction of metals 2. Why is it important for students to know this? - so that learners appreciate electrolysis and to look at how electrolysis addresses local issues 3. What is the previous knowledge needed for electrolysis? - Practical - Question and answer - Demonstration 4. Which teaching strategies do you use in teaching electrolysis? - properties of ionic and covalent compounds - solubility 5. What are the limitations connected with teaching this topic? - laboratory chemicals and equipment unavailability 6. Describe any other factors that influence your teaching of this topic? - availability of chemicals, equipment and learners with a science inclination 7. Describe knowledge about learners that influence your teaching? - full participation of learners / full involvement 8. Explain strategies will you use to ascertain learners conceptions of the topics? - giving questions for learners to answer, asking questions and giving a test Source: Loughran, Mullhall and Berry (2004) 3	**1.Teacher' curricular knowledge** **2.Teacher' curricular knowledge** **3.Teacher' curricular knowledge** **4.Teaching strategies** **5.Challenges to using CBS** **6.challenges to using CBS** **7teaching strategies** **8.teaching strategies**	**1.Content knowledge** **2.Content knowledge and application** **3.properties of ionic and covalent compounds** **4. practical, Q&A, Demonstration** **5.chemicals & equipment, learners** **6chemimals and calibre of learner** **7full participation** **8questioning**	**1.Shows that he considers both the content and application to be imporatant**

School : Loreto National High Class Size : 48 Subject : Chemistry Boys 24 Class : Form 4 Girls 24 Topic : Electricity and Chemistry (electrolysis) Date : 26/06/2017 Period : 6+7 [11:40 - 13:00 hrs] Teaching method : Question and answer Teaching aids : Video Prior knowledge Students should know about conductors of electricity and insulator students should have learnt about the differences between pure liquid and solution Lesson objectives : By the end of the lesson learners should be able to : a) Describe electrolysis b) Draw a labelled circuit diagram for an electrolysis of copp[er] chloride (aqueous solution) between inert electrodes (platinum or carbon) c) Describe electrolysis in terms of the ions present and reacti[ons] at the electrodes in examples given d) State the general principle that metals or Hydrogen are formed at the negative electrode and that oxygen or halogens are formed at the positive electrode Duration | Teacher's activity | learner's activity introduction | Teacher will instruct learners to watch a video and pay more attention to details of the video because later the teacher | learners will watch the video attentively	1.Teaching strategies Teacher' curricular knowldge Teacher' curricular knowledge	1.Question and answer CBS 2.conductors Of electricity Difference between Pure liquid and solution Lesson objective

	will ask questions based on the watched video			
Lesson development	Teacher will ask learners to give a summary of what they have seen	Anticipated answer		
	b) which substance was deposited at the cathode?	Anticipated answer		
	c) state and explain the difference between the electrolysis using carbon electrodes and that when using copper electrodes	Anticipated answer	**Teaching strategies**	
	d) suggest two purposes for which the copper anode could be used in this experiment	Anticipated answer	**Teaching strategies**	
	e) Give the equation for the electrode reaction	Anticipated answer	**Teaching strategies**	
Conclusion				

Questionnaire to be completed before observation

The purpose of this research is to find the difficulties associated with teaching of electrolysis. The information will be used for research purposes only: your responses will be treated with confidentially.

Section A: Demographic information
Table 1: Background information of participants

Name:	
Qualifications:	BSc + PGCE
Gender:	F
Teaching experience:	15 years

Section B

Curricular saliency
Describe how you would prove that hydrogen and chlorine are the gases evolved at the electrodes during the electrolysis of concentrated hydrochloric acid?
By bringing a glowing and a lighted splint. A glowing splint relights in oxygen and a lighted splint burns with a 'pop' sound

2. This question involves three elements, A, B and C from the following list:
aluminium oxide, carbon, copper (II) oxide, sulphur, sodium carbonate, sodium chloride, lead (II) oxide

Substance	appearance	conduction of electricity	molten in water	products at electrodes when molten +pole	-pole
A	dark grey powder	Yes	insoluble	none	none
B	white crystals	Yes	yes	chlorine	sodium
C	yellow powder	No	insoluble	none	none

Use the list and the table above to suggest possible identities for A, B and C.
A = Copper (II) oxide B = Sodium Carbonate C = Sulfur

3. Describe what you would observe on the anode and on the cathode during and after the electrolysis of copper (II) sulfate using copper electrodes.
Anode = chlorine, this is a positive electrode so negative will be attracted
Cathode = hydrogen is positive and found in the negative electrode

2

(questionnaire above)	Teacher' curricular knowledge	**Gives tests for oxygen and hydrogen instead of chlorine**

4. Fill in the blanks by adding one word in each open space. Solid sodium chloride will not conduct electricity. This is because the……ions……..in the crystal are not free to move. When the solid is….heated…….. strongly, it will…melt……..and it will then conduct electricity. If carbon electrodes are used in the electrolysis of molten sodium chloride,…Chlorine………is released at the anode and….Sodium……..at the cathode. **Section C** **Pedagogical content knowledge** 1. What do you intend students to know in this topic?? extraction of Electrolysis, ~~produce~~ Aluminium, manufacture of chlorine 2. Why is it important for students to know this? To understand electrolysis application in electroplating especially in the car industry 3. What is the previous knowledge needed for electrolysis? Electricity in physics. Gaps in the syllabus. A huge gap is existing between JC and O-level. 4. Which teaching strategies do you use in teaching electrolysis? Experimentation, Demonstration, Discussion, Questioning 5. What are the limitations connected with teaching this topic? Ionic bonding which is done in chapter 5, so learners who had problems had no foundation. Some learners are not interested. 6. Describe any other factors that influence your teaching of this topic? Not very confident in electricity unable to identify concrete information from learner 7. Describe knowledge about learners that influence your teaching? Pre-requisite information and unable to meet the teachers demands 8. Explain strategies will you use to ascertain learners conceptions of the topics? Work sheets after each activity (laboratory) Copy and complete exercises and Tests at the end of the topic Source: Loughran, Mullhall and Berry (2004) 3	**Teachers' curricular knowledge** **Teacher' curricular knowledge** **Teacher' curricular knowledge and challenges to using CBS** **Teaching strategies** **Teacher'curricular knowledge and challenges to using CBS** **Teacher' curricular knowledge and teachers' attitude** **Challenges to using CBS and teachers'**	**1 and 2 she mentions applications, no reference to microscopic chemical processes** **3 is aware of importance of curricular saliency** **4gives the teaching strategies she uses** **5 says that if learners missed basics will struggle** **6. accepting that she is not confident in the topic indicating that she has limited curricular**

	curricular knowledge	**knowledge** **7 mentions the importance for learners to have pre-requisite knowledge**

APPENDIX Z

Questionnaire to be completed after using CBS 1. Describe what you intend students to learn in this topic by using this simulation? -Draw a labelled diagram for an electrolytic cell using the terms anode and cathode -Outline the manufacture of Chlorine and Sodium hydroxide 2. Explain the importance of learners to use this computer simulation? Visualisation of the concepts especially movement of ions, it concretises abstract concepts 3. Describe what else do you know about computer simulations that students do not need to know? ~~They do~~ Simulations ~~cater~~ cater/accommodate a few learning styles. 4. Describe the challenges associated with teaching using computer simulations? Availability in the schools. Some schools have access, other school do not have 5. What knowledge can you share about CS that influence your teaching of this topic? - learners are interested more than they are interest on chalkboard writing 6. Describe any other factors that influence your teaching of this topic? Previous knowledge, Chapter on nomenclature Electricity from physics, so many concepts in one topic 7. Describe teaching procedure will you use with the CBS ? High lighting areas of importance before and questioning after the simulations 8. Explain strategies will you use to ascertain learners conceptions of the topics? High order questioning, discussion and worksheets 9. Explain how ~~you~~ the use of CBS contribute to the lesson development? CBS make lesson plan to be quick and effect. It is difficult to prepare and get the apparatus sometimes. Source: Loughran, Mullhall and Berry (2004) 41	**1.teacher' curricular knowledge** **2.Advantage of CBS** **4.Challenges to using CBS** **5. advantages of CBS** **6.teacher' curricular knowledge**	**1.gives what learners have to know** **2.Visualisation of ions and simplifies abstract concept** **4. accessibiltity of computers** **5. raises learners' interest compared to traditional methods** **6.concepts which link with**

	7.Teaching strategies	**electrolysis** **7.class discussion after using CBS**

APPENDIX AA

SCIENCE DEPARTMENT LESSON PLAN

DATE: .... FORM: .... TIME: from .... to .... DURATION: 40 minutes.

TOPIC: Electrolysis SUBTOPIC: Electrolysis of water

LESSON OBJECTIVES: Learners will be able to: – Identify ions in water
– write observations in the Hoffman's Voltameter (ratio of gases).
– write the cathode and anode reactions

TEACHING AIDS: Electrolysis computer simulations

METHOD(S): Expository and questioning

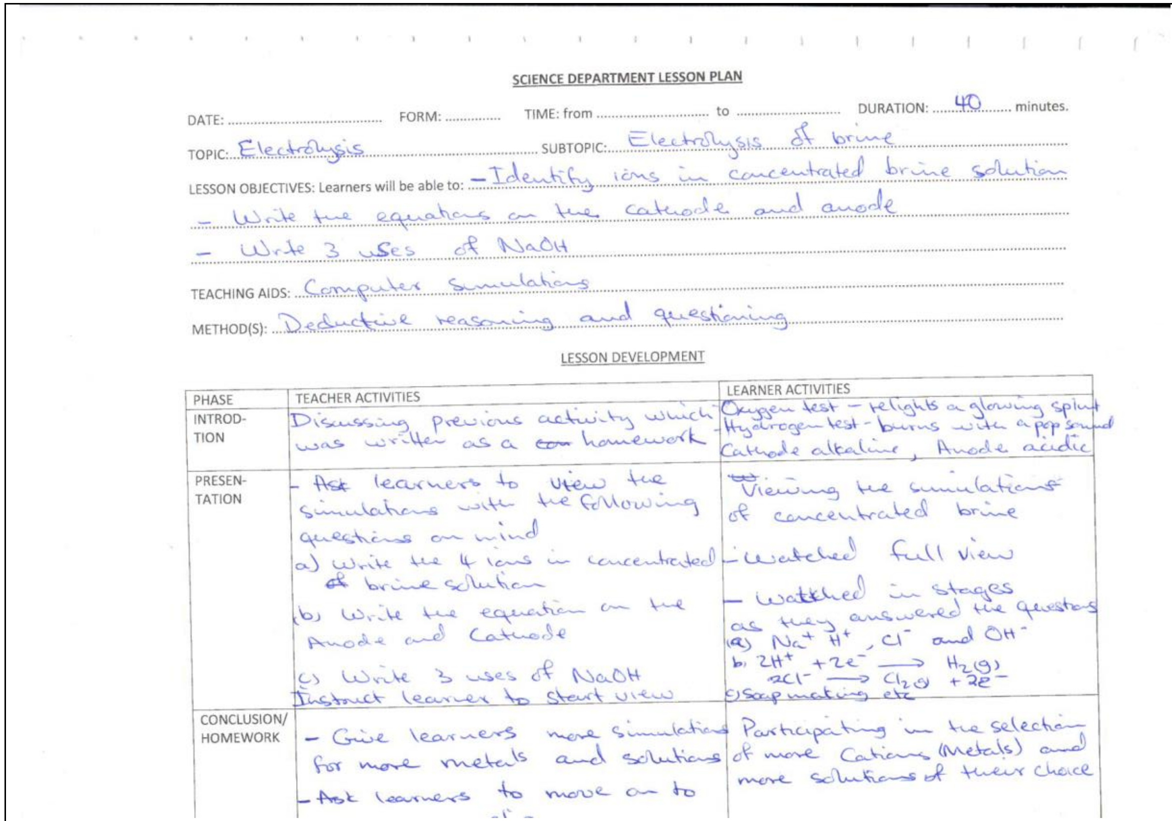
LESSON DEVELOPMENT

PHASE	TEACHER ACTIVITIES	LEARNER ACTIVITIES
INTRODUCTION	– Recapping on the last lesson by asking questions	– Responding and answering the questions
PRESENTATION	– Introducing electrolysis of water – Ask learners to write observations in the a) Cathode b) Anode – Ask learners to also observe and estimate the Oxygen : hydrogen	Identifying the relevant simulation Cathode : Hydrogen gas Anode : Oxygen gas Hydrogen : Oxygen 1 : 2
CONCLUSION/ HOMEWORK	– Ask learners to write the half reactions in the c. i) Cathode ii) Anode	i) $2H^+ + 2e^- \rightarrow H_2(g)$ ii) $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$

Teacher' curricular knowledge	**Gives what learners are expected to know**
Teaching strategies	**Linking with previous lessom**
Teacher' curricular knowledge	**Content of electrolysis**
	What is considered as main points in the lesson

LESSON EVALUATION: Learners had observation difficulties. Teaching methods were switched from expository to discussion /think-pair share. Learners were given a homework i) Describe a test for hydrogen and for oxygen ii Predict the PH nature on the ~~anoter~~ anode and Cathode TESTS FORM: .... TOPIC: .... FORM: .... TOPIC:	**Teacher' curricular knowledge**	**Key points of the lesson**

APPENDIX AB



SCIENCE DEPARTMENT LESSON PLAN

DATE: .... FORM: .... TIME: from .... to .... DURATION: 40 minutes.

TOPIC: Electrolysis SUBTOPIC: Electrolysis of brine

LESSON OBJECTIVES: Learners will be able to: – Identify ions in concentrated brine solution
– Write the equations on the cathode and anode
– Write 3 uses of NaOH

TEACHING AIDS: Computer simulations

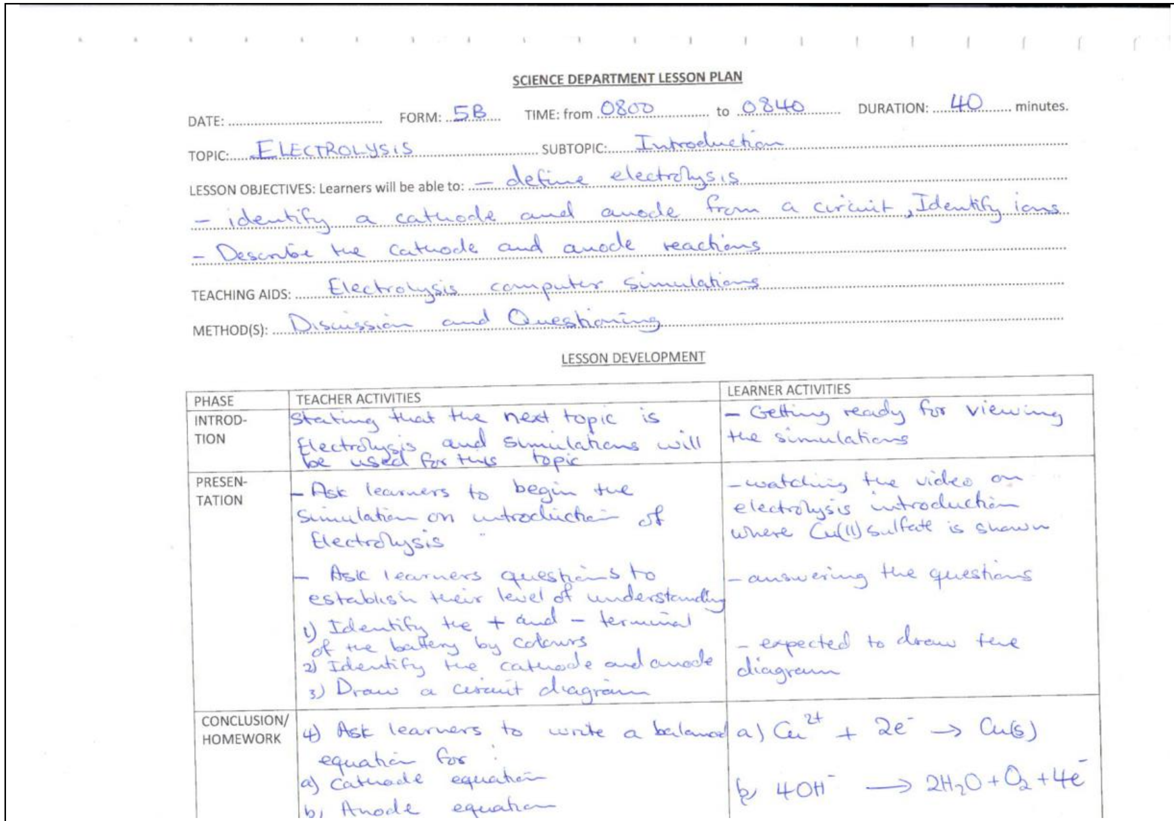
METHOD(S): Deductive reasoning and questioning

LESSON DEVELOPMENT

PHASE	TEACHER ACTIVITIES	LEARNER ACTIVITIES
INTRODUCTION	Discussing previous activity which was written as a ~~con~~ homework	Oxygen test – relights a glowing splint Hydrogen test – burns with a pop sound Cathode alkaline, Anode acidic
PRESENTATION	- Ask learners to view the simulations with the following questions on mind a) Write the 4 ions in concentrated ~~of~~ brine solution (b) Write the equation on the Anode and Cathode c) Write 3 uses of NaOH Instruct learner to start view	Viewing the simulations of concentrated brine - Watched full view - Watched in stages as they answered the questions (a) Na^+ H^+, Cl^- and OH^- b) $2H^+ + 2e^- \longrightarrow H_2(g)$ $2Cl^- \longrightarrow Cl_2(g) + 2e^-$ c) Soap making etc
CONCLUSION/ HOMEWORK	- Give learners more simulations for more metals and solutions - Ask learners to move on to	Participating in the selection of more Cations (Metals) and more solutions of their choice

Teacher' curricular knowledge	**What she intends learners to know**
Teaching strategies	**States the teaching strategies she intends to use**
Teacher' curricular knowledge	**Recaps what was covered on previous lesson**
	Allows the learners to work on CBS, guiding them
Teaching strategies	**Allows learners to work on their own**

LESSON EVALUATION: 70% of the group members were able answer the questions well. ~~And~~ the summary and miscellanous activity was to be done at home, or study time. TESTS FORM: .... TOPIC:.......... FORM: .... TOPIC:		

<table>
<tr>
<td>


SCIENCE DEPARTMENT LESSON PLAN

DATE: .... FORM: 5B TIME: from 0800 to 0840 DURATION: 40 minutes.

TOPIC: ELECTROLYSIS SUBTOPIC: Introduction

LESSON OBJECTIVES: Learners will be able to: – define electrolysis
– identify a cathode and anode from a circuit, Identify ions.
– Describe the cathode and anode reactions

TEACHING AIDS: Electrolysis computer simulations

METHOD(S): Discussion and Questioning

LESSON DEVELOPMENT

<table>
<tr><th>PHASE</th><th>TEACHER ACTIVITIES</th><th>LEARNER ACTIVITIES</th></tr>
<tr><td>INTRODUCTION</td><td>Stating that the next topic is Electrolysis and simulations will be used for this topic</td><td>– Getting ready for viewing the simulations</td></tr>
<tr><td>PRESENTATION</td><td>– Ask learners to begin the simulation on introduction of Electrolysis
– Ask learners questions to establish their level of understanding
1) Identify the + and – terminal of the battery by colours
2) Identify the cathode and anode
3) Draw a circuit diagram</td><td>– watching the video on electrolysis introduction where Cu(II) sulfate is shown
– answering the questions
– expected to draw the diagram</td></tr>
<tr><td>CONCLUSION/ HOMEWORK</td><td>4) Ask learners to write a balanced equation for:
a) Cathode equation
b) Anode equation</td><td>a) $Cu^{2+} + 2e^- \rightarrow Cu(s)$
b) $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$</td></tr>
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<td>

Teacher’ curricular knowledge

Teaching strategies

Teacher’ curricular knowledge

Teacher’ curricular knowledge
</td>
<td>

What the learners have to learn

She states the teaching strategies

Introduces the topic
</td>
</tr>
</table>

LESSON EVALUATION	~~First time~~ - Learners had difficulty ; the simulations were moving faster. Re-watching improved the learning and teaching session - Learners still have issues / problems in naming of ions from an ionic substances, more remedial activity is required.

TESTS

FORM: .... TOPIC:..

FORM: .... TOPIC: ....

Questionnaire to be completed before observation

The purpose of this research is to find the difficulties associated with teaching of electrolysis. The information will be used for research purposes only: your responses will be treated with confidentially.

Section A: Demographic information
Table 1: Background information of participants

Name:	
Qualifications:	BSc with Education
Gender:	Female
Teaching experience:	12 years

Section B

Curricular saliency
Describe how you would prove that hydrogen and chlorine are the gases evolved at the electrodes during the electrolysis of concentrated hydrochloric acid?
Test for the presence of the gases $H_2(g)$ → Burns with a pop sound
$Cl_2(g)$ → bleaches litmus paper

2. This question involves three elements, A, B and C from the following list:
aluminium oxide, carbon, copper (II) oxide, sulphur, sodium carbonate, sodium chloride, lead (II) oxide

Substance	appearance	conduction of electricity	molten in water	products at electrodes when molten +pole	-pole
C → A	dark grey powder	Yes	insoluble	none	none
NaCl → B	white crystals	Yes	yes	chlorine	sodium
S → C	yellow powder	No	insoluble	none	none

Use the list and the table above to suggest possible identities for A, B and C.

3. Describe what you would observe on the anode and on the cathode during and after the electrolysis of copper (II) sulfate using copper electrodes.
The cathod becomes thicker than the anode

2

Teacher' curricular knowledge	**Content knowledge**

4. Fill in the blanks by adding one word in each open space.

Solid sodium chloride will not conduct electricity. This is because the....Particles.....in the crystal are not free to move. When the solid is......heated..... strongly, it will....move.......and it will then conduct electricity. If carbon electrodes are used in the electrolysis of molten sodium chloride,....chlorine......is released at the anode and....H_2..............at the cathode.

Section C

Pedagogical content knowledge

1. What do you intend students to know in this topic??
   - Products of electrolysis
   - Products at the anode and cathode
   - Electrode reactions
2. Why is it important for students to know this?
   This helps the pupils to understand the topic / concepts of electrolysis
3. What is the previous knowledge needed for electrolysis?
   - Ionic bonding
   - Electron movement
4. Which teaching strategies do you use in teaching electrolysis?
   - Question and answer
   - Demonstration
5. What are the limitations connected with teaching this topic?
   Equipment to carry out the simple electrolysis technique
6. Describe any other factors that influence your teaching of this topic?
   The syllabus content to be covered
7. Describe knowledge about learners that influence your teaching?
   Level of students to be taught
8. Explain strategies will you use to ascertain learners conceptions of the topics?
   - Topic test questions done individually and in groups / pair.

Source: Loughran, Mullhall and Berry (2004)

3

1.Focus on the content

2Concerned about content

3previous khowledge relevant to electrolysis

4.question and answer, demonstration

5shoratge of equipment

8topic test

APPENDIX AE

7.2 **Questionnaire to be completed after using CBS** 1. Describe what you intend students to learn in this topic by using this simulation? The process of Electrolysis, the movement of the electrons, change in current, voltage and the mass of the electrodes 2. Explain the importance of learners to use this computer simulation? To visualise the process, observing what changes takes place practically 3. Describe what else do you know about computer simulations that students do not need to know? That computer simulations is/can be used in companies for production and has to be the exact with real situation its representing to avoid misconc 4. Describe the challenges associated with teaching using computer simulations? -The need for enough computers to cater for all the students 5. What knowledge can you share about CS that influence your teaching of this topic? -Its a very effective way of teaching and it keeps all the learners actively participating 6. Describe any other factors that influence your teaching of this topic? It needs more time to teach using the CS and will be impossible to use everyday and complete the syllabus 7. Describe teaching procedure will you used with the CBS ? Teacher demonstrated the use of CBS and discussed with the pupils then have practical as pupils used the CBS 8. Explain strategies ~~will you~~ used to ascertain learners conceptions of the topics? A test was given and pupils performed better on the topic questions 9. Explain how you the use of CBS contribute to the lesson development? They made the theoretically explained concept more clear as pupils could practically carry out the experiment observe and record the results Source: Loughran, Mullhall and Berry (2004) 37	**1teacher' curricular knowldge** **2.advantage of CBS** **4challenges to using CBS** **5advantages of CBS** **challenges to using CBS** **7teaching strategies** **8teaching strategy**	**1.content of electrolysis** **2.visualize the process of electrolysis** **4shortage of computers** **5. learners engagement improves** **6.takes time** **7practical, demonstration and discussion** **8test**

APPENDIX AF

Topic: Electricity and Chemistry   Form 5

Sub Topic: Defining Electrolysis

Date: 08-08-20181

Time: 08.00 – 08.35

OBJECTIVES: By the end of the lesson pupils should be able to:

- describe Electrolysis
- Draw a labelled diagram for an electrolytic cell, using the terms electrode, electrolyte, anode and cathode

Pre-requirest knowledge: Ionic compounds

Teaching materials: Computer simulated Models

STAGE	TEACHERS ACTIVITIES	PUPILS ACTIVITIES
INTRODUCTION	Teacher asks pupils to come up with the defination of electrolysis	The pupils attempt to define electrolysis
DEMONSTRATION OF ELECTROLYSIS	Teacher uses a computer simulated mode of electrolysis of $Cu(NO_3)_2$ using copper electrodes to help pupils understand the meaning of electrolysis	- Pupils observe the simulated electrolysis of $Cu(NO_3)_2$ using copper electrodes by the teacher - Pupils work in their groups and discuss giving the feed back.

Teacher' curricular knowledge	Given as bjectives
Teacher' curricular knowledge	Links lesson with previous lesson and
Teaching strategy	Teacher uses CBS and example of $CuNO_3$
	CBS and discussion

CONCLUSION — The teacher asks the pupils to describe what they have seen during the computer simulation — -The pupils will describe what they have seen -They came up with the correct definition of electrolysis EVALUATION -The pupils were excited by the computer simulation -It helped them to use the actual electron transfers at the electrodes -However a good number of the pupils uncomfortable with the change in approach -Computer simulations went a long way in bringing out some of the hidden concepts …		**Teaching strategy** **Adntages of CBS**	**Discussion** **Learners are able to visualise**

APPENDIX AG

Topic: Electricity and Chemistry   Form: 5
Sub Topic: Electrolysis
Date: 09-08-2018
Time: 08.35 – 09.10
OBJECTIVES: By the end of the lesson pupils should be able to:
- Describe the electrolysis of dilute sulphuric acid (as essentially the electrolysis of acidified water)

Pre-requisite knowledge: Definition of Electrolysis
Teaching Materials: computer Simulated Model

STAGE	TEACHERS' ACTIVITIES	PUPILS ACTIVITIES
INTRODUCTION	-The teacher asks the pupils to recall and recap what they learnt from previous lesson	-Pupils will make an effort to recall and recap what the learnt in the previous lesson
ELECTROLYSIS of $H_2SO_{4(aq)}$	-Teacher asks pupils to work in their groups to study the electrolysis of acidified water using the simulated model. -Teacher helps in the group discussion as she moves around the groups	-Pupils work in their groups of study and describe the computer simulated model on the electrolysis of acidified water -Pupils consult teacher on issues they do not understand

Teacher' curricular knowledge	**Stated as lesson objectives**
	Links with previous knowledge
Teacher's curricular knowledge	
	Discussion and assists in groups
Teaching strategies	

<table>
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<table>
<tr><td>CONCLUSION</td><td>Teacher ask pupils to give feed back on what they had observed
Teacher ask pupils to write individual report on the simulations</td><td>- Pupils give feed back to the teacher and the rest of the class
- Pupils write a report on their group work</td></tr>
</table>
<u>EVALUATION</u>
- Most pupils were ethusiastic about the simulations
- Generally, participation has improved
The computer simulations helped the pupils to understand better.
</td>
<td></td>
<td>Teaching strategies

Advantages of CBS</td>
<td>Discussion

Learners were enthusiastic

Participation</td>
</tr>
</table>

APPENDIX AG

Topic: Electricity and chemistry Form: 5
SubTopic - Electrolysis
Date: 10-08-2018
Time: 1400 - 1435
OBJECTIVES: By the end of the lesson pupils should be able to
- Describe the electrolysis of concentrated sodium chloride solution
- Give examples of industry that relies on electrolysis

Pre-requisite knowledge: Definition of Electrolysis

Teaching Material: computer simulated models

STAGE	TEACHERS ACTIVITIES	PUPILS ACTIVITIES
INTRODUCTION	- The teacher asks pupils to recap what they had learnt the previous lesson	- Pupils discuss and recap what they had done in the previous lesson
ELECTROLYSIS OF BRINE	Teacher asks pupils to work in groups to study the electrolysis of concentrated sodium chloride - Teacher supervises the group work and help whenever there is a need	Pupils work in their groups to study and observe the computer simulated model of the electrolysis of brine They give feedback on what they observed during lesson

CONCLUSION (PRACTICAL APPLICATIONS OF ELECTROLYSIS — The teacher asks pupils to work on identifying practical applications of electrolysis — - Class discussion on the practical applications of electrolysis -Pupils give examples of industries that relies directly on electrolysis EVALUATION Most pupils benefited from the use of the computer simulations - They seem to have been more positive in their approach However a lot still needs to be done in making them more comfortable to use the technology.		Advantages of CBS	More positive in their approach