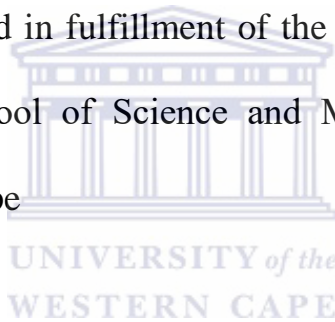


Effects of a Dialogical Argumentation Instructional Model on science teachers' understanding of capacitors in selected Western Cape Schools

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A research proposal submitted in fulfillment of the requirements for the award of Master's Degree in the School of Science and Mathematics Education at the University of the Western Cape



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Year : 2015

ABSTRACT

This study investigated 1) the conceptions on capacitors held by a group teachers in the Western Cape; 2) the effect of a dialogical argumentation instructional model on the teachers' conceptions on the capacitor; and 3) the teachers' perceptions on the implementation of this instructional model. The theoretical framework of the study was based on Toulmin's Argumentation Pattern (TAP) and Ogunniyi's Contiguity Argumentation Theory (CAT). The objective was to retrain science teachers in their awareness and understanding of the Nature of Science and Indigenous Knowledge Systems thereby enhancing their ability and efficacy in integrating science and Indigenous Knowledge Systems. The study involved workshop activities that included the teachers' Reflective Diary, interview sessions, and video-taped lesson observations. The study adopted a Case Study approach and the data was analysed both quantitatively and qualitatively. The findings of the study showed that: 1) the teachers held varying conceptions of the capacitor; 2) the teachers' conceptions of the capacitor improved after being exposed to the Dialogical Argumentation Instructional Model and 3) the teachers were dominantly in favour of the Dialogical Argumentation Instruction Model as a teaching method to be introduced at schools. The implications of the findings for school science and pedagogy were highlighted for closer observation.

DECLARATION

I declare that:

Effects of a Dialogical Argumentation Instructional Model on science teachers' understanding of capacitors in selected Western Cape Schools is my own work and people who have made any contribution in the compilation of this study have been acknowledged. It is the first time that this study will be submitted for a degree at the University of the Western Cape. All the sources that have been used or quoted have been acknowledged with full reference.



Lynn Goodman

Signed:

Date:

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DEDICATION

This thesis is dedicated to my late father, Patrick Michael Goodman who suddenly left this earth on 10 February 2014 to be reconciled with our Heavenly Father. My greatest inspiration, my Hero who always motivated me at all times to pull through and complete my study. I will always love you.



1952-2014

Rest in peace Daddy!!



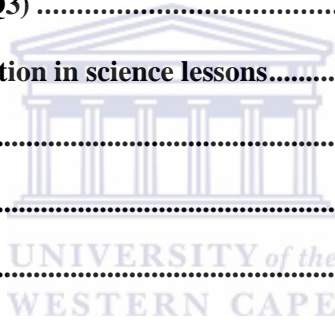
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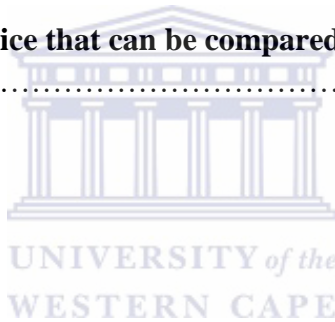
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DEFINITION OF ACRONYMS

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CA

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Department of Basic Education	20
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TAP

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TIMSS

The Trends in International Mathematics and Sciences Study 20

W

WCED

Western Cape Education Department 20



Effects of a Dialogical Argumentation Instruction Model on science teachers' understanding of capacitors in selected Western Cape Schools

Chapter1 Introduction to the study

1.0 Introduction

The main purpose of this study was to investigate what effect the Dialogical Argumentation Instruction Model (DAIM) will have on selected Western Cape teachers' understanding of capacitors. This study was done to raise teachers' interest in teaching complicated topics in physical sciences as well as to raise awareness regarding indigenous concepts that could be used in their teaching.

This is an introductory chapter of the study. It is divided into different sections as follows:

Section 1.1 presents the background of the study while section 1.2 is about the rationale of the study. Section 1.3 presents the research problem. The purpose of the study is presented in section 1.4 followed by section 1.5 which spells out the research questions while section 1.6 presents the theoretical framework adopted by the study. Moreover, section 1.7 presents the significance of the study and section 1.8 highlights the delimitations of the study. Finally, the chapter ends with a summary and organization of the rest of the thesis.

1.1 Background of the study

After the 1994 democratic elections, the education system in South Africa experienced a profound transformation, largely driven by constitutional imperatives, which stress that it is important to serve the needs of the country as a whole, as well as its people. This transformation was characterized by policy changes, influenced by international perspectives and global economic trends (Organization for Economic Co-Operation and

Development, 2008). For example, in 1997, a new Curriculum 2005 (C2005) was articulated in the Revised National Curriculum Statement of 2006.

The Science Curriculum also underwent transformation. Prior to 1994, science teaching encouraged passive learning. The teachers were largely occupied with dictating notes or writing on the chalkboard, while learners copied these notes verbatim. The learners did not have much opportunity to participate in knowledge construction in this process of rote learning. In other words, few higher cognitive abilities, such as application, analysis, synthesis and critical thinking were developed among learners. This resulted in learners failing to acquire the various science concepts taught in their classes. One such concept is that of Capacitors.

The concept of capacitors had been incorporated into the curriculum of physical sciences with the objective of making learners acquire knowledge of the various components that could be found in modern electronic circuits. This is especially so in view of the electronic revolution the world is undergoing. Capacitors perform a variety of functions in electronic circuits, such as filters and as devices for storing energy and releasing it very quickly when required. The learners experienced simple circuits at primary level whereby they learned the subject of electricity systematically (Duit and Rhoneck, 1997).

Many studies on resistors and other aspects of electricity were done in the past but none on capacitors.

Many studies (Aykutlu and Sen, 2011; Aykutlu and Sen, 2009, 2012; Carlton, 1999; Duit and Rhoneck, 1997; Gunstone et al., 2009; Karakuyu and Tuysuz, 2011; Kucukozer and Demirci, 2005; Kucukozer and Kocakulah, 2007; Miokovic, Ganzberger and Radiolic, 2012; Mulhall, McKittrick and Gunstone, 2001; Sencer and Eryilmaz, 2002; Sen and Aykutlu, 2008 Turgut, Gurbuz and Turgut, 2011; Yildirim, Yalcin and Sensoy, 2008 and Rhoneck, 1997; Suchai and Thasaneeya, 2012) indicated learners' difficulties in understanding electric current. Similarly, this seemed to be in the case with the understanding of a capacitor and its operations.

The Department of Basic Education (DBE) reported on the low results obtained for the topic on capacitors in the final matriculation physical sciences examinations (DBE, 2008; DBE, 2010). The Trends in International Mathematics and Sciences Study (TIMSS, 2003) showed that South African foundation (Grades 1-3) to senior phase (Grades 7-9) learners attained the lowest average test scores in both mathematics and science, compared to the other participating countries. The poor performance of Grade 12 learners in science is perhaps not surprising if viewed against the TIMSS study when the same learners were in the lower grades.

The National Senior Certificate (NSC) final Grade 12 examination results clearly indicated the poor performances of the learners in sections of the examination papers. The assessment report released by the Western Cape Education Department (WCED) for the particular district X of the various schools concerning the questions on capacitors showed that 12 out of 57 schools scored between 0-10%; 18 scored between 11-21%; eight scored between 22-32%; five scored between 33-43%; 11 scored between 44-54% and only three scored between 55-65% (DBE, 2010). The average percentage achieved by learners in the question set on capacitors for all the schools in the Western Cape area was a meagre 27% (DBE, 2010). The Chief Marker's Publication Report for 2010 (DBE, 2010) indicated how poorly Grade 12 learners had answered the questions on capacitors.

The poor performance of learners is possibly a reflection of the way in which the subject matter is taught. Mistakes made by teachers about the electricity subject may cause learners not to comprehend these concepts (Cildir, 2005). There are also many misconceptions on capacitors which teachers impart to the learners due to their lack of understanding regarding the topic. This could also be an indicator that teachers themselves might have a poor understanding of capacitors and therefore the study was conducted to identify possible problem areas and redress this. This eventually involved retraining of teachers on this topic. Remedial measures were also implemented that focused on how the teachers could be empowered to carry out a science lesson in a social constructivist manner. This study focused on using Dialogical Argumentation Instruction Model (DAIM) as a vehicle of instruction. An argumentation instructional approach was chosen because several studies

(Erduran, Simon & Osborne, 2004; Simon, Erduran & Osborne, 2006; Ogunniyi, 2004, 2007a & b) have shown it to be effective for equipping teachers with the necessary content and pedagogical content knowledge.

1.2 Rationale of the study

The concept of capacitors which is the focus of this study is one of the challenging topics in the physical sciences syllabus of the South African National Curriculum at grade 12 level.

At the beginning of this study, the researcher identified 15 schools from District X in the Western Cape that obtained low marks on the question of capacitors in their National Senior examinations. These results, as mentioned before, were indicated by the Chief Markers Report (DBE, 2010). During that time of the study, the researcher performed her daily duties as a Curriculum Adviser for physical sciences and decided to visit these 15 identified schools. Monitoring was one of the roles of a Curriculum Adviser in the Western Cape. The focus of the visit was to monitor mainly how teachers presented their lessons on capacitors and also to investigate how learners understood the topic.

The researcher found that during the visits, the teachers showed no or very little understanding of capacitors and its operations. This revealed how to address low marks in the topic on capacitors by the possible retraining of teachers. It was necessary to introduce them to the Dialogical Argumentation Instruction Model (DAIM), a model that will make the teachers active in classroom discourses. It was very difficult to obtain information from the literature of any studies done on the topic of capacitors with respect to the conceptions held by teachers. Since capacitors belong to the broad topic of electricity, a number of studies indicated various misconceptions or problems in dealing with electricity such as that:

- The current as well as the concept of resistance causes misconceptions amongst learners (Gilbert & Watts, 1983).

- Cohen, Eylon and Ganiel (1983) identified current, potential difference and the incorrect use of the $V=IR$ relationship based on Ohm's law to be problematic amongst learners.

These studies made it clear that South African learners and teachers may have problems in understanding physics concepts such as capacitors in this case. The study was thus conducted in order to retrain teachers on this topic. The basis of the training focused on empowering the teachers to carry out a science lesson in a social constructivist manner using DAIM as a vehicle of instruction. The focus and emphasis of the training was on social and communication skills, as well as exploration to gain better understanding of the topic on capacitors. The teacher would have the ability to anticipate and respond to typical learner patterns of understanding and misunderstandings within the content area. This approach provided teachers the intellectual space to freely express their views without feeling intimidated, to clear their doubts and even change their minds after developing a deeper understanding of the issues at stake (e.g. Erduran, Simon & Osborne, 2004; Simon, Erduran & Osborne, 2006; Ogunniyi, 2004, 2007a & b).

Since the inception of the curriculum after 1994, many voices of dissent were raised in South Africa. The African Christian Action (2002) voiced their objections based on religion; so did other Christian pressure groups (Chrishols, 2003). The African Christian Democratic Party (ACDP) fought the education battles during parliamentary sessions, the reason being that the secularization of the curriculum made all religions in South Africa equal whereas in the past, the Christian religion was dominant across all schools in the country. As referring to this study, the author's objective is to raise awareness of a drastic measure that needed to be put in place in order to improve the teaching and learning of science education across all schools in South Africa. The aim with the improved teaching and learning in science education, is to prepare holistic thinkers.

When former President De Klerk (2010) was asked the question on education in South Africa: "Are we still on course?" he responded "No"(p.1). He further commented that the new OBE curriculum would most probably work in advanced First World Countries, but not

in South Africa. He further stressed that most of the schools in South Africa were not well-resourced before the new Outcome Curriculum was implemented. Indeed, the experiences with regard to implementation of the new OBE Curriculum prompted a review in 2000 (DBE, 2011). This led to the first curriculum revision, called the Revised National Curriculum Statement (RNCS) Grades R to 9 and the National Curriculum Statement (NCS) Grades 10 to 12 (2002). Some challenges remained and resulted in a second revision in 2009.

The need for curriculum changes since the first acceptance of the OBE model was based on many learning problems in various school topics. It is hoped that through this study, physical sciences teachers will be challenged to use new methods as well as ways to enhance their knowledge of challenging physics topics. It is also hoped that the learners will benefit from the teaching of the subject matter through DAIM so that their knowledge and examination results could be improved. This study can assist other curriculum advisers in training teachers in DAIM as a teaching method to make challenging topics such as the capacitors in this study more understandable to the learner. The importance of conceptual understanding of capacitors later on in the study was strengthened in the teachers involved with the study.

1.3 Research problem

The study of capacitors forms part of the Grade 11 curriculum but is examinable in the final Grade 12 year during the National Senior Certificate (NSC) examination. The Grade 12 results were one of the indicators used by government and other stakeholders to determine whether or not the education system is succeeding. The average percentage obtained by the Western Cape Province in Paper 1 of the National Paper written in 2010 (which included capacitors) was only 36.1% (DBE, 2011) and as mentioned before, the score obtained by the schools in the Western Cape for the section on capacitors only, was 27%. This poor response of the learners to the questions on capacitors in the National Senior Certificate (NSC) examination was a great concern (DBE, 2010, 2011, 2012).

The lack of teacher training could have been one of the factors that contributed to the poor performances of learners' achievements in the topic of capacitors at the NSC Examination (DBE, 2010). The objective of the Dinaledi concept was to improve the mathematics and physical sciences results. Schools received special grants to improve science and mathematics laboratory facilities. During July 2011, the educational authorities organized training for teachers. Similarly, special winter schools offering tuition by expert teachers were held for Grade 12 physical sciences learners.

Compulsory provincial common assessments were organized to improve the performances of learners doing physical sciences (DBE, 2011). These common assessments included examination question papers set up by the subject specialist. It was expected of all the schools in the particular region to write the same question paper in order to maintain the same acceptable standard. The standard referred to the fact that the questions were balanced and not all low-ordered questions.

Despite all these efforts, such as laboratory resources, special tutorial sessions at schools, Telematics Project involving live broadcast productions on different topics for the Grade 12 physical sciences learners, the poor results continued to be a great cause of concern (DBE, 2011).

As mentioned before, at the beginning of this study, 15 teachers from 15 different schools of District X in the Western Cape area in close reach of the researcher were visited. Through many observations and discussions with the teachers, it was observed that most of the teaching did not engage in higher order thinking skills of the learners. Higher Order Thinking (HOT) involves the learning of complex judgemental skills such as critical thinking ([http://en.wikipedia.org/wiki/Higher-order thinking](http://en.wikipedia.org/wiki/Higher-order_thinking)). Critical thinking involves reasoning and critical judgement in order to change, reconstruct and rework the thinking process of the learner. The observations in those 15 schools indicated that many teachers had great difficulties in conducting their lessons on capacitors.

The following observations might have contributed to the learners' lack of knowledge:

- The lack of knowledge of capacitors and the teachers' inability to present the lesson on capacitors.
- The attempts to transfer the information (word for word) from the textbook to the learners without any explanation.
- Teachers did not have an example of a capacitor to show the learners.
- Teachers were unable to practically demonstrate how a capacitor is connected in an electric circuit. They were unable to show how a capacitor charges up and how it is discharged.
- Teachers were unable to explain the concept of the time constant for charging and discharging of the capacitors.
- No connection was made to the real world application of capacitors and its importance in electric and electronic circuits.

The Diagnostic Report of the NSC (DBE 2011) on the analyses of questions stated: "Owing to inadequate teaching and learning, learners presented muddled answers to straightforward questions" (p.116). This suggested that the teachers lack some content knowledge (CK) and pedagogical content knowledge (PCK). According to Lzadi (2012), many learners are like novices that see physics more as isolated pieces of information unrelated to the real world.

The problem areas identified by the researcher that caused concern among the teachers regarding their understanding of capacitors were the functioning of a capacitor, its role in electric circuits, how a capacitor is constructed and its applications. Similarly, learners in the classes of the 15 different teachers were asked questions in order to fathom their understanding of capacitors. The classroom visits highlighted the need for retraining on the topic as well as the need for employing alternate teaching strategies.

In order to improve the conceptual understanding of capacitors among the teachers, it was agreed by the author (acted as a Curriculum Adviser for physical sciences then at that time) to

(i) retrain teachers in the concept of capacitors and to (ii) introduce the teachers to a new teaching methodology that could have a positive impact on the learners' results. The researcher started off with training the 15 teachers in developing their pedagogical content knowledge (PCK) on the content of capacitors and new teaching methodology of DAIM, but unfortunately could not continue with further training and assessment with this particular group due to logistical reasons.

As the researcher relocated from District X to District Y, new subjects had to be selected. The researcher thought it best to do an intense case study with a sample that was easily accessible. This is called a convenient sample. A convenient sample is when the researcher uses the subjects who are available to participate in this study and are within easier reach of the researcher (stattrek.com/statistics/dictionary.aspx). The convenient sample consists of 4 teachers only who were in easy reach of the vicinity to which the researcher relocated.

Therefore in this study, the 15 teachers are regarded as the Initial Group of teachers. An Initial group is a group of people selected in an Initial study which is a mini version or a trial run done in preparation of the complete study (Van Teijlingen & Hundley; 2001:1). The 4 teachers are regarded as the Case Study Group of teachers. A Case Study Group are individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research.

The data collected from the Initial Group will be used in some cases to strengthen some of the findings of the Case Study Group regarding the model used and teachers' conceptual understanding of capacitors.

1.4 Purpose of the study

The purpose of this study was to investigate whether DAIM as a teaching methodology could be used to enhance the teachers' understanding of a capacitor. The focus was also to investigate whether it was possible to use DAIM to promote traditional knowledge or

indigenous knowledge (IK). Using DAIM would allow for alternative views of any topic chosen and discussed.

1.5 Research Questions

It was thus decided to address the following research questions:

- 1 What conceptions of capacitors do the teachers under the study hold?
- 2 What effect does DAIM have on the subject teachers' scientific and indigenous conceptions of capacitors?
- 3 What are the teachers' perceptions on the use of DAIM in the teaching of capacitors?

1.6 Theoretical framework of the study

Physical sciences investigate physical and chemical phenomena. This is done through scientific inquiry, application of scientific models, theories and laws in order to explain and predict events in the physical environment (DBE, 2011). A scientific inquiry involves making observations, formulating a hypothesis and conducting scientific experiments. The steps of the scientific method are to:

- Ask a question
- Do background research
- Construct a hypothesis
- Test your hypothesis by doing an experiment
- Analyze your data and draw a conclusion
- Communicate your results

In addition, to refine the above scientific approach, the researcher found it necessary to expose teachers to the idea of constructing an argument. An argument is the presentation of a reason or case which is constructed and recruited as support for the view being proposed. The teachers experienced scientific practices to be grounded in and applied to contexts that were familiar to them. The teachers became active in the construction and production of scientific knowledge through DAIM.

This process of DAIM also offers the opportunity to interact with scientific materials and with peers. Scientific inquiry requires provision of reasons in order to reach the conclusion. According to Browne and Keeley (2003), it is the reasons recruited in an argument that support the credibility of the conclusions. Therefore, in this DAIM model, when discussions and reasoning take place, automatically learners will be making claims and justifications in this study of what they believe as truth.

This study is therefore underpinned by the Argumentation framework, as espoused in Toulmin's (1958) Argumentation Pattern (TAP) and Ogunniyi's (1997) socio-cultural context, based on Contiguity Argumentation Theory (CAT). Ogunniyi's (1997) CAT plays a major role in this study since the study also involved indigenous knowledge, including logical and illogical reasoning.

1.6.1 Toulmin's Argumentation Pattern (TAP)

Toulmin's Argumentation Pattern (TAP) provides a framework for an argument. Within Toulmin's perspective, the individual does not necessarily construct a new understanding through the DAIM process, but rather engages in an argument to persuade others of the soundness of his/her already developed ideas (Toulmin, Rieke, & Janik, 1979). Toulmin's Argumentation Pattern (TAP) was used in this study, because it specifies the important elements of an argument commonly used in scientific discourse.

According to Toulmin (1958), logic is involved in and expressed by the way a person thinks and argues. This thinking has to do with logical reasoning. The researcher agreed with Toulmin because a subject matter, in this case physics, cannot be discussed or understood meaningfully without paying attention to the structure of arguments

employed to describe or explain a phenomenon. Krummheue (1995) defines an argument as “the intentional explication of the reasoning of a solution during its development or after it” (p.231).

In certain cases, the ‘intentional explication’ that Krummheue (1995) talks about is also referred to as a comological argument, following a single line of thought. In other cases, a number of people may take part in the reasoning process, thus allowing a number of contrasting lines to develop. The latter is often referred to as a dialogical argument. TAP can be used to analyze the structure of an argument and to indicate how a certain reasoning protocol has been used to support and establish a specific claim. TAP does not guarantee that the desired outcome would be achieved, though, because the “arguments are set out and presented in a sequence of conforming to certain basic rules” (Toulmin, 1958, p.43).

The researcher found the description of the elements of TAP informative and useful for the purpose of the study. Essentially, the basic elements of TAP are described below and it was expected of the teachers to provide their own examples based on their experiences:

- **Claim** – A statement or assertion made on a given subject matter that is “a conclusion whose merit we are seeking to establish” (Toulmin, 1958: 97).
- **Data** – The evidence adduced to support the claim, meaning it is all the “facts we appeal to as a foundation of the claim” (Toulmin, 1958: 97).
- **Warrants** – Explain or provide the link between the claim and the data. If the claim is challenged, data is supported by warrants, therefore there is justification made to link the data to the claim. The warrants depend on the context (Driver et al., 2000).
- **Backings** – Underlying assumptions or additional support to the warrant.
- **Qualifier** – The contingent conditions in which the claim can be taken as true; these represent limitations on the claim.

- **Rebuttals** – These specify the conditions when the claim will not be true and are contrary statements to the claim (Erduran, Simon and Osborne, 2004: 11).

Deploying TAP elements makes it easy for a teacher or a researcher to detect erroneous claims, inappropriate warrants or backings made in a discourse and to make the necessary corrections to false reasoning concerning a subject matter. Due to the complexity and sometimes overlapping nature of TAP elements, Erduran et al. (2004), modified the framework to three basic elements namely: claim; grounds (data, backing and warrants) and rebuttals.

However, as useful as TAP is for analysing the structure of an argument, it only deals with syllogistic or logical forms of deductive and inductive arguments. It does not address the illogical arguments and value-laden arguments essential in certain contexts, e.g. motivation, interests, appreciation, beliefs and other matters that impact on human reasoning and which may be justified in certain situations (Ogunniyi, 2004). For this reason, Ogunniyi (2007a & b) proposed what he termed the Contiguity Argumentation Theory (CAT).

1.6.2 Contiguity Argumentation Theory (CAT)

Ogunniyi (2004) proposed the Contiguity Argumentation Theory (CAT) in which the learners' beliefs and culture had an influence on the learning process. This is a dialogical framework that offers both logical and illogical interpretations made by people in general, and learners in particular. The framework of CAT suggests that learners must first engage in an internal argument regarding a competing idea. According to CAT, two distinct co-existing thought systems, such as science and IKS tend to couple readily with each other to create an optimum cognitive state (Ogunniyi & Hewson, 2008). CAT incorporates cultural knowledge, for example when people with an indigenous worldview are confronted with a scientific worldview. CAT tends to encourage a meaningful co-existence between the two thought systems.

With CAT, conflicts arising from clashing ideas or cosmologies such as science and IKS could be resolved, for instance, through the process of accommodation,

integrative reconciliation and adaption. CAT makes it possible for ideas to come together in order to interact, overlap, or be in conflict with each other. One way of integrating such conceptions, according to Ogunniyi (2004), is to find a larger, synergistic conception. According to Ogunniyi (2005), DAIM can be used as an instruction method to integrate science with indigenous knowledge (IK). The teachers' perceptions about IKS changed. It improved their understanding regarding IKS and they could value the fact that IKS embraces one another's cultures. This leads to a deeper level of comprehension than was previously possible.

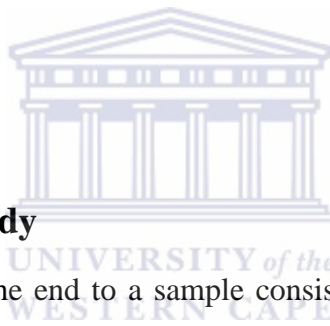
According to Ogunniyi (2008), learners must therefore be able to negotiate the meanings across the two distinct thought systems in order to integrate them. CAT proposes five categories in a dynamic state of flux in a person's mind. According to Hewson and Ogunniyi (2008), the five categories are designated as follows:

- **Dominant:** A conception becomes dominant when it is the most adaptable to a given situation.
- **Suppressed:** In another context, the same dominant conception can become suppressed by a previously suppressed cognitive state.
- **Assimilated:** A conception becomes assimilated when it capitulates to another more datable conception.
- **Emergent:** An emergent conception arises when an individual has no previous knowledge of a given phenomenon, e.g. learning that the discharge of a capacitor can be associated with the phenomenon of lightning.
- **Equipollent:** An equipollent conception takes place when two competing ideas or worldviews exert comparably equal intellectual force on an individual.

1.7 Significance of the study

In pursuing this study, it is hoped that this study would contribute to:

- Exposing physical sciences teachers to the approach of DAIM as an instruction method to teach challenging concepts in physics like capacitors.
- Enabling physical sciences teachers to integrate indigenous knowledge into their science lessons by means of demonstrative DAIM lessons.
- Giving teachers the opportunity to identify and recognise the value of indigenous knowledge.
- Raising awareness that DAIM as an instruction method has the potential to integrate IK with sciences and enhance science learning.
- Providing a framework that will assist teachers in the teaching of the topic of capacitors, and any other topic.



1.8 Delimitation of the study

The study was limited in the end to a sample consisting of only 4 teachers (3 Physical Sciences teachers of three different High schools and one Science teacher (lecturer) of the Technical Vocational and Education Training (TVET) College in the Western Cape area. The reason for the sample, as mentioned before, was based on the fact that the researcher relocated to a different district. More reasons for choosing the above sample are indicated in chapter 3.

In other words, the three teachers and one TVET teacher (lecturer) could not be regarded necessarily as a representative sample of the over 50 high schools and approximately five TVET colleges in the study area.

The teachers were trained in the TAP model of DAIM and were taken through three DAIM lessons on capacitors during which the researcher served as the facilitator. The first DAIM lesson was practically orientated and the other two DAIM lessons took the format of case studies. Video recording lessons took place. The researcher was in this case the facilitator and the teachers acted as the learners experiencing the DAIM model and learning about capacitors.

1.9 Definition of Terms

Indigenous Knowledge Systems (IKS) - A system of thought peculiar to people of a local geographic location or socio-cultural environment (Ogunniyi, 2008:6). IKS is a way of doing things and of thinking about things that developed over a long time as people learned to adapt to their living environments (Moji, 2009).

Electroplating - A process that uses electrical current to reduce dissolved metal cations so they form a coherent metal coating on an electrode.

National Curriculum Statement (NCS) - A policy document setting guidelines for curriculum implementation from Grades 1-12 (DBE, 2011).

Lightning (Western view) - A massive electrostatic discharge between electrically charged regions within clouds, or between a cloud and the earth's surface (Wikipedia, 2000).

A natural phenomenon - 'Non-artificial event in the physical sense', and therefore 'not produced by humans', although it may affect humans (Ward, 2012).

Dialogical Argumentation - Involves one making a claim, and using evidence to logically back one's position. It also involves people proposing alternative views, challenging claims made by others and finally reaching a consensus through convincing arguments (cited by Angaama, 2012).

Misconceptions - Include all the incorrect descriptions, misinterpretations, or inaccurate explanations of a scientific concept created by the learner (Yip, Chung & Mak, 1998:320).

School science - The science that is taught and learned at school using standard texts derived from European and Western backgrounds.

Capacitors - Electronic components that are similar to batteries in that the capacitors are designed to store and discharge electrical energy very rapidly (Laukkonen, 2007).

1.10 Thesis Outline

Chapter one represents the introduction of the study. Chapter two is a review of the relevant literature in the field of conceptual change in teachers, argumentation and capacitors as a device used in modern electronics. In Chapter three, the research process, research design, methodology and analyses of data are clearly represented. Chapter four represents the results followed by discussions.

Chapter five concludes the study by indicating the findings. These findings are accompanied by the implications and some recommendations for various stakeholders - physical sciences teachers, curriculum advisers, policy makers, and so on.



Chapter 2 Literature Review

2.0 Introduction

This chapter is about issues related to this study and it is divided into eight sections. Section one discusses the Curriculum changes, section two the Misconceptions on capacitors, section three the Instructional challenges, section four the Instructional strategies, section five on DAIM as an Instructional method , section six on Indigenous knowledge concepts , section seven on Indigenous comparisons of capacitors and lastly section eight on Other studies on DAIM.

2.1 Curriculum changes

Curriculum changes are intended to replace or improve on a system. It can be successful from the start if the role players are part of it and if it is well planned and thought through in order to fulfil the needs of the population. Any change is needed, even in an education system as Eistein was credited with stating, ” *We can't solve problems by using the same kind of thinking we used when created them.*”

There have been various changes for example to the curriculum in Britain. Coughlan (2013) reported the following “Prime Minister David Cameron says this revolution in education is vital for the country's economic prosperity”, referring to the revolution of doing Mathematics via computers. However, Brian Lightman, leader of the ASCL head teachers' union, said that heads shared the aspiration for high standards, but warned of the practical problems of implementation. This followed the introduction of a new curriculum in England by Education Secretary Michael Gove, who said that the changes to the curriculum were necessary to keep pace with the achievement of pupils in other countries. No national curriculum can be modernised without paying close attention to what's been happening in education internationally.

In South Africa, the Outcomes-Based Education (OBE) system was introduced in 2005, then later revised and became known as the National Curriculum Statement (NCS) in 2008. The National Curriculum Statement (NCS) for Grades R to 12 (2012) was based on the principles of acknowledging the rich history and heritage of South Africa as important contributors to

nurturing the values contained in the Constitution (DBE, 2011). This goal includes critical thinking, respecting the contributions of others, and expressing sensitivity to people's views and beliefs. This new document presented its own challenges for teachers in that the guidelines were not specific enough.

Amidst this confusion, the Curriculum and Assessment Policy Statement (CAPS) was introduced (CAPS, 2010). CAPS provide comprehensive and concise details (for every subject in each grade) of the rich history and policies of South African education, content that teachers ought to teach and assess on a grade-by-grade and subject-by-subject basis (DBE, 2011). This statement thus gives clear guidelines on each topic, how it should be assessed each term, and how much time should be spent on each specific topic. Despite these clear objectives and guidelines, however, teachers can still decide how they would like to present their lessons. This means that each teacher can follow his/her own teaching methodology with regard to the subject matter. However, implementation of CAPS was only introduced in 2013 for grade 11 and in 2014 for grade 12.

One of the challenges in teaching physical sciences is to make it more meaningful to the learner. According to Sendur (2012), effective learning could take place if it is perceived in a real life context. The new South African curriculum saw the introduction of a number of new and somewhat problematic topics, such as capacitors. Curriculum changes often bring with it a fair share of problems. In the case of a new science curriculum, it can cause many problems that could lead to misconceptions and low marks in examinations.

The changes brought about in South Africa since 1994 have not necessarily had the desired effect. One of the major South African stumbling blocks in curriculum changes is little or no consultation of teachers that are the implementers of curriculum changes in the classroom. The teachers felt that they had no input in the change of the curriculum, and struggled to grasp some of the physics concepts. Some of the complaints were inadequate teacher training and the introduction of a new curriculum for the wrong reasons (Jansen, 1999). The result of this is poor performance in the final grade 12 examinations. Despite the boasting of high pass rates the quality of passes was very low possibly due to all the changes.

Curriculum changes also bring confusion among teachers' expectations and even misconceptions in the classroom. As the curriculum changed, some concepts and terminologies regarding physical sciences subject matter changed as well. This researcher observed when moderating question papers of a final grade 12 internal examination how teachers themselves had problems with certain concepts. For example:

- In vertical projectile motion, sign conventions are often erroneously applied where “g” the gravitational constant is involved.
- Another one is whether friction does or does not do any work in the work energy theorem calculations. In organic chemistry, the naming of organic compounds results in much confusion when the IUPAC rules are not applied correctly.
- Misconceptions with Markownikov's rule and reactions and naming of organic compounds were prominent and this confirmed the Sendur's findings (2012).

2.2 Misconceptions on capacitors

According to Von Rhöneck (1998), the current which is a flow of electricity as well as the concepts of resistance causes misconceptions in learners. Özmen and AYAS (2003) and Özmen (2004) reported that many misconceptions can be found in science teaching, such as chemical bonding. Beaty (1996) and Clement (1987) both reported on some erroneous beliefs or misconceptions in understanding capacitors.

According to Beaty (1996), energy is permanently trapped in the di- electric which is not the case. Capacitors do not store charge, but it is a charge of energy provided. The word charge referred both to electrical charges and quantities of energy (Beaty, 1996). This misconception is based on the misleading experiment called Dissectible Leyden Jar. Many learners do not understand what is happening when a capacitor charges (Bell, 1985).

According to Clement (1987), there are some beliefs or ideas about capacitors that may be misconceptions. These are that electricity is stored, some is stored inside the capacitor and the

rest flows through the circuit. In practice, energy is stored in the electrostatic field and the dielectric between the plates passes a small amount of leakage current.

Another belief is that a capacitor lights up the light bulb, because the battery charged up the capacitor and the rest of the charge will remain inside the capacitor until it is connected to a second light bulb. In fact, it is current that flows from the battery to charge up the capacitor. This is when a battery, capacitor and light bulbs are connected in a circuit. When the capacitor is connected to a battery, the light bulb will light up at the beginning, but will gradually become dimmer as the capacitor is charged. When the capacitor is fully charged and still connected to the battery, the light bulb will have gone out. In order for the light bulb to work again, the battery must be removed and replaced with a conducting wire. The capacitor will start to discharge and cause the light bulb to light up again for a short while. Apart from light bulbs, capacitors could be used in many different devices used in everyday life, for example in washing machines, hairdryers, and sound systems and so on.

According to Krause (2012), a capacitor will not make your sound system suddenly sound much louder although it can improve it slightly. It will not increase the potential difference in your car's system but it will help maintain it. A capacitor will not provide extra power for devices but it will maintain it.

The study by Cohen, Eylon and Ganiel (1983) identifies current flow, potential difference and the incorrect use of the $V=IR$ relationship based on Ohm's law as problematic amongst learners. Nasr, Hall and Garik (2005) stated that despite the ubiquity of electricity in everyday life, electrical circuitry remains, even in its simplest structures, significantly abstract for learners to comprehend. Even after repeated instruction, basic electricity concepts such as potential, potential difference and capacitance continue to be stumbling blocks for learners.

These researchers admit that at the time there were many problems with understanding concepts associated with electricity. They also expressed the sentiment that very little research has been done on engineering concepts of filtering. Filtering refers to the use of capacitors with

other components in many electronic circuits, to reduce voltage (potential difference) or current spikes.

However, one of the difficulties we have encountered is that there is also little scholarly literature on misconceptions. These few literature references to capacitors may indicate that there is little understanding amongst many scholars on the topic and not much research has been done on conceptual understanding of it. When we find that teachers and learners struggle with capacitors, it was not unique. This suggested that there may be valid reasons for retraining the teachers in our own situation.

Discussions with teachers of the schools the researcher visited, confirmed that many teachers themselves had difficulties in understanding capacitors. They felt that the topic of capacitors did not fit in with the study at this level of school sciences. At cluster meetings, many teachers agreed that they received very little training on this topic and it was unclear to them how and what to teach with regards to capacitors. This was one of the flaws discovered in the implementation of the NCS curriculum in 2008. Many teachers complained about the lack of support they received from their superiors.

As a curriculum adviser at that stage, one of my roles was to try and identify problems teachers had with the curriculum and try to address them. The topic of capacitors was certainly one of the problems. There were many schools in the district with low marks in physics and in particular on questions such as capacitors and electricity, all of which clearly indicated the need for retraining. In discussions with learners at some of the schools where grade 12 results were low, I discovered that they had problems with the charging and discharging of capacitors, the concept of storing charge as they have stated it and also on how capacitors are connected in circuits. Learners struggled to understand why a dielectric was required in a capacitor. The application of capacitors was one of the major issues and teachers themselves seemed to struggle comprehending the context of how and where capacitors are applied to, therefore they experienced great challenges in conducting the lesson on capacitors. Strategies for helping learners to overcome their misconceptions are based on research about how we learn. The key to

success is ensuring that learners are constructing or reconstructing a correct framework for their new knowledge. In order to overcome the misconceptions, the measures for understanding capacitors could be taught through the engagement of discussions.

According to Van Drivel, Verloop and Vos (1997), there is a need for pedagogical strategies in order to enhance understanding and making science more meaningful. It is of vital importance that teachers should have sufficient content knowledge (CK) and pedagogical content knowledge (PCK) in order to make science more meaningful to the learner. Content knowledge represents the teachers' understanding of the subject matter taught. According to Ball, Thame and Phelps (2008), content knowledge includes direct attention to the role of content in teaching. The teacher needs extended expertise with certain science practices. They need to be able to talk explicitly about how science language is used. The teacher must explain and justify the learner's science ideas, for example why a charge is flowing through a capacitor if all the charges only built up on one plate of the capacitor. The emphasis is thus on the deep understanding of the subject matter taught at school.

Schulman (1986) further asserted that the Pedagogical Content Knowledge (PCK) is knowledge needed to make the subject more accessible to the learners. Learners are perceiving knowledge in different ways. If teachers have the PCK, multiple representations of transferring of knowledge will be used. In this way, learners will be able to make connections within, as well as between concepts relating to the subject matter. PCK is the bridge between content knowledge of the subject matter and the practice of teaching (Schulman, 1986).

Despite all the instruction challenges that might have been aroused, the researcher still found it necessary to ensure that the teachers obtained over the necessary skills in order for their learners to be able to make the connection between the concepts related to capacitors as reflected in this study.

2.3 Instructional Challenges

Many teachers were set in their own methods of ‘talk and chalk’ or expecting learners to read and study sections that they as teachers were uncomfortable with. This researcher found that quite often teachers would simply read a section from the textbook with the learners in class.

In defence of many teachers, it must be said that many of them were forced to teach physical sciences due to a lack of qualified and available physical sciences teachers around. One young teacher trained with life sciences as major subject was thrown into the deep end and had to teach physical sciences for Grades 10-12 at her school. Her principal insisted that they could not find any qualified teacher in that field. She was out of her depth with physical sciences. At another high school, a mathematics teacher with no physical sciences background also had to teach physical sciences. This is an unfortunate scenario that repeated itself in many of the township schools. There were just too few physical sciences and mathematics teachers and not many received formal training at the training institutions. As cited by Lizer (2013) shortage of science teachers and science expertise is a reality that exists in many schools, therefore there are not many role models who actually made sciences more attractive to the learners.

It seems as if learners steer clear of studying mathematics and science. This is a cause for concern as it impacts on the teaching methodologies, learner understanding of science and the possibility of many misconceptions that are not adequately addressed in the class by the teacher. By the time the National Senior Certificate (NSC) examinations are written, it is too late. This situation created an important opportunity to redress the approach to teaching certain concepts through teacher training as well as through the introduction of alternate instructional/teaching strategies.

2.4 Instructional strategies

Argumentation as an instructional strategy or methodology has received wide research over the last few decades. Science researchers are especially aware of the need for trying or adopting alternate teaching methodologies. Hewson (1992) is of the opinion that conceptual change is one such approach. Newton (1999), Erduran (2004), Ogunniyi, (2004, 2006, 2007), Reddish and Steinberg (1999) are of the opinion that argumentation based on Toulmin’s (1958)

Argumentation Pattern can be used as an instructional methodology. The underlying assumption is that learners should be involved or engaged in constructing knowledge in the classroom. The notion of 'learners' voice' emphasises learners as active teachers in education. This is in line with the requirements of the DBE (2006) documents that learners be active teachers in the classroom.

It is important for each teacher to employ some methodology to make learners understand the topic. This may require that teachers evaluate their own instructional methods or that somebody advises them to try different approaches, focusing on helping the learner increase his understanding of the subject. The ideas of Vygotsky (1978) are that learning is both personal and social, in that even the languages that an individual uses are derived from his/her community. As an individual interacts socially with others, he/she is able to expand his/her knowledge and negotiate meanings. The knowledge he/she gains in the process of interacting with others, especially more knowledgeable persons such as the teacher, is what he calls scaffolding.

Scaffolding is an effective method for helping learners to develop higher-order thinking skills; it is an instructional strategy which gradually and systematically shifts the responsibility and control over learning from the teacher to the learner (Glasgow, Mc Nary & Hicks, 2006). Diamond (2006) reported on learners who spent about two-thirds of their waking lives outside of formal schooling. The science teachers still tend to ignore the crucial influences that outside experiences have on the learners' beliefs, attitudes and motivation to learn. What learners bring to the science classroom, whether from their cultural background or from out-of-school experience, is reflected in their inclination to form and express their own opinions. The notion is that it is better to provide evidence for knowledge claims instead of using empirical work as the basis of a scientific investigation. According to Osbourne (1998), the emphasis should be on basic methodical skills and practices, which seek to empower young people and develop their scientific literacy.

It is thus necessary to adopt an instructional approach that gives learners an opportunity to overcome their doubts, ameliorate their misconceptions and freely externalize their thoughts about their areas of concern regarding capacitors. One such instructional strategy is the Dialogical Argumentation Instructional approach. The word 'Dialogue' according to Newton

(1999) refers to some notions of argumentation for the purposes of reaching some consensus. This method has been found by researchers in different parts of the world to increase learners' reasoning abilities and to improve performance compared to the traditional methods of instruction (Erduran, 2004; Ogunniyi, 2004, 2006, 2007; Reddish and Steinberg, 1999; Wilson, 2010).

2.5 Dialogical Argumentation as an instructional method

Dialogical Argumentation takes place with an audience in mind and the audience is the judge of success or failure. Argumentation occurs under conditions of uncertainty which implies that things could be otherwise; the outcome is not known for sure. It has been observed by researchers that argumentation is increasingly viewed as a leading instructional approach and as an educational goal for science education (Bricker & Bell, 2008; Erduran, Simon, & Osborne, 2004).

The argumentation theory provides a guide to elicit classroom dialogue (Ogunniyi, 2004). Through argumentation, learners would be empowered to be critical and to negotiate their own learning process. As described by Angama (2012), the key elements of argumentation teaching are similar to conceptual change teaching by Hewson (1992). These elements include:

- a meta-cognitive stage whereby learners step back and reflect about their ideas or those of others
- a classroom climate where there is respect by both the teacher and learners for the ideas of others, even when they seem to be contradictory
- a classroom environment where the teacher provides opportunities for learners to express themselves without fear of ridicule, and finally
- a classroom environment where learners take responsibility for their learning, respect the ideas of others and where the learners are free to change their ideas when they find others better than theirs.

According to Erduran, et al. (2006), it is important to train teachers in argumentation as an instruction tool. The teachers must first be introduced to the different stages and steps in an effective argumentation process as proposed by Toulmin (1958) and Ogunniyi (2004). The School of Science and Mathematics at the University of the Western Cape started under the supervision of Ogunniyi and his team from the Science and Indigenous Knowledge System Project (SIKSP) to train a few teachers in the Western Cape in the process of argumentation and how to conduct a Science-IK lesson. The aim of the project is to expand the scientific knowledge of the teachers on indigenous knowledge. This will contribute to the development of the country and also assist in the development of Science and IK material for teachers.

2.5.1 The purpose of argumentation

The purpose of argumentation in science is to examine different perspectives and finally reach an agreement on acceptable claims (Driver, 2000). A claim could be advanced, which may or may not be accepted immediately. If it is accepted, the matter ends, and there is no further argument.

If it is not accepted, evidence must be produced to support the claim. If the evidence is not immediately accepted, then there are two options: if the truth of evidence is not accepted, then a separate argument will advance to establish it. If the truth of evidences is accepted but it is not seen as justifying the claim, then a warrant is provided for the inference from evidence to claim. If the warrant is not accepted, then there will be a separate argument to substantiate it. Exceptions may be noted and the claim may need to be qualified. This process continues until the arguers reach an agreement, or the dispute is resolved by a third party.

Argumentation is a useful tool for engaging oneself in a meaningful discourse which could advance the individual or group to justify or refute a claim in order to attain the approval of an audience (Van Eemeren, Grootendorst & Henkemans, 2002).

The process of dealing with expressed cognitive conflict helps learners develop confidence and skill for processing knowledge as they are given opportunities to accept or reject others' views and express their own.

It is also believed that if teachers apply argumentation instruction in their lessons, the learners will be able to articulate reasons for supporting a particular claim, convince or persuade their peers, express doubts, ask questions, relate alternative views and point out the unknown. In other words, learners will develop a skill to convince others in the group of the relevancy of the argument by proposing a claim which is defended via warrants/rebuttals.

In this manner, knowledge becomes personally relevant and important to the learners. They will adopt a critical thinking style which will allow them to become independent thinkers.

The preliminary results of the study of Erduran, et al. (2004), indicated that collective reasoning is strongly influenced by the nature of teaching and how teachers mediated the argumentation-rebuttal process.

According to Van Eemeren and Grootendorst (2004), the goal of argumentation is that it should be born in the mind of the learner. However, the primary aim of critical discussion is not to maximize agreement, but to test contested standpoints as critically as possible by means of a systematic critical discussion of whether or not they are tenable.

Osborne, et al. (2004), expressed the view that learners must be explicitly taught in argumentation in order for them to be able to construct ideas in a meaningful way. As learners get involved in arguments, they gradually become familiar with the way that scientific knowledge is constructed by the scientists.

2.5.2 Argumentation in Greater London, United Kingdom

Between the years of 1999 and 2001, Osborne and Associates carried out a study in the Greater London area using argumentation in science lessons. This research was conducted in two phases.

In the first phase, research pertained to the development of teaching material and strategies to support argumentation in the classroom. The teachers were assessed in their teaching of argumentation. The analyses show that there was significant development amongst most of the teachers involved in the project with respect to their organization of argumentation lessons across the year.

The second phase of the research was where the teachers taught the experimental group a minimum of nine lessons involving scientific argumentation. Teachers taught similar lessons at the beginning of the year and at the end of the year. In the second phase, the learners' progress was evaluated with argumentation and the progress made by learners with reference to argumentation was very visible (Osborne et al., 2004).

The researcher agreed in this study with the findings on argumentation by Ogunniyi (2005), that it could also be a teaching method to integrate science with indigenous knowledge.

2.6 Indigenous knowledge concepts

According to Brockman (1997), colonial oppression has contributed to the loss of culture and identity in indigenous communities. These colonial countries (such as the French, British and other European countries) have a huge impact on the structure of our education system today. The plea in this study is for lost knowledge to be rediscovered as proposed by Ogunniyi (2007), and used as a method to enhance understanding.

According to Busia, (1964) indigenous knowledge can be developed over a certain period in a culture/community as follows:

- In African communities, the older generation passes knowledge, skills, the appropriate modes of behaviour and beliefs for playing social roles in adult life on to the younger generation.
- The young are taught how to cope with their environment - how to farm, hunt, fish or prepare food.
- They are taught the language and manners and the general culture of the community.
- The methods are informal, the young learn by participating in activities alongside their elders.

- The young basically learn by means of observation how to live as members of their community.

It is important to stimulate interest by creating relevant systems of education such as developing a curriculum that builds on national culture and traditions through schooling. In this study, the concept of a distinct indigenous worldview recognizes the belief system inspired and protected by indigenous knowledge and values. Battiste and Henderson (2000) believed that indigenous societies are characteristic of the creative adaptation of a people to an ecological order and the accompanying belief that all aspects of the universe are interrelated. According to Semali and Kincheloe (1999), IKS have a more holistic nature as it originates from multiple sources like traditional teachings, empirical observations and revelations (cited by Phiri , 2008).

More recently, there has been an increasing recognition of the need to ensure a more balanced integration of indigenous and Western systems of knowledge. Indigenous knowledge is no longer considered acceptable as an add-on to Western knowledge systems. Instead, it must be included in a more central and fundamental way. According to the Minister of Education (Angie Motsegka), the National Curriculum of South Africa is the culmination of our efforts over a period of seventeen years to transform the curriculum bequeathed to us by Apartheid (DBE 2011). She then stated that the curriculum is inspired by our Constitution (Act 108 of 1996) which aims to:

- Heal divisions of the past and establish a society based on democratic values, social justice and fundamental human rights.
- Improve the quality of life of all the citizens, lay the foundations for a democratic and open society whereby each citizen is equally protected by law (DBE, 2011, p. 4).

2.6.1 Indigenous Knowledge Systems (IKS)

One of the requirements of the curriculum (DBE, 2002; 2009; 2011) is that learners be made aware of the importance of cultural or indigenous concepts. Many topics in the curriculum can be traced to some indigenous phenomenon or cultural activity. Sound and music studies can be related to the indigenous musical instruments that are part of the African heritage. Angama

(2012) wrote at length about indigenous musical instruments and their practical relevance. In some of the townships, the playing of cultural drums at religious gatherings is a common sight.

Riffel (2012) discussed indigenous weather predicting methods. It is difficult to comprehend that many of the older folks were very accurate in predicting weather patterns. They did this without the modern instruments and technology that are now available. In the science classroom, the topic of capacitors is quite often linked to lightning. Many traditional beliefs exist around the concept of lightning, which many scientists link to capacitors.

The question that may arise is, “Why add indigenous knowledge (IK) to the teaching of capacitors?” Firstly, this was in response to the newly implemented inclusive science curriculum which required teachers to integrate IK with science to make school learning relevant to the life worlds of learners. Secondly, it was thought that the topic of capacitors deals with many materials or natural phenomena, such as lightning that are familiar to both teachers and learners in their daily lives rather than something encountered only in the physical sciences curriculum or classroom.

According to Fémi, Òtúlàjà, Cameron and Msimanga (2012), integrating IKS in South African classrooms is still a contentious subject, underlined by the fact that while each curriculum change has maintained the importance of inclusion of IK, specific directions on how to implement IK in science at the school level are still lacking. Those interested in integrating IK tend to be isolated in their attempts at implementing an effective inclusion of IK in the curriculum.

One of the big challenges for teachers and the Department of Basic Education (DBE) is that there are few available resource materials. To this end the SIKS Project at the University of the Western Cape holds the development of resource materials to be used in class, as one of its objectives. The Project has arranged a number of seminars and conferences with the objective of assisting and equipping teachers with a basic understanding of IKS.

It is vital that indigenous knowledge systems be addressed at school level in order to shift the focus of the content within a formal as well as informal education system. The emphasis should be on regaining the indigenous knowledge lost through the process of colonialism.

Indigenous communities would be able to reclaim and revalue their languages and cultures. The indigenous classroom setting encourages cooperative learning whereby learners become active teachers in the lesson. The indigenous model involves not only the learners and teachers but also the contribution of the community.

This is why the South African Government adopted the Indigenous Knowledge Systems (IKS) Policy in 2004. The objectives were to recognise, affirm, develop, promote and protect IKS in the country. A number of indigenous groups or products have benefitted from it since then. The “San” people benefitted from the development of products derived from the indigenous Hoodia plant. The indigenous rooibos tea is also protected and it benefits the producers financially. Similarly, the honey bush and the buchu are other indigenous plants that are protected to the benefit of those that produce it.

This policy is in line with the World Bank’s (1998) view that IKS can be a means of economic development by the local people and that it provides the basis for problem solving strategies for local communities, especially the poor. It represents an important component of global knowledge on development issues. IK is an underutilized resource in the development process. Learning from IK, by investigating first what local communities know and have, can improve understanding of local conditions and provide a productive context for activities designed to help the communities.

Understanding IK can increase responsiveness to clients. Adapting international practices to the local setting can help improve the impact and sustainability of development assistance. Sharing IK within and across communities can help enhance cross-cultural understanding and promote the cultural dimension of development. Indigenous knowledge is a way of doing things and of thinking about things that developed over a long time as people learned to adapt to the environments they lived in. It is knowledge that forms part of a specific community for a number of years.

At school, teachers and learners (along with every other citizen) are expected to collect, treasure and enhance their understanding of IKS. The financial benefits are not always reaped but a better understanding of IKS can improve many lives. As an example, there is the tragic

case where a number of diamond diggers were killed in 2012 in the Northern Cape because they used the basic cultural methods and tools to dig tunnels in search for diamonds. Many miners died by going down old gold mine shafts and digging for gold using old methods that worked before but were unsafe at those depths. This tragic could have been prevented if only the miners were trained properly in these indigenous tools and indigenous methods used to dig tunnels in search for diamonds.

The integration of IKS in the curriculum will hopefully raise awareness and pride in heritage amongst the learners. According to Mushayikwa and Ogunniyi (2011), this will indeed prepare the learners to defend and protect indigenous intellectual property rights. Therefore, it is important for the learners to take responsibility for their learning.

2.6.1.1 How to introduce IKS in sciences?

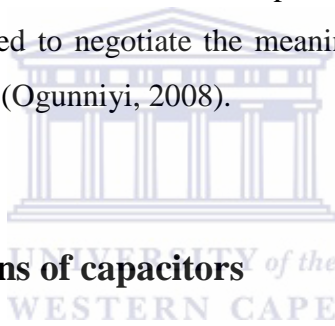
One of the challenges of the modern teacher is to introduce indigenous knowledge (IK) concepts in the classroom. Many teachers are opposed to IKS as they believe it brings witchcraft and black magic into the classroom. Although much work has been done in Canada, Australia and Africa where there are various research groups looking at IKS, it still remains a taboo topic.

The focus of teaching science should not be on detailing what we already know, but should be on how we know it and why we believe it in the scientific view (Duschl, 1990; Driver et al., 1996). This type of approach will not only externalise the thinking of the learner, but will also develop beliefs and cultural views. The teachers should engage learners in constructive pedagogy. When the teacher tries to link the topic under discussion with its possible origins and in traditional or cultural practices, this may spur learners on to share some of their beliefs or customs.

One of the teachers in the district where this researcher worked dealt with the preparation of alcohols during organic reactions. Great was his amazement when first one and then many more learners started talking of making alcohol during beer-making. This became a good starting point for that teacher to regularly introduce IKS concepts. The classroom discussions that followed were nothing but a form of dialogical argumentation. Tippet (2009) called argumentation the language of science.

For the learners to value and comprehend the Science in IKS and the IKS in science, they must be interactive teachers in discussions. Engagements could occur via the use of various media, storytelling (Ogunniyi, 2004), newsletters, prints, videos, digital media, dances, indigenous games and instruments and implements (indigenous technologies). I once looked on at a wedding where a Portuguese young lady was involved. The family later gave a splendid show of folk dancing practiced at weddings. Similarly, the capacitor could be viewed differently via storytelling and indigenous technologies.

As suggested by Hewson and Ogunniyi (2008), the explanation of a capacitor could be introduced in the mind of the learner as an equipollent conception according to CAT. An equipollent conception takes place when two competing ideas or worldviews exert comparably equal intellectual force on an individual. In order to adapt a deeper level of understanding about capacitors, the learners are expected to negotiate the meanings across the two distinct thought systems as mentioned in Chapter 1 (Ogunniyi, 2008).



2.7 Indigenous comparisons of capacitors

2.7.1 Capacitor compared with a natural phenomenon (Lightning)

The formation of lightning can be regarded as an example of how a capacitor operates. Lightning is an atmospheric discharge of electricity, usually during a rainstorm. The first process in the generation of lightning is charge separation. One theory states that opposite charges are driven apart and energy is stored in the electric field between them. The comparison is made where the two plates of the capacitor is seen as the cloud and the earth whereas the air molecules in the environment represented the dielectric material of a capacitor.

Between these two plates, an electrical charge occurs. After an electric field has occurred between the two plates, cloud electrification occurs which appears to carry water droplets upwards by cooling them to -10°C to -20°C . A collision takes place with ice crystals to form a soft ice-water mixture called graupel. The ice crystals will experience a positive charge whereby the graupel will experience a slight negative charge due to the collision. Updrafts drive lighter

ice crystals upward, causing the cloud top to accumulate increasing positive charge. The heavier negatively charged graupel falls towards the middle and lower portions of the cloud, building up an increasing negative charge. The separation of charge and accumulation occurs until there is sufficient electric potential to initiate lightning discharges. A strong electric field forms. Franklin (1952) proved that lightning was indeed electrical in nature (Cited by Uman, 2008). He attached a metal key to the bottom of a dampened kite string and flew the kite in a storm-threatened sky. A succession of sparks which jumped from the key to the back of his hand showed that lightning was indeed electrical in nature.

As a thundercloud moves over the earth's surface, an equal but opposite charge is induced in the earth below. The induced ground charge follows the movement of the cloud. When the electric field becomes strong enough, an electrical discharge between the clouds and earth (ground) occurs. During the strike, electrons and positive ions of portions of air molecules are pulled away from each other and forced to flow in an opposite direction. The electrical discharge causes the air to expand rapidly and produces a shock wave known as thunder.

Lightning in the environment may directly damage nerves and muscles by the high voltage producing holes in their cell membranes, a process called electroporation; metallic objects in contact with skin during lightning will result in more serious injuries; the skin would burn due to the superheated metal. Nitrogen molecules break into the air to react with oxygen to form nitrogen oxide. The nitrogen oxide reacts with the rain to form nitrates that are returned to the earth. Lightning plays an important role in photosynthesis, allowing plants to grow faster and greener.

2.7.2 Indigenous capacitor as a protecting device

The farmers can construct their own capacitor when dealing with the soil. Over the years and still today in the areas where much lightning takes place, farmers make use of galvanizing steel and copper rods. They put both rods parallel within a certain distance apart from one another into the soil. Galvanized steel makes the soil more conductive for any electrical charge to pass through. The two rods are a representation of the two metal plates in a capacitor. The soil which surrounded the two rods under the ground is the representation of the dielectric material between the plates of a capacitor. An electrical field occurs between the plates. Energy is being stored in

the electric field which is the function of any capacitor. Any damages to the crop would be prevented when lightning strikes, because direct current will be blocked by the capacitor.

2.7.3 Speculations of a capacitor as intrinsic to the Ark of the Covenant

According to Meyer (2011) speculations were made that the Ark of the Covenant may have operated as an electrical capacitor. The Ark of the Covenant was a rectangular box made of wood (probably Acacia Arabia), measuring about four and a half feet long, two and a half feet wide, and two and a half feet tall. All surfaces, interior and exterior, were plated with gold. A gold crown or moulding was wrapped around the structure. Gold rings were attached to each corner, to be used in conjunction with carrying poles. A gold lid sat on top of the Ark. On top of the lid rested opposing golden cherubim, with their wings stretching out towards each other.

According to the Book of Exodus, Moses built the Ark of the Covenant based on instructions he received from God while on top of Mount Sinai. The Israelites proceeded to carry it for the following forty years while they wandered through the desert. While at rest, they stored it inside a portable, sacred, temple-like structure known as the Tabernacle. “When they came to the threshing-floor of Nacon, Uzzah reached out and took hold of the ark of God, because the oxen stumbled. The Lord’s anger burned against Uzzah because of his irreverent act; therefore God struck him down and he died beside the ark of God.” II Samuel 6: 6-7

It was unapproachable while in the Tabernacle: “Moses could not enter the Tent of Meeting because the cloud had settled upon it, and the glory of the Lord filled the tabernacle.” Exodus 40:35

As cited by Meyer (2011) “There, above the cover between the two cherubim that is over the ark of the Testimony, I will meet with you and give you all my commands for the Israelites.” Exodus 25:22.

However, the Ark does preserve the jar of manna and Aaron’s rod that budded, and that may be attributed both to the power of God as well as possible static energy stored within the Ark as a result.

2.7.3.1 A comparison of commonalities between the two worldviews (IKS and Science) of capacitors and the Ark as espoused by Ogunniyi's (1995) Contiguity Argumentation theory

IKS worldview (Ark)

- Tesla (1915) believed that the Ark generated static electricity by air rubbing against the curtains. The tabernacle was a roofless, three-walled wooden structure closed off with curtains made of different materials. These materials included goat's hair and ram's skin that were rubbed against each other to create an initial static charge.
- Static electricity was created which was again stored inside the Ark.
- According to Blackburn and Bennet (1915), an electric charge was built up in the tabernacle that was at the back of the Ark (cited by Redfern, 1964). The electric charge according to Blackburn and Bennet electrified the Ark that was capable of carrying a charge in the range of fifty thousand volts.
- The build-up of electricity within the tabernacle was so high that it kept Moses out of it.
- The communication of God according to the Bible (Verbi Bible, 2005) could be explained by an electrical discharge. In other words, when the static electricity within the Ark reached a certain level, it would have been able to overcome air resistance and in effect, jump from one cherub to the other one.
- Anyone who touched the Ark suffered an immediate death.

Science world view (capacitor)

- In terms of the science, an explanation of static electricity would be that when materials such as wax and wool are rubbed against each other a physical attraction is produced.
- By storing electricity, the Ark became a giant Leyden jar (first capacitor).

- When the voltage across a capacitor is increased, it draws current from the rest of the circuit, acting as a power load. In this condition the capacitor is said to be charging, because there is an increasing amount of energy being stored in its electric field.
- Suffice to say that whenever a voltage exists between two points, there will be an electric field manifested in the space between those points.
- When the voltage across a capacitor is decreased, the capacitor supplies current to the rest of the circuit, acting as a power source. In this condition, the capacitor is said to be discharging.
- Its store of energy held in the electric field is decreasing now as energy is released to the rest of the circuit. Capacitors are very dangerous to touch, then, because if you touched them you would get shocked where the charges move through your body

2.8 Other Studies on DAIM

A wide range of studies on DAIM have been completed by SIKSP members of the school of Science and Mathematics across South Africa and abroad, many of them under the provision of Prof Ogunniyi from the University of the Western Cape, South Africa. DAIM was used in these studies to practically implement a science - IK curriculum. A few of these studies of integration were based on

Diwu (2010) carried out a study on Fermentation. His research was based on finding out what scientific/IKS conceptions of fermentation do grade 10 learners hold and do these conceptions related to their ages, gender and/or rural/urban upbringing? His findings were that the learners in both study groups held relatively good scientific conceptions of the fermentation processes; learners had a relatively positive attitude towards science and to some degree IKS as well. He also looked at whether the learners who were exposed to DAIM's understanding of the Nature of Science (NOS) and the Nature of IKS (NOIKS) enhanced more than those not so exposed and that was exactly the situation. The learners exposed to DAIM showed a greater awareness and understanding of the NOS and the NOIKS than the learners who were not exposed to DAIM.

Angaama (2012) study investigated grade 11 learners' conceptions of sound before and after being exposed to DAIM. His findings revealed that the experimental group which were the learners exposed to DAIM, changed their alternative conceptions that were worked with into structured argumentation activities better than those which were not exposed to DAIM. He also found that the attitude of learners towards IKS was positive towards the use of indigenous knowledge in the science class.

Hlazo & Afonso (2012) looked at the conceptualization of lightning. Their study examined two groups from different schools of grade 10 learners' conceptual understanding of lightning using DAIM as a teaching method and the traditional lecture method. The findings revealed that prior to DAIM, the two groups of learners had both scientific and the indigenous knowledge about lightning. After being exposed to the DAIM, most of the learners in the experimental group were found to have changed to the more scientific worldview about the cause of lightning and protective measures against lightning. On the other hand, the control group learners' conceptions about lightning wavered between the scientific and traditional worldviews.

Berhe (2015)'s study focussed on Pre- Service teachers (students)' ability to use DAIM as a teaching instruction. She specifically looked at the pre-service teachers' understanding of DAIM before and after the DAIM intervention, their ability to construct an argument and lastly at their ability to implement DAIM in sciences classrooms. The findings before DAIM were that the pre-service teachers did not have any understanding of the Dialogical Argumentation Instruction Model, because it was all new to them, but after DAIM their understanding of the model enhanced. Due to their understanding, they were able to construct an argument and therefore were also able to implement the DAIM in the classroom.

The present study follows in the same mode, but with a slight difference in focal point. As all of the above studies mainly focused on the learners or students (pre- service teachers), this study will mainly focus on in-service teachers. The next Chapter will be referring to the Research Methodology and Design of this study.

Chapter 3 Research Methodology

3.0 Introduction

This Chapter showed how the research was performed and how the data was collected. The methodological approach deals with the process, precepts, laid down rules, techniques and procedures used in collecting data as cited by Fatoba (2013). The research methodology has been described comprehensively in this Chapter in order for the reader to have good content knowledge of the research procedure. The subsections describe the research setting, the research sample, research design, research instruments and their validations, analyses of data and the ethical considerations.

3.1 Research setting

This study was conducted in the Western Cape Region of South Africa which consists of eight Educational Districts who are serving the various schools of those particular Districts.

At the beginning of the study, a group of 15 teachers from 15 different schools in one of the eight Districts (District X, anonymous name for ethical reasons) participated in this study. These schools formed part of the schools in the Western Cape that obtained low marks in the topic of capacitors as indicated by the Chief Markers Report (DBE, 2010). Unfortunately the researcher relocated to a different District (Y) and could not continue with this group. However, she decided not to discard the data gathered from them but instead discuss it under the name “Initial Group” for the rest of the study. The new location could only provide four teachers who were willing to be part of the study. As a result, the researcher then decided to do an intense case study by using a smaller sample in the specific vicinity, in close reach of the researcher. These four teachers will hereafter be referred to as the Case Study Group

3.2 The research Sample

The research sample consist of two groups namely the Initial Group and the Case Study Group.

3.2.1 The research sample of Initial Group of teachers –District X

In the capacity of physical sciences Curriculum Adviser, this researcher had an opportunity to visit and teach at the underperforming schools in the particular District X. The Initial Group of physical sciences teachers of different ethnic groups volunteered from District X to form part of this research case study.

Table 3.1 Sample distribution of Initial Group of teachers (District X) (n=15).

Gender	Frequency	Teaching Experience
<i>Female</i>	6	Minimum 3 years
<i>Male</i>	9	Maximum 29 years

It was envisaged that only the 15 teachers from 15 different schools would form the Initial Group as explained before.

3.2.2 The research Case Study Group sample- District Y

The researcher relocated to a Teacher and Vocational Education and Training College (TVET) in District Y. It was decided to invite 10 low performing high schools (according to the Physical sciences Chief Markers Report of DBE, 2010) in the particular District (Y) to participate in the study. The TVET College in the District was also invited. Only 4 teachers responded to the invitation - 3 high school teachers and 1 teacher from the TVET College. This sample was regarded as a convenient sample, because of its accessibility as explained in Chapter 1.

The table below represents the teachers who participated in the intense case study.

Table 3.2 Sample distribution of Case Study Group (District Y)(n=4)

Sample	Gender	Years of teaching	Training Region	Qualification
<i>Physical sciences teacher (Teacher 1)</i>	Male	18	High school	Bachelor in Sciences Education in Chemistry (B.Sc)
<i>Physical sciences teacher (Teacher 2)</i>	Male	28	High school	Higher Education Diploma with a certificate of two years Physical sciences completed.
<i>Sciences Teacher (Teacher 3)</i>	Male	21	TVET College	Bachelors in Sciences with Physics at level 1(B.Sc)
<i>Physical sciences Teacher (Teacher 4)</i>	Female	25	High school	BEd. Honours (Curriculum Studies); Advanced Certificate in Education(ACE)in Physical sciences)

The four teachers volunteered from District Y to form part of this intense research case study. A teacher from the TVET College was included because he used to teach Grade 12 physical sciences at high schools for 17 years and was then teaching the topic of capacitors to first year students at the College in the discipline of electronics.

The demographics of the sample are clearly displayed in the above table 3.2. It included one female teacher and three male teachers. Their years of teaching experience varied from 18 years to a maximum of 28 years. In terms of their qualifications, all of the teachers did do some Physics in their formal training courses, but did not major in it throughout their studies. For Teacher 1 has a Bachelor's Degree in Science Education, but majored in Chemistry only. Teacher 2 has a Higher Education Diploma with a certificate of only two years of formal training in physical sciences. Teacher 3 taught grade 12 physical sciences with only physics at first year level of content knowledge. Teacher 4 holds an Advanced Certificate in Education (ACE) and is currently teaching grade 12 physical sciences.

The aim of the researcher was to introduce DAIM as a teaching method to teach capacitors to all teachers, whether teaching at a high school or a TVET College. Therefore this study was not restricted to high schools only, but included TVET Colleges as well. The researcher refers to the 4 teachers in this study as the Case Study Group from District (Y). A Case Study Group is a form of qualitative research in which a group of people are asked about their perceptions, opinions, beliefs and attitudes, in other words evidence is offered to support a claim (Collins, 2006).

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3.2.3 Criteria for selecting the sample of the Case Study Group (District Y)

The selection of the sample in this study was based on the following criteria:

- The researcher relocated to the study area.
- The teachers were willing to participate in the study.
- The teachers were all involved in teaching physics where capacitors appeared to be available.
- The teachers were within easy reach of the researcher.
- The teachers were well aware of the poor physical sciences results among grade 12 learners across the country.
- The teachers were all in agreement that a capacitor is an important electronic device.
- The teachers were also aware of their own inability to teach capacitors effectively to their learners.

3.3 Research design

Morton (2006) describes a research design as a plan of how the researcher will conduct the research. It is:

A logical task undertaken to ensure that the evidence collected enables us to answer questions or to test theories as unambiguously as possible. We should look for evidence that has the potential to disprove our preferred explanations.

(<http://www.nyu.edu/classes/bkg/methods/005847ch1.pdf>)

A research design includes all the processes such as Research Questions, theoretical framework, data collection, data analysis, write-up and validation. This study used a case study as its research design.

3.3.1 Case Study

A case study (also known as a case report) is an intensive analysis of the conceptions and the perceptions regarding their understanding of an individual unit, for example a person, group or an event stressing developmental factors in relation to the context. In this case study, an intensive analysis was performed on the Case Study Group of teachers regarding their conceptual understanding of capacitors. The case study is a research approach that is situated between concrete data intake techniques and methodological paradigms (Lanmek, 2005).

Case studies are often seen as prime examples of qualitative research which adopts an interpretive approach to data, studies 'things' within their context and considers the subjective meanings that people bring to their situation. It is erroneous to equate a particular research design with either quantitative or qualitative methods. Yin (1993), a respected authority on case study design, has stressed the irrelevance of the quantitative/qualitative distinction for case studies. (<http://www.nyu.edu/classes/bkg/methods/005847ch1.pdf>)

A case study is one of the main methods in gathering qualitative data but in this study, the researcher has made use of both qualitative and quantitative data, called a mixed-method methodology. As cited by Fatoba (2013), case studies can be seen as unique techniques to gather

data qualitatively direct from the source which should be based on experiences, storytelling, explanations and events (Dick & Ferguson, 2008). According to Lamnek (2005), a case study anchors between procedures and methodology of the research. A case study encourages and gives room for freedom of expression.

A case study is a "published report about a person, group, or situation that has been studied over time" https://en.wikipedia.org/wiki/Case_study. Case studies are used to determine possible aspects of failures or successes of a particular programme. All the aspects of DAIM were considered to determine whether this model was workable as a teaching methodology in order to enhance the understanding of teachers in particularly challenging topics such as capacitors in this case. According to Patton (1990), "Case studies are particularly valuable when the evaluation aims to capture... unique variations... from one program experience to another." (p.54).

The case study is not limited to any specific data collection methods according to Merriam (1998), as long as the focus is on holistic descriptions and explanations. Within this focus, this case study can be further described as heuristic. A heuristic case study is able to make sense of a specific phenomenon that allows the reader to extend their experience, discover new meaning, or confirm what is already known. It clearly explains the reasons for a problem, the background of the situation in terms of what happened and why it happened.

According to Merriam (1998), it is not necessary for the evidence to be recorded and managed systematically. Stake (2000) maintained that "case studies are useful in the study of human affairs because they are down-to-earth and attention-holding" (p.19). Stake (1995) believed that the most important role of the case study researcher was that of an interpreter. Simons (1996), researching in the field of education, indicated that the pressure for quantification and the growth of multi-site case study design in policy research has obscured the "original vision and utility of case study for understanding complex educational phenomena...and thereby an opportunity [has been] diminished for new ways of knowing" (p.1).

3.4 Research Methods

The study will use the three research methods, namely, Qualitative, Quantitative and Mixed Methods.

3.4.1 Qualitative Research Method

Qualitative data is more effective when people are interviewed in their natural setting instead of an artificial setting. According to Denzin and Lincoln (2005), qualitative research can be defined as studying things in their natural setting, attempting to make sense or to interpret phenomena in terms of the meanings people bring to them. Qualitative research asks “*What is going on here?*” rather than seeking evidence to answer a specific question. Corbin and Strauss define it as: “A process of examining and interpreting data in order to elicit meaning, gain understanding and develop empirical meaning” (Corbin et al., 2008:1). According to Creswell (1998), qualitative research is described as an inquiring process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem.

Qualitative research in this case involved the collection of experiential data rather than numerical values. In other words, the data cannot be tested numerically, because the information was gathered in words. The reason for a qualitative study was to focus more on the teachers’ approach in dealing with the conduct, presentation and their understanding of capacitors. The qualitative data included the collection and analysis of semi-structured interviews, DAIM intervention lessons, transcription of video recordings and literature study on DAIM, capacitors and indigenous knowledge systems.

3.4.2 Quantitative Research Method

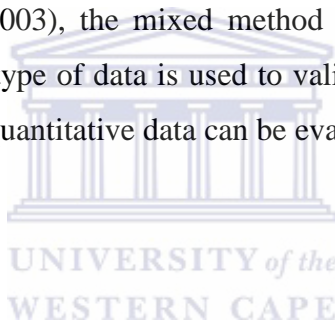
During quantitative research, illustrations and experiments were done by taking measurements for analysis. Key issues of a quantitative research are data reliability and sufficiency. The quantitative approach includes figures, while the qualitative approach focuses on the meaning and the perceptions people have of their world. According to Ogunniyi (1996), a quantitative approach refers to a causal relationship between the independent and dependent variable. In this regard, the independent variable refers to the achievement or attitude of the teachers which can be manipulated and the dependent variable refers to the framework of DAIM being measured.

The quantitative data in this case study was captured in both the Initial Group and Case Study Group samples of this study to determine the teachers' conceptual understanding of capacitors before and after the DAIM intervention. Therefore, in this study, both qualitative and quantitative approaches are of value, forming a mixed method.

3.4.3 Mixed Research Method

The approach adopted for this study was a pragmatic one that acknowledged both qualitative and quantitative research. According to Creswell (2007), pragmatism means that you do what works best for your study by valuing both subjective and objective knowledge. There are a growing number of researchers who have made use of the mixed method approaches that integrate both the quantitative method with the qualitative (Barnes, 2011).

According to both Creswell (2003), the mixed method design followed in this study is a triangulation design whereby one type of data is used to validate or expand the other data type. For this study, the qualitative and quantitative data can be evaluated at the same time.



3.5 Research Instruments

The research instruments used in this study were interviewing schedules, video recordings a, Capacitor Assessment (CA) Test, DAIM worksheets and a Reflective Diary.

3.5.1 Teacher interview schedule

According to Merriam (1998), an interview is conducted in order for the researcher to determine what information is held in the mind of the person being interviewed. There are four types of interviews, namely structured, semi-structured, informal and retrospective interviews.

“Frankel and Wallen (1993) described structured and semi-structured interviews as verbal questionnaires that can be formal and designed in a way to elicit specific answers from the respondents “(cited by Fatoba, 2013). During informal and unstructured interviews, respondents have the opportunity to freely express their responses. These informal and unstructured interviews require careful planning to obtain the best results (O’ Hanlon, 2003). If not carefully planned, an inexperienced researcher may become involved in interesting conversations that may

not produce useful insights and fail to obtain important information (O' Hanlon, 2003). In this study, an interview schedule with semi-structured questions was submitted to the teachers. It used open-ended questions that allowed the teacher to create options for responding. In this way the teachers could voice their experiences and perspectives freely. In this study, interviews were held with the teachers to answer part of Research Question 2.

3.5.2 Capacitor Assessment Test (CA)

When the researcher performed the study with the Case Study Group of four teachers from District(Y), she discovered that the CAPS document required the learners to have further information on electrical motors as one of the applications of a capacitor. Therefore, the researcher thought it best to use the CA test (Appendix 1.1) as an instrument to retrieve any information to answer Research Question 1 in part. Part of Research Question 1 was based on teachers' scientific conceptions regarding the application of capacitors in electrical motors. The Capacitor Assessment (CA) test had been provided to the teachers prior to the capacitor content training in order to test their existing knowledge on capacitors and electric motors. The memorandum for CA was validated by an electronics lecturer who is an expert in the field of electricity to determine the appropriateness of the questions. All scripts of the CA test were marked by the researcher and moderated by a colleague in the science department from the Western Cape area. The CA-Test consisted of seven questions (A1-A7). The questions A1-A4 were posed to determine the teachers' knowledge on electrodynamics, specifically looking at electric motors. Questions A5-A6 gave the researcher an idea of how much the teacher knew about the capacitor. The last question, A7, allowed the teacher to freely share any other information they know about capacitors as well as to make requests on what they would like to know at a later stage of the training.

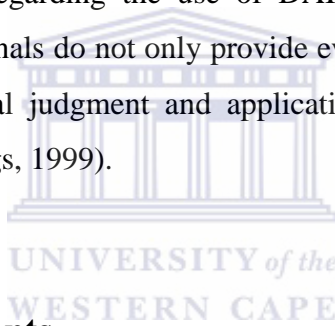
3.5.3 Video Recording

As the researcher acted as the facilitator during the DAIM interventions, the researcher decided to have the entire training session video-taped. The recordings were done by two competent young men. These videotapes were used to collect data and were listened to after the relevant information was recorded for the purpose of analysis. The videotapes assisted the researcher in analysing and interpreting the involvement of the teachers in the lessons. The body

language of the teachers was also analysed. The audios in the videotapes were transcribed and Afrikaans responses were translated into English. The videotapes also showed this researcher where to improve on her facilitation skills. The videotapes gave the researcher a clear indication of teachers' interactions within their smaller groups and as the whole class. This information was used by the researcher as part of the discussion and results of this study.

3.5.4 Reflective Diary

The teachers had to reflect on the teaching and learning activities that had taken place during the DAIM intervention. They were expected to express their learning in a personal way and to relate and apply their learning to their own teaching and assessment practice. The purpose of the Reflective Diary (Appendix 1.5) was to answer Research Question 3 to retrieve the Case Study Group of teachers' perceptions regarding the use of DAIM as a teaching method. As an assessment method, reflective journals do not only provide evidence of understanding of content knowledge, reflection, professional judgment and application, but also enhance critical self-reflection and self-awareness (Biggs, 1999).



3.6 Validation of instruments

Curriculum advisers, moderators of examination papers, university professional staff and a group of 20 members of the SIKSP (Sciences and Indigenous Knowledge Research Group) were asked to evaluate and complete the instruments to help ensure their validity. These instruments were scrutinized and any comments for improvements were applied to it. The instruments were accepted once the evaluators agreed that it was suitable for assessing the subjects.

The validity ensured that the instruments measured what they were supposed to measure every time they were used. The Kuder-Richardson Coefficient of Reliability (KR_{20}) for the instruments of the Initial and Case Study Group was found to be 0.6555. This was an indication of good reliability, indicating that the instrument was consistent. The number of questions in these instruments was deliberately minimized as many respondents quickly become bored and distracted when answering questions.

3.7 The research intervention

The intervention that was used in this study was the model of Dialogical Argumentation Instruction Model (DAIM) developed by the Science and Indigenous Knowledge Systems Project (SIKSP) at the University of the Western Cape, South Africa.

The SIKS project played a vital role in enhancing teachers' skills due to the provision made in training teachers since 2004. SIKSP has encouraged the professional development of teachers. These teachers do not only hold a valid understanding of the Nature of Science (NOS) but also know the strengths of using DAIM as an effective tool for enhancing teachers' ability to implement a Science-IKS curriculum in their classroom. The SIKSP model has the potential to transform the teaching of Science and Mathematics in an innovative manner to improve learners' performance in understanding challenging topics in physical sciences. The IKS component of the model helps teachers and learners to integrate learning outcomes, LO1 (scientific inquiry and problem-solving) and LO3 (nature of science in relation to technology, society and the environment) as described by the National Curriculum Statement (NCS).

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The DAIM component of the model focuses more on how the learners express themselves. Part of the main aim of the SIKS Project (SIKSP) is to bring learner discussions back into science lessons. Also, seeing that many teachers formed part of this SIKSP, the need was identified to focus more on the development of physical sciences integrated with IKS material for teachers which might currently be in great demand. Once the material is developed, training sessions to teachers on how to utilise the material could be done which was exactly the status quo in this study.

3.7.1 The training sessions for teachers

The study organised training sessions for each of the groups.

Case Study Group training session

The training of the Case Study Group teachers on the intervention was spread over 12 hours. The researcher designed a booklet to record the response of the teachers during the intervention. The booklet consists of 35 pages and five (A-E) sections.

The teachers were first given a test after which they were given three intervention lessons. At the end of the lessons they were then asked to write their reflections in the Reflective Diary.

Figure 3.1 Booklet designed by researcher (Content of booklet: Appendix 1)



A detailed description of the intervention follows below:

3.7.1.1 Three hours - Capacitors content Training

Ball, Thame and Phelps (2008) stated that content knowledge represents the teachers' understanding of the subject matter taught. The researcher thought it best to invite the teachers in

District Y to the capacitor training session held on a Saturday morning for three hours. The aim of the workshop was to reinforce and improve the teachers' scientific knowledge on capacitors. The capacitor content training workshop was conducted by two lecturers who are experts on the field of electricity in the Electronic Department of the TVET College. The workshop was practical and models were introduced to the teachers to illustrate applications of a capacitor.

The first model was an illustrated single-phase induction motor. The second model introduced was an oscilloscope (figure 3.2). The importance of how the oscilloscope measured the charge and discharged of a capacitor was explained and illustrated. This section of the content of electric motors forms part of the Grade 12 electrostatics section of the current National Curriculum Statement (NCS).

Figure 3.2 The effect of a capacitor in an oscilloscope and in an induction AC Motor

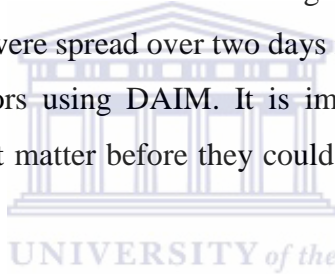


The workshop took the form of a theoretical introduction as to what capacitors are, how they function, the construction and the applications of capacitors. This was followed by a practical session where the teachers actually handled the models to reinforce their scientific knowledge of capacitors.

The focus of the content training on capacitors was as follows:

- What do teachers know about capacitors?
- How is it constructed?
- What is the dielectric material and why is it there?
- How does a capacitor charge and discharge?
- The application of capacitors.

After the foundations of the content knowledge and daily applications of capacitors were laid, teachers were ready to receive a further 9 hours of training on teaching capacitors using DAIM as espoused by TAP. The 9 hours were spread over two days in a 3-hour session on TAP and a 6-hour session on teaching capacitors using DAIM. It is important that teachers have content knowledge about a specific subject matter before they could engage in any argument (Sadler & Fowler (2006); McNeil (2011)).



3.7.1.2 Three hours: DAIM training on sound using the Toulmin's Argumentation Pattern (TAP) model

The researcher thought it best to first have a trial, presenting training on DAIM on a different topic than capacitors. The trial training provided useful information to the researcher as to what to expect in the actual study and also assisted in identifying certain flaws in the instruments or methods. The necessary steps could be taken to correct the flaws before engaging in the main study. The same sample of teachers who participated in the trial training participated in the main study.

During the trial DAIM training session, one topic of discussion was on sound (Krause, 2012). The researcher chose sound as a topic for the trial DAIM training session as capacitors are found in sound systems. The main purpose of that day was to train the teachers on how to apply the underlined principles of TAP as espoused by Toulmin (1958) in a Dialogical Argumentation Instruction Model (DAIM) lesson.

The question posed by the researcher to the teachers was as follows:

“Does sound with a certain frequency sound softer during the day, but much louder during the night if the frequency of the sound remains the same? Explain.”

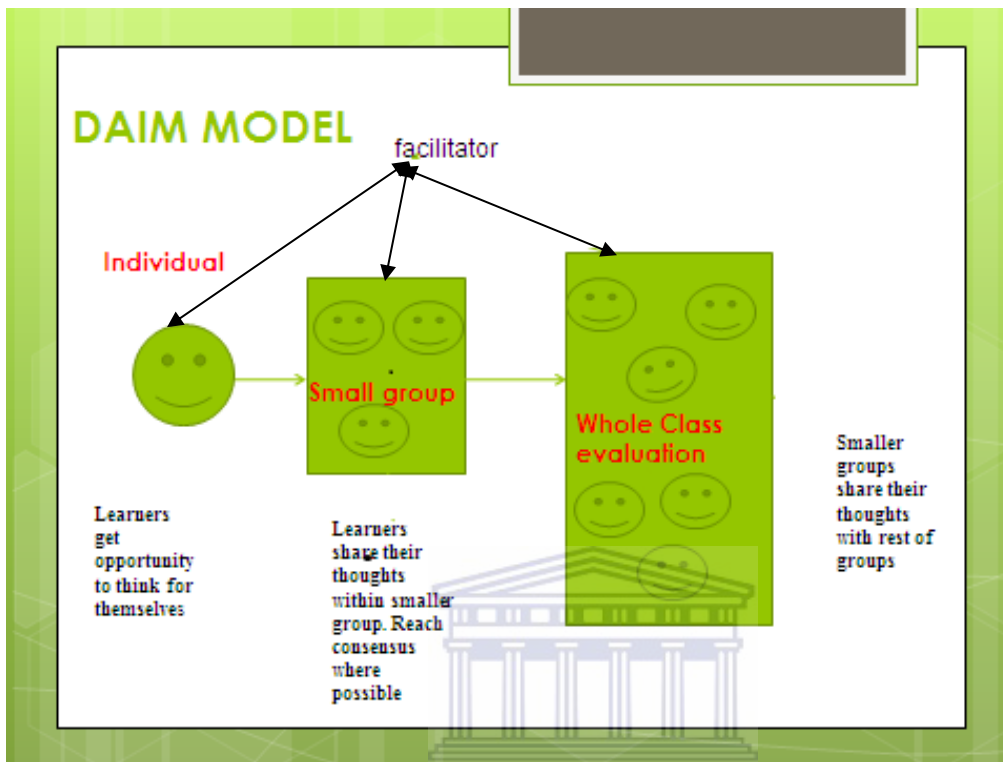
As mentioned in Chapter 1, TAP is framed in six basic elements – claim, data, warrants, backings, qualifiers and rebuttals. It was expected of the teachers to analyse the question on sound according to the six basic elements according to TAP.

3.7.1.3 6 hours: Main DAIM training on Capacitors using TAP

In the main study, the topic of capacitors was chosen to demonstrate how DAIM as a teaching methodology could be applied in the teaching of capacitors. The researcher developed a booklet with three different examples of DAIM lessons (Appendix 1.1; 1.2 and 1.3). These sessions of the DAIM intervention took the form of individual thinking space, then small group sharing space then whole class presentations, discussion and interpretive space. The first stage is where guided questions are asked to determine what scientific and indigenous concepts teachers hold of capacitors as in this study. This helps determine the individual’s cognitive level of the specific matter. This type of argument is called intra-argumentation. The next level is where the smaller group members share their ideas within the group in order to reach a common agreement (inter-argumentation). A class representative within the smaller group is selected to share with the whole class the issues agreed upon, as well as their rebuttals. The purpose of the group activities was to encourage discussions to take place in science discourse.

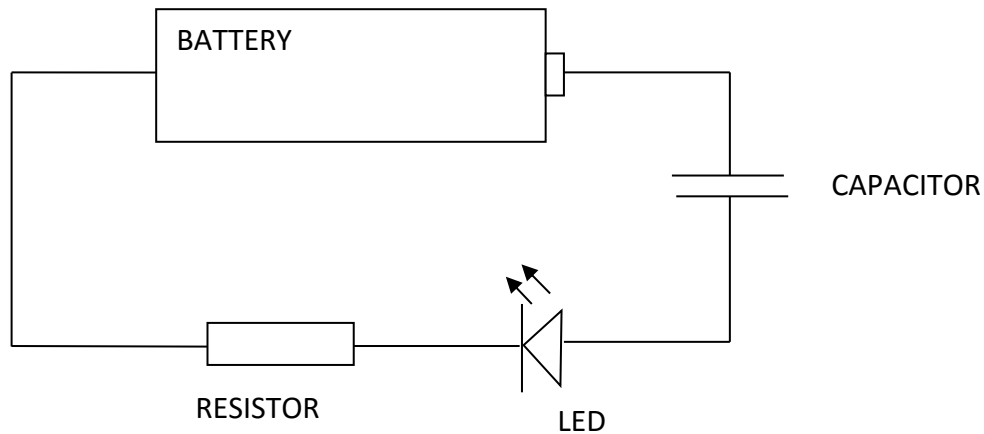
Once all the representatives of the small groups presented their conclusions, the facilitator then stepped in to manage the whole class discussion regarding the topic. In this study, this researcher acted as the facilitator. The facilitator’s role was to facilitate throughout each phase of the lesson by ensuring that a consensus is reached as far as possible as an outcome of the whole class discussions. The purpose of the facilitator is also to seek trends of understanding of the topic by referring to both scientific and indigenous knowledge. The format of the DAIM model is clearly illustrated by Figure 3.3 below:

Figure 3.3 DAIM Model



Lesson 1 (Appendix 1.2) was a practical lesson on electric circuits whereby the charge and the discharge of capacitors was illustrated.

Individual Interrogation: Before doing the practical activity, the teachers first had to answer the questions by referring to Figure 3.4.

Figure 3.4 Circuit Diagram (RC- Circuit)

The questions posed were as follow:

- B1.1** What is the function of a capacitor in the circuit? What is/are your ground(s) for your answer?
- B1.2** Name any natural phenomenon that a capacitor could be compared to? What is/ are your ground(s) for your answer?
- B1.3** Will the Light Emitting Diode (LED) light up if you switch the LED in an opposite direction?
- B1.4** What will happen to the LED when the battery is removed from the closed circuit and only the capacitor is present in the closed circuit? What is/are your ground(s) for your answer?

The purpose of the questions posed to the teachers was to provide teachers with a thinking space by testing their knowledge regarding the operation of a capacitor within an electric circuit (Intra- argumentation). After the teachers answered the four questions, they shared their findings within a smaller group.

Small Group Discussion – The teachers had to build the circuit (Figure 3.4). The claims and backings were shared amongst the members of groups (Inter- argumentation). Discussions took place and consensus was reached as far as possible.

The purpose of the practical activity was to illustrate the charge and discharge of a capacitor. They had to relate the effect of the discharge of a capacitor to a natural phenomenon or any phenomenon that could be related to the environment they lived in. The natural phenomenon

chosen was lightning. Many ideas flowed. The teachers were expected to find similarities between the structure of a capacitor and the phenomenon of lightning from the information provided to them by the facilitator. These discussions continued in the small groups. The researcher acted as the observer and did not interfere in any of the discussions that took place. The teachers were freely allowed to interact on the given task. All of the discussions and interactions were video recorded during this session and later transcribed by the researcher. The small groups were expected to reach consensus as far as possible on the given task. The small group had to nominate a scribe and a presenter to share their ideas with the whole class.

Whole Class Discussions – Feedback was provided to the rest of the group. The researcher facilitated the process throughout the lesson. Each small group took part in a class discussion as a whole. Consensus was reached regarding the scientific/indigenous structure, function and applications of a capacitor. The facilitator concluded the lesson and attempted to clear all misconceptions the teachers had on the topic of capacitors such as the fact that their textbooks indicate that capacitors store charge instead of energy. The idea was also to obtain the different thought systems that may have risen from the discussions based on the different beliefs the teachers had regarding the phenomenon of lightning when compared to a capacitor.

The second DAIM lesson was in the form of a case study (Appendix 1.2). In this lesson, the researcher tried to emphasize the function of a capacitor as a storing device as well as the fact that any capacitor could be regarded as a protective device. In this lesson, the scientific worldview of a capacitor was compared to an indigenous worldview to explain the capacitor as a protective device used by farmers.

The third DAIM lesson (Appendix 1.4) was also in the form of a case study whereby the structure of the capacitor was specifically compared to the phenomenon of lightning. Video recording equipment was used in all three DAIM lessons to determine the teachers' DAIM interaction as well as their body language.

The training sessions of the Initial Group (District X) of teachers also took the same format as described above of the Case Study Group (District Y). The only difference between the Initial and the Case Study Group's training was that the following information was not known at that

stage when training was performed with the teachers of District X. The unknown information at that stage is indicated below:

- The models illustrated in the capacitor content training
- The second DAIM case study lesson (Annexure 1.2)
- The applications of capacitors in electrical motors

As mentioned before, this case study can be regarded as a heuristic case study where new meaning of a capacitor was discovered. The above information only became known when the researcher underwent a change of environment and when she was doing an intense case study with the Case Study Group.

3.8 Analysis of the Data

This section provides the procedures employed by the researcher in collection and analysis of the research data to generate concise results to present to others (Merriam, 1998). According to Bogden & Bilken (1982), analysis involves working with the data, organizing it, breaking it into manageable units; what is important, what is to be learnt and lastly what message should go out to others (cited in Merriam, 1998).

In this study, the data of both the Initial Group and Case Study Group will be used to answer Research Question 1. Research Question 2 could be answered using the Case Study Group data only, because the researcher had relocated. The Case Study Group was assessed intensively by the researcher. The data of the responses of the teachers of the DAIM intervention section in the booklet and the video recording transcripts formed the data that was analysed according to TAP and CAT to answer Research Question 2.

The teachers were provided with DAIM intervention lessons whereby their responses were recorded in the booklet to identify whether the DAIM model influenced their understanding regarding capacitors. The responses according to TAP and CAT in the booklet and the transcripts generated from the video recordings were compared by looking for patterns in the data. The findings as indicated in the booklet and those retrieved from the video recordings were

sorted under one category. The DAIM intervention lessons were also designed to raise awareness of IK regarding capacitors among teachers.

Table 3.3 The levels of TAP in DAIM discourse: Ogunniyi, 2009 (modified after Erduran, Simon & Osborne, 2004).

Quality	Characteristics of DAIM
Level 0	Non-oppositional
Level 1	DAIM involves a simple claim against a counter claim with no grounds or rebuttals.
Level 2	Argument involves claims or counter claims, with grounds but no rebuttals.
Level 3	Argument involves claims or counter claims with grounds but only a single rebuttal challenging the claim.
Level 4	Argument involves multiple rebuttals challenging the claim but no rebuttal challenging the grounds (data, warrants and backing) supporting the claim.
Level 5	Argument involves multiple rebuttals and at least one rebuttal challenging the grounds.
Level 6	Argument involves multiple rebuttals and at least one challenging rebuttal.

The data analysis was done quantitatively by using statistical analyses, such as calculating the percentages and frequencies. The qualitative data was derived from the responses in booklets and video recording lessons. The qualitative data was in the form of words such as description of events, transcripts of written documents (Fitz-Gibbon and Morris, 1987). In some cases the quantitative data was translated into qualitative data. According to Fitz-Gibbon and Morris (1987), both kinds of data are needed in a complete evaluation and each compliments and supports the other (p. 10).

3.9 Ethical Considerations

According to Neuman (2003), the researcher must explain what the research entails to all teachers and why the research takes place in that particular setting. All teachers have the right to insist on the results of the particular research. The Research Ethics Framework published by the Economic and Social Research Council in the UK, as cited in Angaama (2012, p.79) has set out a framework of ethical principles for educational research which institutions of higher learning seem to apply to a fair degree. These principles require that:

- Research should be designed, reviewed and undertaken to ensure integrity and quality.
- Research staff and teachers had been fully informed about the purpose of the research as mentioned before.
- The confidentiality of the information supplied by the researcher and the anonymity of the teachers must be respected.
- Any harm to research teachers must be avoided, etc.

In line with all mentioned above, the researcher made ethical commitments to the University of the Western Cape and abided by them. In other words, the researcher followed all the guidelines prescribed by the University of the Western Cape in order to perform the research. A letter of permission was submitted to the following:

- Western Cape Education Department accompanied by a letter from the University and a copy of the proposal (Appendix 4 and 5).
- The principals and teachers of the sampling schools in District X and District Y (Appendix 2 and 6).

Chapter 4 Results and Data Analyses

4.0 Introduction

The previous Chapter focused on the research design and methodology guiding the study. This Chapter presents results for this study entitled ‘The effects of a Dialogical Argumentation Instruction Model (DAIM) on Science teachers’ understanding of capacitors in selected Western Cape Schools.’ The general aim was to see whether DAIM had an effect on the teachers’ understanding of capacitors. The researcher’s aim was also to raise awareness regarding indigenous knowledge systems amongst teachers in the sample. Results shall be indicated both quantitatively, as well as qualitatively.

The study was designed to answer the three Research Questions which are:

1. What conceptions of capacitors do the teachers under study hold?
2. What effect does DAIM have on the subject teachers’ scientific and indigenous conceptions of capacitors?
3. What are the subject teachers’ perceptions on the use of DAIM in the teaching of capacitors?

The data was analyzed according to the order of the three Research Questions. Data was analyzed using the theoretical framework of TAP and CAT as espoused by Toulmin (1958) and Ogunniyi (2007). First to be presented, in Research Question 1, is the scientific and indigenous conceptions of teachers regarding capacitors before any engagements, discussions and trainings are determined. In Research Question 2, the focus was to examine whether DAIM had an influence on the understanding of the scientific and IK concepts teachers hold regarding capacitors. Lastly, the perceptions of teachers regarding the use of DAIM are presented. In this study, the instrument used for the perceptions of teachers was a Reflective Diary provided by the teachers. In each case, the data was analyzed according to TAP and CAT using the mixed method technique which incorporates both qualitative and quantitative. The presentation of results in the order of the Research Questions follows below:

4.1 Research Question 1(RQ1): What conceptions of capacitors do the teachers under study hold?

The researcher divided the responses of the teachers into three subsections: the structure of the capacitor, the function of the capacitor and the applications of a capacitor. In all three subsections, the researcher classified the responses of the teachers into a scientific and indigenous subsection where applicable. The instrument used to answer RQ1 was called a Capacitor Assessment test (CA test) which is found in the Booklet designed by the researcher under section A (See Appendix 1.1). The researcher also included the individual responses of the teachers (where applicable) during the three DAIM lessons in the booklet to determine what their conceptions of capacitors were before any engagement of discussions took place between the teachers.

The following sub-Research Questions were identified in order to construct a valid research approach for this question.

4.1.1 What are the teachers' scientific conceptions of capacitors?

The responses of both the *Initial Group* and the *Case Study Group* of teachers regarding their scientific knowledge on the structure and the function of a capacitor are shown below. The Initial Group (as mentioned in Chapter 3) was the group of teachers who participated at the beginning of the study, but because of a change in circumstances another group of teachers (Case Study Group) from a different District was selected for an intense case study.

As for the scientific knowledge of the application of a capacitor, only the data of the Case Study Group is shown as the circumstances had changed and no further assessment of the Initial Group of teachers took place.

4.1.1.1 The structure of a capacitor

The item A6 in the CA test was used to elicit teachers' scientific conceptions on the structure of a capacitor. The item A6 stated the following:

Item A6: Name the parts of any capacitor. Name the source of your information.

For the above question, the responses of the teachers (Initial and Case Study Groups) regarding their knowledge on the scientific structural parts of a capacitor and the frequency of teachers' responses is shown below:

Table 4.1.1 The responses of the Initial Group of teachers' regarding the structure of a capacitor.

Response	Frequency of teachers	Percentages (%)
<i>2 parallel plates and di-electric (correct all three)</i>	7	47
<i>Parallel plates (one part)</i>	1	7
<i>Di-electric material (one part)</i>	1	7
<i>None of the above</i>	6	39

The Case Study Group of teachers' responses regarding the structure of a capacitor

- T1 and T4** : *Di-electric (insulator) and two parallel metal plates*
- T2** : *input also rechargeable cell to output to store*
- T3** : *n elektroniese stophek, Bron: 'n werkswinkel in Bellville*

Discussion

It seemed evident that an average of approximately 48% of both the Initial and the Case Study Groups of teachers knew the scientific structure of a capacitor. Based on the above response, it was clear that T2 and T3 from the Case Study Group and about six teachers from the Initial group did not have any idea of the structure of any capacitor consist of. This was quite disturbing seeing that the researcher assumed that the scientific structure of a capacitor should be known and familiar to all of them. No sources were indicated by the teachers. They stated that the only information they had on capacitors which was that a capacitor consists of two metal plates and a di-electric (insulator) was obtained from the

school textbook (Govender, 2012). The insulator is a material whose internal electric charges do not flow freely, making it impossible to conduct an electric current under the influence of an electric field [<https://en.wikipedia.org/wiki/insulator>].

4.1.1.2 The function of capacitor

Item B1.1 in the individual section of the practical DAIM lesson asked the question:

What is the function of a capacitor in a circuit?

The responses of the Initial Group of teachers are indicated in Table 4.1.2 below:

Table 4.1.2 The Initial Group of teachers' responses regarding the frequencies and percentages on the function of a capacitor.

Response	Frequency	%
<i>Storing charge</i>	10	67
<i>Storing energy</i>	1	7
<i>No Response</i>	4	26

The responses of the Case Study Group were as follows:

- T1:** *The capacitor is charged through the battery and it also direct the flow of charge*
- T2:** *Om elektriese stroom in verskillende rigtings te laat vloei[To allow the electric current to flow in different directions]; Grounds: sodat die elektriese motor kan beweeg[so that the electric motor can move]*
- T3:** *It seems like it is there, together with the battery, store energy; Grounds: Battery usually supplies energy. Capacitors store overflow energy*
- T4:** *Stores charges, a capacitor gets it charge from the battery and release it to the LED. Grounds: LED lights up, doesn't matter how you switch the direction of the capacitor/how charge flows*

Discussion

In the Initial Group, the majority (67%) of the teachers indicated that the function of a capacitor is to store charge. Only one teacher indicated that the capacitor stores energy and about 26% of the teachers did not give any response. As for the Case Study Group, all the teachers had their own opinions and responses on the function of a capacitor. Once again 50% of the Case Study Group of teachers included the word “charge” when explaining the function of a capacitor.

Therefore, an average between both groups of 58% indicated that the only function of a capacitor is to store charge, 11% indicated that the capacitor stores energy and 31% gave different answers far from the correct answer which is the response of the minority with an average of 11%. This might be because teachers’ only frame of reference is textbooks stating that capacitors store charge. As cited by Grayson, Harris, McKenzie, Schreuder, Dilraj, Harris & Cohen (2008) ‘A capacitor is a device for storing charge’ (p.105).

The word ‘charge’ as mentioned before has many meanings (Beatty, 1996) but it appeared in text books, therefore teachers accept ‘charge’ as the correct term used. In practice, energy is stored in the electrostatic field that forms between the two plates of the capacitor. It is therefore necessary to use a teaching method or model like DAIM to help the teachers overcome these misconceptions (Aarons, 1990 and 1998).

4.1.1.3 The Application of capacitor

Some items in the CA-test were used to elicit the Case Study Group teachers’ conceptions on the application of a capacitor which include how capacitors are applied in electrical motors as well as how capacitors are charged and discharged in an electric circuit. As mentioned before, no data could be collected from the Initial Group with reference to the application of capacitors due to changed circumstances.

Table 4.1.3 displays the frequency distribution of the teachers’ correct responses (Pre-and Post) regarding their conceptions of capacitors in relation to electric motors.

Table 4.1.3 Frequency distribution of teachers' pre- test and post-test conceptions of capacitors relating to electric motors (Appendix 1)

Categories	Pre (Freq)	Pre (%)	MEAN PRE	Post (Freq)	Post (%)	MEAN POST
A1: What is an electric motor?	2	50	12,5	3	75	18,75
A2: Two types of electric motors	2	50	12,5	4	100	25
A3: Type of AC motor that assists in minimizing Electrical noise and electrical sparks in electrical appliances.	0	0	0	3	75	18,75
A4: Device needed to get an induction motor started in a certain direction	2	50	12,5	4	100	25
A5: How world first came in contact with capacitors.	1	25	6,25	2	50	12,5
A6: Parts of a capacitor	2	50	12,5	4	100	25
Total			9,4			20,8

Some of the problems that surfaced were that the teachers did not understand how a capacitor could be used in everyday life and how it could be applied to an electric motor. This showed that the general knowledge and understanding of both electric motors and capacitors of teachers seemed to be poor.

It shows in the pre-test that the teachers obtained an overall mean rank score of 9.4. It is evident that item A3 has the poorest response followed by A5. It is clear that teachers seemed to lack a deeper understanding of electrical motors, especially referring to the fact that they did not know a type of an AC motor and that DC and AC motors play a vital role in everyday life. The CAPS document states that: "This curriculum aims to ensure that children acquire and apply knowledge and skills in ways that are meaningful to their own lives" (p.4). The correct response to A3 is that an induction motor is needed to minimize electrical noise and electrical sparks in electrical appliances. It was very discouraging to the researcher that not one of the teachers could provide the correct answer, for example

Their responses were:

- T1:** *conductor ac-motor;*
T2: *“wisselstroom” transformer;*
T3: *an oscilloscope will show these changes, but there must be set of organiser,*
T4: *no response.*

Not even one of the responses was close to the correct answer. Item A5 was also very poorly answered. . It was obvious that most of the teachers did not give much appreciation to the acknowledgement of the rich history or everyday experiences of a capacitor in this case. As mentioned by Diwu (2010), the history and everyday experiences from home can be termed IKS.

The following are the responses for Items A1; Item A2; Item A3 and Item A4:

Item A1: What is an electric motor?

In this item, the teachers were required to show understanding of what an electric motor is. The mean rank score for the first category was 12.5, which indicated that very few teachers knew the correct answer.

Their responses were:

- T1** Pre: *It uses electric energy to generate mechanical energy A1.*
 Post: *A device that changed electrical energy into mechanical energy*
- T2** Pre: *Provides electricity to objects.*
 Post: *Electrical energy is changed into mechanical energy*
- T3** Pre: *An apparatus that cause drive. Motors are used to drive or turn things, for example in a toy- electric car.*
 Post: *Energy conversion from mechanical to electrical.*
- T4** Pre: *It is a device that converts electrical energy to mechanical energy.*
 Post: *Same as in the pre-test*

Only 50% of the teachers in the pre-test could provide the correct answer to the question posed, namely that the electrical motor is a device that converts electrical energy to

mechanical energy. Teacher T4's response is the best to the question asked. However, a critical glance at the data shows that T2 and T3 did not seem to have any idea of what an electrical motor was at first. Teacher T2 showed some progress at the post-test, but T3 switched the two types of energies around.

Item A2: Name two types of electrical motors

Again, the mean rank score (12.5) revealed that very few of the teachers could name the two types of electric motors.

Their responses were:

- | | |
|-----------|--|
| T1 | Pre: <i>'Gelykstroom Motor', WisselstroomMotor [DC and AC motors]</i>
Post: <i>AC and DC-motors</i> |
| T2 | Pre: <i>haardroeer, wasmasjien [hairdryer, washing machine]</i>
Post: <i>DC and AC</i> |
| T3 | Pre: <i>AC- Motors (motors to drive small appliances) and DC- Motors (motors to drive bigger appliances)</i>
Post: <i>Direct Current and Alternating Current Motors</i> |
| T4 | Pre: <i>hairdryer, fan</i>
Post: <i>AC and DC</i> |

Two of the teachers (50%) indicated that the two types of electrical motors are AC and DC motors. T2 and T4 seemed to get mistaken between the type of motors and the electrical appliances where such motors could be found. Although the response of T3 was correct, the basis of the response was incorrect and misleading. In the post-test all the teachers could recall that AC and DC motors are the two types of electrical motors.

Item A3: Name one type of AC-motor that assists in minimizing electrical noise and electrical sparks in electrical appliances.

This item required the teachers to relate an induction AC-motor where a capacitor is needed, to aspects of daily living. The mean score obtained by the teachers for this particular

question was zero and this shows that none of the teachers seemed to have a deeper understanding of electric motors.

Their responses to the question were:

- T1** Pre: *conductor-ac- motors*
Post: *AC induction Motor*
- T2** Pre: *'wisselstroom' transformer*
Post: *Single- Phase Induction motor*
- T3** Pre: *an oscilloscope will show these changes but there must be some set of organiser*
Post: *Induction Motor*
- T4** Pre: *No answer*
Post: *Conduction Motor*

In Item A3, teachers were expected to demonstrate understanding of Alternating Current (AC) motors, but the percentage in Table 4.1.3 for A3 was considerably low (0%). This was very disturbing to the researcher as the teachers were very experienced. None (0%) of the teachers could provide the correct answer, namely that the induction motor assists in minimizing electrical noise and electrical sparks in electrical appliances. In the post-test, three of the teachers (75%) provided the correct response and only T4 gave an incorrect response.

Item A4: What device is needed to get the induction motor started? Name it. What is the reason/grounds for your answer?

For this item, it was evident that even though teachers did not know how an induction motor is used in real life, they seemed to have a clearer idea on what the induction motor needed to get it started. The mean score for this particular category was 12.5, once again very low.

Their responses were:

- T1** Pre: *conductor*
Post: *Capacitor, because it directs current*
- T2** Pre: *die starter by 'n motor car*
Post: *Capacitor, shows the induction motor in which direction it should turn*
- T3** Pre: *Capacitor, because it stores electric energy*
Post: *Capacitor, gives direction to the windings*
- T4** Pre: *Capacitor stores charges (energy) energy needed for*
Post: *Capacitor, direct the current in a certain direction.*

Only two (50%) teachers knew that an induction motor needed a capacitor as a starter to send the motor in a certain direction. All (100%) the teachers in the post-test agreed with the above statements. The teachers showed almost no knowledge of how capacitors could be applied in real life. This might be the reason for including Electrodynamics in the grade 12 physical sciences curriculum of South Africa. The Grade 12 physical sciences curriculum requires that teachers have thorough knowledge on electrodynamics that forms part of the broader topic of Electricity and Magnetism, a term 3 Topic as indicated by the Curriculum and Assessment Policy Statement (CAPS). This includes knowledge of the electrical motors, alternating current, capacitive and inductive circuits, active circuit elements, LED's and so on. The researcher therefore decided to do an intense investigation to see whether teachers have conceptual understanding of electrodynamics, specifically referring to electric motors. The idea was to investigate whether the teachers knew how to apply capacitors to an electric motor.

Another application of a capacitor is when it charges and discharges in an electric circuit. The researcher tried to obtain information from the individual responses of the teachers to find out whether they knew when a capacitor charges and when a capacitor discharges. In the booklet, on item B1.4 the question stated:

What will happen to the LED when the battery is removed from the closed circuit and only the capacitor is present in the closed circuit? What is your ground(s) for your answer?

The responses of the teachers were as follows:

- T1:** *When battery is removed from the circuit, the LED will still light up, because capacitor will be discharge.*
- T2:** *Die stroom sal vloeï totdat die elektrisiteit opgebruik is [The current will continue flowing until the electricity is used up] Grounds: None*
- T3:** *It will stay on for a while and if it is not discharged, it will stop emit light. Grounds: I saw it at the charger of my laptop.*
- T4:** *LED does not light up; Grounds: Without the battery, no charges are transferred to the capacitor.*

When looking at the above excerpts, one could assume that teachers did not know when a capacitor charges and discharges in an electric circuit. Two of the teachers (50%) seemed to know that the reason for the LED to continue to emit was because the capacitor was discharging. Based on the responses, the other two teachers (50%) seemed to believe that a battery needs to be present in order for the LED to light up.

Summary

For the teachers in this study, effective teaching methodology and lack of pedagogical content knowledge (PCK) on capacitors and its applications is a key challenge. T2: *'Ek wil graag weet hoe werk 'n capacitor en waar word dit in die werklikheid gebruik'* [I really want to know more about a capacitor and where in the real world is it used]. T3: *I know little*

about capacitors, I know a couple of appliances. These teachers in this study seemed very enthusiastic and eager to know more about a capacitor that they used to find very challenging to present to their learners.

The teachers' responses that emerged after a careful inspection of data, was predominantly from a scientific view, based on science school textbooks as claimed by them. Referring to Table 4.1.3, it is very evident that the scores of correct responses vary from 0-50% in the pre-test. The CA-test results provided useful information to the researcher as to what knowledge the teachers held on capacitors and its applications, specifically looking at electric motors prior to any engagements and trainings sessions. The data suggested that teachers held very little knowledge of electrical motors. In the Pre-test, the percentages of correct responses obtained by T1, T2, T3 and T4 were 50%, 0%, 33% and 67% respectively. The mean score obtained was 37.5% which is very low light of the teachers' teaching experience and their competence to teach physical sciences at Grade 12 level.

In response of the application of capacitors, teachers have had very little conceptual knowledge and understanding on how a capacitor could be applied to an electrical motor and in an electric circuit (Sendur, 2012). This might be related to the CA test result that indicated their poor knowledge and conceptual understanding of electrodynamics.

4.1.2 What are the teachers' indigenous conceptions of capacitors?

The data of both Initial and Case Study Groups are included for the structure and the function of a capacitor only. The structure of the capacitors is compared to a natural phenomenon, but as this study further developed, another indigenous view emerged regarding the structure and the function of a capacitor.

The structure of a capacitor

A capacitor is an electronic device that can be compared to some phenomena in nature. In item B1.2 of the individual responses, the following question was asked: "Name any natural phenomenon that a capacitor could be compared to. What is/are your ground(s) for your answer?" The responses of the Initial and Case Study Groups are indicated below respectively.

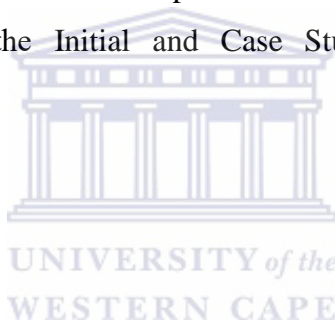


Table 4.1.4 Initial Group teachers' responses regarding the comparison of a capacitor with a natural phenomenon

Response	Frequency	%
<i>Lightning</i>	5	34
<i>Clouds</i>	2	13
<i>Charging and Discharging</i>	2	13
<i>Static electricity</i>	6	40

Discussion

A capacitor could be compared to the natural phenomenon of lightning. According to Table 4.1.4, only 34% of the Case Study Group teachers understood this. Furthermore, 13% of the teachers claimed that a capacitor could be compared to clouds; another 13% claimed capacitors could be compared to charging and discharging and 40% teachers claimed that a capacitor could be compared to static electricity. Judging from their responses, one could assume that most of the teachers did not understand what was meant by a natural phenomenon.

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The **Case Study Group's** responses regarding the comparison of a capacitor with a natural phenomenon were as follows:

- T1** : *Lightning, cloud, tree; Grounds: It stores and build up energy Booklet: B1.2*
- T2** : *generator, son, laaier van rekenaar; grounds: elektrisiteit word gestoor en dan verskaf aan die bron[generator,sun,computer; grounds: electricity is being stored and then provided to the source]*
- T3, T4** : *Thunder/Lightning; Grounds: great discharge during thunderstorms*

It was clear that T2 did not seem to understand what was meant by a natural phenomenon. The dominant response was that a capacitor could be compared to the phenomenon of lightning as indicated by many physical sciences textbooks.

Item C1 was used for comparing the scientific and indigenous applications or viewpoints of a capacitor.

C1 (Individual) stated: By reading Marc's Plan, tabulate the similarities of the three different parts of a western capacitor to the indigenous capacitor (Marc's capacitor) used by farmers.

The responses of the teachers (Case Study Group only) were summarized as indicated in Table 4.1.5 below:

Table 4.1.5 Case Study Group's responses regarding the comparison of the structure of a capacitor with an indigenous capacitor

Teachers(T)	Response	Frequency	%
T1,T2,T3	<i>Plate 1 of capacitor- Galvanized steel rod</i>	3	75
T4	<i>Plate 1 of capacitor- Copper rod</i>	1	25
T1,T2,T3	<i>Plate 2 of capacitor- Copper rod</i>	3	75
T4	<i>Plate 2 of capacitor - Steel rod</i>	1	25
T1,T2,T3,T4	<i>Di-electric(between the plates)- ground/soil</i>	4	100

In the mind of the teacher, a western structure of a capacitor was compared with a more indigenous structure of a capacitor. Galvanized steel was used to make the soil more fertile in order to supply plant nutrients. Galvanization is the process of applying a protective zinc coating to steel or iron in order to prevent rusting (<http://en.wikipedia.org/wiki/Galvanization>).

The above Table 4.1.5 gave the researcher an indication of how each teacher compared the different parts of a capacitor with an indigenous capacitor used by farmers in areas where much lightning takes place. For example T1, T2 and T3 compared Plate 1 of a capacitor with a Galvanized steel rod while T4 compared Plate 1 with the copper rod of the indigenous capacitor and vice versa. The indigenous capacitor was designed in order to perform a certain function.

Function of a capacitor

An indigenous capacitor could serve as a protecting device. Item C2.5 stated:

In your group, discuss how this capacitor of Marc could perform its function as a protective device.

The responses of the teachers on item C2.5 were as follows:

- T1:** *Yes, it would attract the lightning, thus makes it softer for the people in the area. Copper would attract the electrons very effectively.*
- T2:** *Konnek die koper en staalpype om n 'goeie afleiding te kry. [Connect the copper and steel pipes to get a better]*
- T3:** *No response (answer left out)*
- T4:** *No response (answer left out)*

Based on the above responses, the teachers seemed to know that the copper and steel rods had something to do with the indigenous capacitor, but they have seemed to find difficulty in expressing them clearly. Their grounds were based on scientific explanations, referring to T1's response above. The information regarding the man-made capacitor used by farmers to protect their crops on farms was totally new information to the Case Study Group.

Summary for Research Question 1 Findings

It is very evident that teachers did hold very limited scientific knowledge on the structure and the function of the capacitor. What was very evident was the fact that teachers were lacking understanding for the applications of a capacitor. The teachers' conceptual knowledge on the applications of the capacitor was extremely poor. The teachers could not make the connection between electrostatics and the capacitor device. The teachers showed no evidences of any indigenous knowledge concepts about the capacitor.

. The knowledge teachers held was more based on the nature of sciences (NOS). All information held by the teachers regarding capacitors, according to them, was retrieved from the school's textbook prescribed to them.

4.2 Research Question 2: What effect does DAIM have on the subject teachers' scientific and indigenous conceptions of capacitors?

In order to answer Research Question 2, three DAIM lesson templates were designed by researcher as indicated below:

- Lesson 1 – Item B (Appendix 1.2 – Practical DAIM lesson on the Charge and Discharge of Capacitors)
- Lesson 2 – Item C (Appendix 1.3 – Case Study on Capacitors versus Marc's Capacitor)
- Lesson 3 – Item D (Appendix 1.4 –Case Study on Capacitors versus the Phenomenon of Lightning)

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4.2.1 Analysis of the teachers' conceptions of capacitors according to TAP

Toulmin's (1958) Argumentation Pattern (TAP) has been used by many researchers in science education to promote scientific discourses in the science classroom. Using Toulmin's Argumentation Pattern (Toulmin 1958; Erduran, Simon and Osborne, 2004: 11; Driver et al., 2000) teachers apply DAIM to classroom discourse as previously referred to by Erduran and Jiménez-Aleixandre (2008).

According to Ogunniyi and Hewson (2008), TAP is one of the tools in science education that enable teachers to understand the nature of science. In order to resolve some of the difficulties faced by the learners and teachers, Erduran, Simon and Osborne (2004) collectively termed the data, warrants and backing as "grounds" as explained in Chapter 3.

In this section, the data of the Case Study Group (n=4) only was obtained from the video transcriptions and observations recorded in the booklet during the three DAIM lessons on Capacitors. The levels of TAP were used to characterize the arguments of teachers as illustrated in the sub-sections below.

Level 0	Non-oppositional - At this level, no arguments.
Level 1	Argument involves a simple claim against a counter claim with no grounds or rebuttals. At this level, teachers made a claim only before and after DAIM, but without any grounds.
Level 2	Argument involves claims or counter claims, with grounds but no rebuttals.
Level 3	Argument involves claims or counter claims with grounds but only a single rebuttal challenging the claim. At this level, teachers made claims with grounds before DAIM and made claims with grounds and a single rebuttal after DAIM.
Level 4	Argument involves multiple rebuttals challenging the claim but no rebuttal challenging the Grounds (data, warrants and backing) supporting the claim.
Level 5	Argument involves multiple rebuttals and at least one rebuttal challenging the grounds.
Level 6	Argument involves multiple rebuttals and at least one challenging rebuttal.

The data obtained from the Case Study Group (n=4) was analysed according to TAP under the three subsections of the capacitor: the structure of a capacitor, the function of a capacitor and the application of a capacitor. It is important to note that the same responses of the teachers before DAIM regarding the structure of the capacitor found in Item A6 had been used in both Items C1 and D1 for analysis purposes.

4.2.1.1 Analysis of the teachers' conceptions of structure of capacitors according to TAP LEVELS 1, 2 AND 3

At TAP level 1, Tables 4.2.1 below indicates the teachers' responses to the CA test item A6 before and after DAIM had been introduced to the Case Study Group that were classified as TAP level 1.

Item A6: Name the parts of any capacitor. Name the source of your information.

Table 4.2.1 below shows the Case Study Group's responses for item A6 according to TAP level 1.

Table 4.2.1 Teachers' Responses to item A6 according to TAP level 1

Teacher (T)	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1	<i>Di-electric and two parallel metal plates</i>	1	<i>Two parallel metal plates and di-electric</i>	1
T2	<i>n elektroniesestoph ek[electronic stopgate]</i>	1	<i>two metal plates that are parallel with a di-electric separated the plates</i>	1
T3	<i>input- also a rechargeable cell to output- store energy.</i>	1	<i>di-electric and two metal plates</i>	1
T4	<i>2 plates separated by an insulator</i>	1	<i>2 metal plates separated by a di-electric</i>	1

Discussion

At this level, teachers made a claim only before and after DAIM without any grounds. From Table 4.2.1 above, what seemed evident was that the teachers' claims shifted from an incorrect statement to a correct statement as shown by T2 and T3. As different capacitors were provided to the teachers by researcher, T1 said, *"I never knew that a capacitor is found in a round shape, because the text book describes it as parallel"*. This was again disturbing as many other teachers also expressed the idea of a capacitor being parallel.

The teachers were also shown through the model of the single-phase induction motor where and why capacitors are used. T4 responded: *"Although I know the three parts of a capacitor, I have never seen a capacitor before"*. This was very discouraging because it is expected of teachers to be lifelong learners. This teacher should have done research on capacitors or visited an electronics shop to ask them what a capacitor looks like.

At TAP Level 2, the information below shows that teachers' conceptual understanding progressed regarding the structure of a capacitor in response to items C1 and D1. The teachers were capable of comparing the different parts of the capacitor as identified by them before DAIM, with the different parts of an indigenous capacitor and the phenomenon of lightning after they were engaged in discussions. These comparisons were supported by grounds which resulted in a level 2 discourse according to TAP. Their responses were captured in Tables 4.2.2 and 4.2.3 below.

Item C1 (Individual): By reading Marc's Plan, tabulate the similarities of the three different parts of a western capacitor compared to the indigenous capacitor used by farmers.

Table 4.2.2 below shows the Case Study Group's responses to item C1 shifted from TAP level 1 to TAP level 2.

Table 4.2.2 Teachers' Responses to item C1 according to TAP level 2

Teacher (T)	Before DAIM	Level of Argument	After DAIM	Level of Argument
T4	2 plates separated by an insulator	1	Copper Rod (negative plate); Grounds: take negative charges from steel rod; Steel Rod (+ plate) Grounds: charges move from ground to rod, insulator- soil; Grounds: charges do not flow from 1 plate to another. The two charges get separated by the di-electric.	2

Item D1: From the information above (case study about lightning), write three things about lightning that could be compared to the three parts of a capacitor (refer to the scientific structure of a capacitor).

Table 4.2.3 shows the teachers' responses to item D1 shifted from TAP level 1 to TAP level 2.

Table 4.2.3 Teachers' Responses to item D1 according to TAP level 2

Teacher(T)	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1	<i>Di-electric and two parallel metal plates</i>	1	<i>Negative Plate: Cloud, because electrons build up in the clouds; Positive plate-earth, because electrons goes from negative to positive; Dielectric- Air, because it keeps the charges apart</i>	2
T4	<i>2 plates separated by an insulator</i>	1	<i>Clouds; Grounds: Clouds brush against each other, resulting in charges formed. Plate 2- Earth; Grounds: If lightning strike, charges flow to the earth. Plate 3- Air-different from other insulators. I know charges flow through the air.</i>	2

Discussion

Tables 4.2.2 and 4.2.3's arguments refer to the concepts regarding the structure of a capacitor and the comparisons made to it. The comparisons were meant to stimulate interest amongst teachers and to make the teaching of capacitors more holistic in nature as suggested by Semali and Kincheloe (1999).

The information in Table 4.2.2 is an indication of the responses of the teachers to the question asked in item C1. Teachers were required to compare the scientific structure of a capacitor with an indigenous capacitor used by farmers in areas where

much lightning takes place. It seems clear that T4 was capable of doing the above with grounds after DAIM which resulted in a level 2 discourse.

In Table 4.2.3 in D1, teachers were required to compare the structure of a capacitor to the phenomenon of lightning. It can be said that Teacher T1 was in the position to compare the structure of a capacitor with the clouds involved in the phenomenon of lightning. As energy builds up in one plate of a capacitor, energy also builds up in the clouds.

T4 opined that the plates of the capacitor should be separated by a di-electric which is an insulator according to the textbooks. T4 was initially troubled by where the lightning stroke came from if the air is di-electric. According to her knowledge, if lightning strikes, then how could air be an insulator, because no charge is supposed to go through the di-electric that acted as the insulator. *“I know charge flows through air”*. As the discussions proceeded, the point was raised that air is not a perfect insulator, but it can be made to conduct, so that the separation of the charges from the cloud to the ground could be bridged. Such an event is called a lightning strike.

At TAP level 3, the teachers gave a claim supported with grounds and a single rebuttal challenging their claims after exposure to DAIM.

The information below is a comparison of the structure of the capacitor with indigenous knowledge and lightning respectively.

Item C1: Individual: By reading Marc's Plan, tabulate the similarities of the three different parts of a western capacitor compared to the indigenous capacitor used by farmers.

In Table 4.2.4 below, 75% of the teachers' conceptual understanding progressed from a TAP level 1 to a TAP level 3 argument discourse, challenging the opinions that they had before DAIM with supported grounds.

Table 4.2.4 Teachers' Responses to item C1 according to TAP level 3

Teacher	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1 and T4	<i>Di-electric and two parallel metal plates</i>	1	<i>Plate 1- Galvanized steel, because it does not rust in the ground; Plate 2- Copper rod, it attracts the electrodes; Die-electric is Ground, the plates are in the ground and separate the plates</i>	3
T2	<i>'n elektroniesestophek [electronic stopgate]</i>	1	<i>Plate 1- Steel and copper rod; Plate 2- Lightning; Di-electric- soil; Grounds: Conductive plates</i>	3
T3	<i>input- also a rechargeable cell to output- store energy</i>	1	<i>Galvanized steel rod(positive);Grounds- Less resistance, copper rod(negative); Grounds: Huge resistance, di-electric- ground/soil; Grounds- is the insulator between the rods</i>	3

Discussion

In response to item C1 during the DAIM case study, Table 4.2.4 indicated that 75% of the teachers experienced a mind shift moving from a level 1 to level 3 arguments according to TAP. Another angle has been brought forward to make scientific knowledge of capacitors more meaningful and easy to relate to (Osborne, et al;2004). In this study, the teachers were able to relate the scientific structure of a capacitor with a man-made capacitor used by Farmers. After DAIM, T1, T3 and T4 were able to compare the scientific structure of a capacitor with those capacitors handmade by the farmers to protect their crops.

In the case of T2 (Table 4.2.4), he compared the second plate of the western capacitor with the phenomenon of lightning instead of the second plate being metal. According to T3, copper plate with a high resistance was used due to its conductivity and the second plate of the capacitor could be compared to the galvanised plate used by farmers due to its low resistance, meaning it is less conductive than copper. T1, T2, T3 and T4 agreed that the soil/ground that covered the plates could be regarded as the di-electric, seeing that the soil keeps the two galvanised and copper plates apart. The question came out in the discussion why specifically galvanised steel and not just steel. From the conclusions drawn due to their discussions one can assumed that the galvanized steel's purpose was to make the soil more conductive as stipulated by T4: *Perhaps galvanized makes the ground soft so that an electric current can pass through*". At this stage, the teachers were able to argue from level 1 (arguments with no claims) to level 3 (arguments with claims with grounds and even challenging the claim) as indicated above in Table 4.2.4 (Van Eemeren, Grootendorst & Henkemans, 2002).

Apart from comparing capacitors to an indigenous capacitor used by the farmers, it could also be compared to a natural phenomenon of lightning as indicated by the responses in Table 4.2.5 below after DAIM.

Item D1: Individual: From the information above (case study about lightning), write three things about lightning that could be compared to the three parts of a capacitor (refer to the scientific structure of a capacitor).

Table 4.2.5 below shows the teachers' responses to item D1 shifted from TAP level 1 to TAP level 3.

Table 4.2.5 Teachers' Responses to item D1 according to TAP level 3

Teacher	Before DAIM	Level of Argument	After DAIM	Level of Argument
T2	<i>n elektroniese stophek[electronic stopgate]</i>	1	<i>Plate1- cloud ; Grounds-energiebou op in wolke, Plate 2- earth; Grounds: induced ground di-e;ectric - air; Grounds: beweegdeur lug vanaf wolk en aarde.</i>	3
T3	<i>input- also a rechargeable cell to output- store energy</i>	1	<i>Clouds (negative);Grounds-changes are generated here/Buildup of electrons; Ground(positive plate); Grounds: Changes flow here, air- di-electric; Grounds: It keeps the changes apart/isolated.</i>	3

Discussion

T2 moved from not knowing what the structure of a capacitor was to a cognitive state where the teacher could compare the capacitor with a natural phenomenon like lightning.

T3 moved from an incorrect response to a correct response at level 3 according to TAP. The above proved that there was clearly a cognitive shift that took place in both cases moving from level 1 to level 3 discourses.

4.2.1.2 Analysis of the teachers' conceptions of the function of capacitors according to TAP LEVELS 1, 2 AND 3.

The information in Tables 4.2.6, 4.2.7 and 4.2.8 show the teachers' responses to item B1.1 before and after DAIM.

Item B1.1: What is the function of a capacitor in the circuit? What is/are your ground(s) for your answer?

At TAP level 1, T4 made statements without grounds or reasons. This argument results in a level 1 discourse according to TAP as seen in Table 4.2.6.

Table 4.2.6 below shows the teachers' responses according to TAP level 1.

Table 4.2.6 Teachers' Responses to item B1.1 according to TAP level 1

Teacher(T)	Before DAIM	Level of Argument	After DAIM	Level of Argument
T4	<i>Stores charges, a capacitor gets it charge from the battery and release it to the LED.Can work both ways depending to which pole it is connected.</i>	1	<i>The capacitor can change the direction of rotation .Energy do come from battery.</i>	1

Discussion

As indicated by the response of T4, a capacitor stores charge. According to T4, the charge is obtained from the battery and releases it to the LED which is not the case. The energy is obtained from the battery and the LED shows that a current flows through the circuit. No grounds were added before and after DAIM which makes this argument of T4 a level 1 discourse.

Some of the Case Study Groups' responses seemed to be at TAP level 2 as shown in Table 4.2.7 below:

Table 4.2.7 Case Study Group's responses according to TAP level 2.

Teacher(T)	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1	<i>The capacitor is charged through the battery and it also direct the flow of charge. The capacitor takes energy from.... /Grounds: I've learned it from the text book.</i>	2	<i>The capacitor takes energy from the current that means the capacitor is charged. Grounds: The LED burns weaker and goes off eventually. The capacitor stores the energy</i>	2

Discussion

By the response of T1, it is clearly evident that the teacher's reasoning before DAIM is text book bound. The teachers only indicated that the function of a capacitor is to store charge as indicated by the textbook. From the response of T1 with grounds, one can assume that T1 then only believes that a capacitor charges and no discharging takes place, therefore no mind shift took place in the case of T1.

In Table 4.2.8 as shown below, some of the Case Study Groups' responses seemed to have shifted from TAP level 2 to TAP level 3.

Table 4.2.8 Teachers' responses according to TAP level 3.

Teacher	Before DAIM	Level of Argument	After DAIM	Level of Argument
T2	<i>“Om elektriese stroom in verskillende rigtings te laat vloei” [To allow the electric current to flow in different directions], Grounds: “sodat die elektriese motor kan beweeg.” [In order for the electric motor to move].</i>	2	<i>The capacitor takes energy from the current that means the capacitor is charged. Grounds: The LED burns weaker and goes off eventually. The capacitor stores the energy</i>	3
T3	<i>It seems like it is there, together with the battery, store energy; Grounds: Battery usually supplies energy. Capacitors store overflow energy</i>	2	<i>The capacitor can change the direction of the rotation in an electric circuit. Grounds, we have change the polarity of the battery. Capacitors are polarity sensitive</i>	3

Discussion

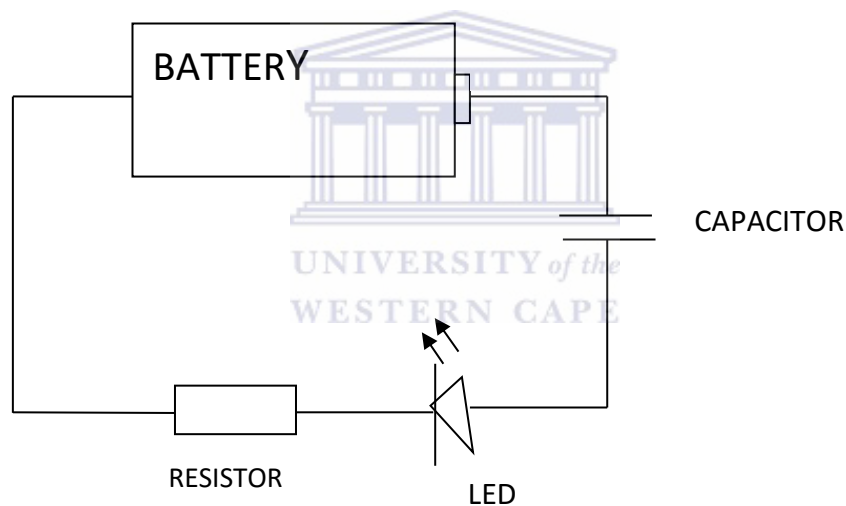
In Table 4.2.8, T2 and T3 had a mind shift from level 2 to level 3 arguments according to TAP in terms of their claims and grounds after discussions took place. It seemed that the teachers' conceptual understanding regarding the function of capacitors had improved as they could support their claims with valid grounds. Initially, when teachers were asked what the function of a capacitor is, their only response in some cases was that it stores charge, but after DAIM, an emergent concept arose which was that a capacitor could direct rotation of an electric motor in a particular direction as T3 and T4 stated that *“the capacitor can change the direction of the rotation in an electric circuit.”*

4.2.1.3 An analysis of the teachers' conceptions of the application of capacitors according to TAP LEVELS 1, 2 AND 3.

The arguments at different levels according to TAP, illustrated the conceptual understanding of the application of the capacitor, specifically referring to the charge and discharge of a capacitor.

The teachers had to determine whether the LED would light up in the circuit as shown in Figure 4.2.1 below and afterwards when the battery is removed from the circuit and only the capacitor is present.

Figure 4.2.1 RC (Resistor Capacitor) Circuit.



With reference to figure 4.2.1, there were no responses that could be identified for the application of a capacitor as level 1 argument according to TAP. All claims of arguments in this category were supported either before and after or only after DAIM with grounds and backings.

In Tables 4.2.9 and 4.2.10, the responses are according to TAP level 2 obtained from items A4 and B1.4

Item A4: What device is needed to get an induction motor started? Name it.

What is/are your reason(s)?

Table 4.2.9 below shows the teachers' responses obtained from Item A4. After the teachers discussed item A4 in their small groups, some of their arguments shifted from level 1 to level 2.

Table 4.2.9 Teachers' Responses to item A4 according to TAP level 2

Teacher	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1	Conductor	1	Capacitor, because it directs current.	2
T2	"Die starter by 'n motor car". The starter of a motor car	1	Capacitor, because it shows the induction motor in which direction it should turn	2
T3	Capacitor, because it stores electrical energy	2	Capacitor, it gives direction to the windings.	2
T4	Capacitor stores charges(energy) needed for	2	Capacitor, direct the current in a certain direction	2

Item B1.4: What will happen to the LED when the battery is removed from the closed circuit and only the capacitor is present in the closed circuit? What is/are your ground(s) for your answer?

Table 4.2.10 below shows the teachers' responses obtained from B1.4 before and after DAIM. After the teachers discussed item B1.4 in their small groups, some of their arguments shifted from TAP level 1 to TAP level 2.

Table 4.2.10 Teachers' Responses to item B1.4 according to TAP level 2

Teacher	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1	<i>It will still be lightening/</i>	1	<i>Yes, the LED is turned slightly:/ Grounds: The LED burnt until all the energy in the capacitor is used up</i>	2
T2	<i>“Die stroom sal vloei totdat die elektrisiteit opgebruik is”;</i> [the current will flow until all the electricity is used up].	1	<i>“ Ja, Rede: Die LED se ligsal brand totdat energie opgebruik is van die capacitor.”</i> [Yes, the LED is turned slightly: / Grounds: The LED burnt until all the energy in the capacitor is used up].	2

Discussion

In Table 4.2.9, the responses of T1 and T2 clearly indicated that the teachers underwent a cognitive shift in their thoughts, moving from level 1 arguments according to TAP level 2 arguments whereby they have supported their claims with grounds after being exposed to DAIM. After DAIM, all of these teachers agreed that a capacitor is needed to start an induction motor and to rotate the motor in a certain direction as T2 indicated “*the capacitor, because it shows the induction motor in which direction it should turn*”.

In Table 4.2.10, only 50% of the responses were correct and teachers were only after DAIM in the position to provide their claims with reasonable backings which resulted in a level 2 discourse according to TAP.

The responses below in Table 4.2.11 seem to reveal a TAP level 3 discourse and are retrieved from items B1.4 during the practical DAIM lesson on capacitors.

Item: B1.4: What will happen to the LED when the battery is removed from the closed circuit and only the capacitor is present in the closed circuit? What is/are your ground(s) for your answer?

Table 4.2.11 below shows the teachers' responses according to TAP level 3 obtained from B1.4. After the teachers discussed item B1.4 in their small groups, some of their arguments shifted from TAP level 2 to TAP level 3. T2 had no response indicated.

Table 4.2.11 Teachers' Responses to item B1.4 according to TAP level 3

Teacher	Before DAIM	Level of Argument	After DAIM	Level of Argument
T3	<i>It will not stay on for a while and if it is not discharged, it will stop emit light. Grounds: I saw it at the charger of my laptop.</i>	2	<i>The LED lit up slightly. Grounds: because the capacitor discharged quickly</i>	3
T4	<i>LED does not light up; Grounds: Without the battery, no charges are transferred to the capacitor.</i>	2	<i>It lit up slightly and go down, because the capacitor discharged quickly. Grounds the voltmeter indicated.</i>	3

Discussion

When the switch is closed, current will flow through the resistor and build up on the capacitor as a function of time. The product of the resistance and the capacitance is called the time constant, $t = RC$. To study the charging of a capacitor, we apply Kirchhoff's rule for potentials to the circuit containing a battery, capacitor and resistor. The maximum charge on the capacitor is a product of the potential difference of the battery and the capacitance of the capacitor, VBC . The charge on the capacitor cannot be seen, but we can see how the potential difference across the capacitor changes with time using a voltmeter to measure the voltages.

When the switch is opened, current will flow from through the resistor and will eventually neutralize the capacitor. Table 4.2.11 shows examples of teachers that underwent a mind shift from levels 2-3 after been introduced to DAIM. At this level, the teachers were in the position to make claims and to provide grounds as to whether the LED would light up/not if the battery was removed from the circuit and only the capacitor present. According to Ogunniyi and Hewson (2008), reasons for supporting a particular claim strive to persuade others about the truthfulness of such a claim.

At this level, due to the discussions and being practically involved, the teachers were in the position to challenge the claim by a single rebuttal, judging by the responses of teachers T3 and T4. They both agreed that the LED would still continue to burn, because of the fact that the capacitor was discharging. If we disconnect the battery from the circuit by opening the switch, the capacitor will discharge through the resistor. Once again, the charges cannot be seen as it left the capacitor, but could be expressed in terms of the potential difference across the capacitor as it changes with time using voltmeter.

[<http://Minerva.union.edu/labbrakes/Capacitance%20and%20Resistance.pdf>]. In other words, when the capacitor discharges, the current will flow (for a short time) in the opposite direction. T3 said: *It lit up slightly, because the capacitor discharged quickly.*

In order to know that a current flows through an electric circuit, the researcher thought it best to connect a LED to the circuit. The responses of the teachers in terms of the LED are indicated according to TAP level 3 in table 4.2.12 below:



The responses below in Table 4.2.12, seem to reveal a TAP level 3 discourse and are retrieved from items B1.3 during the practical DAIM lesson on capacitors.

Item B1.3: Will the LED light up if you switch the LED in an opposite direction?

Table 4.2.12 below shows the teachers' responses according to TAP level 3 obtained from items B1.3. In the smaller groups after the discussions took place, the arguments shifted from TAP levels 1 and 2 to TAP level 3.

Table 4.2.12 Teachers' Responses to item B1.3 according to TAP level 3

Teachers	Before DAIM	Level of Argument	After DAIM	Level of Argument
T1	<i>Yes, the current still flow if you connected to the capacitor</i>	2	<i>No, because the LED works only in a certain direction</i>	3
T3	<i>Yes. A LED does nothing other than showing that there is a current.; Grounds: Many appliances have LED's for example: A computer, cellphone, music systems, etc.</i>	2	<i>No, it was tested, because we changed the polarity of the LED and the battery.</i>	3
T4	<i>Yes</i>	1	<i>No, Does not light up; Grounds: + terminal connected to -terminal.</i>	3

Discussion

The purpose of discussing the LED was to ensure that teachers have sufficient knowledge of a LED. The capacitor acts as a power source as it dumps its voltage much quicker than a battery in order to switch on the LED for a short period. Therefore, it is important to have knowledge on LED's when connected to a capacitor.

The researcher also tried to investigate whether the LED had the same characteristic of being polarity sensitive as the capacitor.

In response to B1.3, it was the majority of the teachers (75%) who shifted from levels 1 and 2 arguments to a level 3 argument when defending their claims. Their grounds were due to the fact that the LED was polarity sensitive in this case. *A LED is a diode that emits light, which means that current only flows through an LED in one direction* according to T1, T3 and T4. If you try to make the current flow in an opposite direction, no current will flow. T1: *“No, the LED only works in a certain direction.”* There were no level 4-6 arguments. The author observed that the major reason for only level 1-3 arguments according to TAP to occur, might be due to lack of in depth content knowledge pertaining the capacitor as an electronic device.

4.2.2 Analysis of the teachers’ conceptions of capacitors according to CAT

The teachers’ conceptions were analyzed in terms of the theoretical framework of CAT (Ogunniyi, 2007). CAT is a theoretical framework that is concerned with how conflicting ideas such as the scientific/indigenous explanations of a capacitor are resolved to gain a higher level of consciousness or understanding (Ogunniyi, 2011). The theory postulates that when two different thought systems meet, co-existence could only be possible through cognitive shifts. As a reminder from Chapter 2, five different CAT categories describe the movement of conceptions in the mind of the individual or among individuals who are engaged in dialogue around related perceptions that are used in this study. These perceptions are: dominant, suppressed, assimilated, emergent and equipollent (Ogunniyi and Hewson, 2008, p.162).

4.2.2.1 Scientific worldview versus indigenous worldview in teachers' conceptions of a capacitor according to CAT

In this section the researcher wanted to find out whether DAIM had actually enhanced the Case Study Group's awareness about the Nature of Science (NOS) and the Nature of IKS (NOIKS). They were given Case Study 1 to discuss.



Case Study 1(Appendix 1.3) - as indicated below:

“Many, many years ago, Marc and Louise lived on the upper east side of Cape Town. After a few years of living in the city, they have decided to move to the rural area close to Wellington, just outside of Cape Town. Marc became a real farmer and it was expected of him to grow some crops. Marc noticed that their soil was in a terrible state and their stony fields were unsuitable for growing crops. He also noticed that the area suddenly underwent loads of lightning strokes which was very unlikely in the area. The lightning was the main purpose behind all the damages. He realized that the high frequency electron energy needed to be dispersed quickly in the earth body.

“What to do!” the farmer cried out loudly. He soon came up with a plan, which was as follows:

MARC’S PLAN

Due to the constant lightning strikes in the area, Marc decided to connect a galvanized steel rod and a copper rod (Figure 4.2.2) parallel (next to each other) into the soil , large spacing between the rods to reduce the overall inductance. Each rod was surrounded with soil and was resistively separated from the other.”

Figure 4.2.2 Galvanized steel and copper rods



Teachers **T1, T2, T3** and **T4** investigated the case study and found similarities between the structure of the scientific capacitor device and the capacitor made by the

farmers to protect their crops. Their views on the structure of a capacitor were asked before DAIM and after being exposed to DAIM.

They shared their individual responses of what they thought a capacitor consisted of. The responses of T1 and T4 seemed to be correct. It seemed that T2 was trying to give an example of where a capacitor could be applied to and T3 rather gave the function of a capacitor instead of providing the three parts a capacitor consists of. All of the responses were scientific of nature.

Some of these responses (Before DAIM) were as follows:

- T1** : *Di-electric and two parallel metal plates (scientific)*
T2 : *n elektroniese stophek [an electronic stop gate]*
T3 : *input- also a rechargeable cell to output- store energy*
T4 : *2 plates separated by an insulator (scientific)*

Through these discussions within their small groups (T1 and T2/T3 and T4), T2 and T3 took the assimilated view of T1 and T4 by agreeing that the correct structure of a capacitor consists of 2 plates and a di-electric material.

The Case Study Group of teachers within their small groups were able to compare the 2 plates of a capacitor with steel and copper used by the farmers and the di-electric with the ground/soil as indicated by Marc's plan in the case study. There were even grounds attached to the responses of the teachers that indicated to the researcher that the teachers' conceptual understanding of capacitors might have been improved due to the exposure to DAIM. The teachers could add much more information regarding the structure of a capacitor in comparison with their responses before they have engaged in any discussions.

Some of their (small group) responses were as follows:

Table 4.2.13 Small Groups' (T1 and T2/ T3 and T4) responses regarding the scientific structure versus the indigenous structure of a capacitor

T1	T2
<p><i>Plate 1 of a capacitor compared to the Galvanized steel, because it does not rust in the ground;</i></p> <p><i>Plate 2 of a capacitor compared to the Copper rod, it attracts the electrodes;</i></p> <p><i>Die-electric between the plates of a capacitor is Ground, because the plates are in the ground and separate the plates</i></p>	<p><i>Plate 1 of a capacitor compared to the Steel rod; Conductive plates, Galvanized steel: to make ground more fertile</i></p> <p><i>Plate 2 of capacitor compared to the Copper rod</i></p> <p><i>Di-electric between the plates of a capacitor compared to the soil;</i></p>
T3	T4
<p><i>Plate 1 of the capacitor compared to the Galvanized steel rod (positive); Grounds- Less resistance,</i></p> <p><i>Plate 2 of the capacitor compared to the copper rod (negative); Grounds: Huge resistance,</i></p> <p><i>Di-electric between the plates of a capacitor compared to the ground/soil; Grounds is the insulator between the rods(Emergent/Equipollent)</i></p>	<p><i>Plate 1 of the capacitor compared to the Copper Rod (negative plate); Grounds: take negative charges from steel rod;</i></p> <p><i>Plate 2 of the capacitor compared to the Steel Rod(+ plate) Grounds: charges move from ground to rod,</i></p> <p><i>Di-electric/ insulator between the two plates of the capacitor compared to the soil; Grounds: charges do not flow from 1 plate to another (Emergent/Equipollent).</i></p>

After the small groups had reached a consensus, their inputs were shared within the whole class. During the whole class discussions, the Case Study Group of teachers reached a consensus and seemed to understand that the structure of a capacitor can be equipollent viewed as a scientific device with the comparative indigenous applications or viewpoints as indicated by Tables 4.2.14 below.

Table 4.2.14 Whole Class consensus reached by Case Study Group of teachers regarding the structure of a western capacitor compared to an indigenous capacitor.

Scientific (Capacitor)	Indigenous Knowledge
One of the plate in a capacitor being compared with the galvanized steel rod.	The galvanized steel rod could be compared with the one plate of a capacitor
The second plate of a capacitor s compared with the copper rod.	The copper rod could be compared with the second plate of the capacitor
The die- electric material between the plates that separates the plates could be compared with the ground/soil which surrounds the rods	The soil/ground surrounding the rods could be compared to the di-electric material that separates the two plates in a capacitor.

The purpose of building an indigenous capacitor by the farmers as illustrated in the above case study was to protect the soil against lightning. Whenever the teachers were asked before DAIM what the function of a capacitor was, they only responded that the capacitor stores charge (scientific). After being exposed to DAIM, the Case Study Group came to realize that the capacitor could also perform an indigenous function by serving as a protective device. This emergent information, according to CAT, only became known to the Case Study Group during their discussions when addressing the case study. According to Ogunniyi and Hewson (2008), DAIM enhances teachers' conceptual knowledge and understanding of complex topics.

The responses of the Case Study Group regarding the function of the capacitor before and after DAIM were as follows:

The function of the capacitor Before DAIM (Individual responses)

The Case Study Group individually responded to the function of a capacitor as follow:

- T1:** *Stores Charge*
T2: *Stoor lading [Stores charge]*
T3: *Stores*
T4: *Stores charge*

The function of the capacitor After DAIM (Small Group discussions)

The individuals shared their input with one another in small groups and consensus was reached in terms of the function of the indigenous capacitor as indicated by the following small groups' responses below:

- T1 and T2:** *Protecting the soil against lightning / “Beskerm grond teen weerlig” [Protect the soil against lightning]*
T3 and T4: *Protecting tool / Protect the ground against lightning. The crops will last longer*

The function of the capacitor

Whole Class Discussions

As mentioned before, it was discovered that capacitors do not only have one scientific function, but also an indigenous function as indicated by T1's response: “Yes, never knew you could construct your own capacitor to help saving the crops.” This function of the capacitor was emergent according to CAT to these teachers, because the only function of a capacitor known to the Case Study Group of teachers, was the fact that a capacitor stores charge as prescribed by textbooks according to them. The Case Study Group did not know that a capacitor could be used by farmers

to protect their crops against lightning. As this was new knowledge to the Case Study Group, could therefore be regarded as Emergent according to CAT.

The knowledge as mentioned by T1 above could be seen as local knowledge which has its basis in indigenous knowledge (Morgan, 2005). Many authors (Warren et al., 1995; Rajasekaran, 1993; Chiwome, 2000) have defined indigenous knowledge (IK) as local knowledge that is unique to a given culture or society. They hold that IK is the systematic body of knowledge acquired by local people through the accumulation of experiences, informal experiments and intimate understanding of the environment in a given culture (Rajasekaran, 1993; Luna, 2005).

Summary

For the above, the structure of the capacitor is a schema from one worldview (scientific explanation, in this case) challenged by a schema from the other worldview (indigenous knowledge explanation, in this case). CAT calls this the equipollent category which refers to a situation where teachers find the explanation of the structure of a capacitor from two different worldviews equally powerful, convincing and appealing. In this case, the teachers shifted from their scientific position (obtained from textbooks) of the structure of a capacitor to embrace their indigenous explanations. Therefore the teachers' conceptions on IK became assimilated according to CAT after DAIM.

In terms of IK, what teachers failed at the beginning to understand about IK was that it provides some similar theories about the material world, derived from the process which is parallel to western scientific thought. From the research it emerged that some teachers were not very comfortable with the comparisons made to sciences with IK. The teachers felt that IK is only relevant to a certain group of people and is not relevant to the sciences, because learners will not be examined on IKS. The following responses were obtained from the interview session the researcher had with the Case Study Group of teachers before DAIM:

Interview Question: What is/are your view(s) on the use of IK concepts in Physical sciences?

Before DAIM

- T1:** *“I thought of IK as knowledge of the witchdoctor...(smiling), actually did not have a clue about IK.” IKS is unnecessary.*
- T2:** *“Nee, Sillabus is baie vol. Daar sal nie nog tyd wees daarvoor nie” [The syllabus is too packed, no time for IKS].*
- T3:** *‘No, I don’t think that a new subject could be introduced that would include IKS - or it could be included in Life Orientation’.*
- T4:** *‘No, we should compete international and should make use of more modern science, investigate new discoveries, why dwell on the past?’*

After DAIM

- T1:** *IK is good, never knew you could construct your own capacitor to help saving the crops.*
- T2:** *Ja, die samewerking en bespreking met ander het my 'n beter insig gegee van IK [Yes, the collaboration and discussions with people gave me a better understanding of IK].*
- T3:** *As mentioned in the previous question (E5) I somewhat get an understanding and view on IKS on capacitors.*
- T4:** *Yes, what farmers did to protect their crop, actually interest me.*

Summary

At the beginning before DAIM, the teachers opposed the idea of IK being integrated into the Physical sciences curriculum. Judging on the response of T3, the teacher seemed to be unaware that IKS is already included in the policy document of the Physical sciences curriculum in South Africa and it cannot be ignored or discarded. In the case of T4, she opposed the integration of science and IK on the grounds that IK is ill- equipped to be purposeful to modern science classrooms. The

use of IK had been regarded as time consuming seeing that it is not examinable and not on the priority list of education authorities.

After the teachers were exposed to DAIM, their' viewpoint regarding IK started to change. This change could be regarded as an assimilated viewpoint according to CAT. Therefore, due to DAIM the conceptual teachers' understanding of capacitors has improved when the linkage was made between the scientific structures of the capacitor with the structure of a capacitor used by the farmers (IK).

4.2.2.2 Teachers' conceptions of a capacitor when compared to a Natural Phenomenon according to CAT

The Case Study Group of teachers had to compare the scientific structure of a capacitor with the phenomenon of lightning by discussing the Case Study below.

Case Study 2 (Appendix 1.4)

“Lightning is an atmospheric discharge of electricity usually during a rainstorm at times. The enormous energy of lightning breaks nitrogen molecules and enables their atoms to combine with oxygen in the air forming nitrogen oxides. These dissolve in rain, forming nitrates that are carried to the earth. Lightning plays an important role in the nitrogen cycle, returning nitrogen to the soil that is lost by denitrifying bacteria. So lightning indirectly affects photosynthesis, by "fertilizing" plants allowing them to grow greener (they have more chlorophyll) and thus are better photosynthesis, the net effect of which is that they grow faster.

Lightning jumps between a part of a cloud having one electrical charge and the ground and another part of the cloud having the opposite charge. The electrical charge of the cloud is the sum of all the charges of the droplets of water of which the cloud is composed. As these minute charges leap toward an opposite charge, they flow together. The formation of lightning can be regarded as an example of how a capacitor operates (Figure 4.2.3).

Figure 4.2.3 A capacitor, a device that can be compared to the phenomenon of Lightning.



The first process in the generation of lightning is charge separation. One theory states that opposite charges are driven apart and energy is stored in the electric field between them. The comparison is made where the two plates of the capacitor is seen as the cloud and the earth. Between them two, an electrical charge occurs.

The separation of charge and accumulation occurs until there is sufficient electric potential to initiate lightning discharges. A strong electric field forms. As a thundercloud moves over the earth's surface, an equal but opposite charge is induced in the Earth below. The induced ground charge follows the movement of the cloud. When the electric field becomes strong enough, an electrical discharge between the clouds and ground occurs. During the strike electrons and positive ions of portions of air molecules are pulled away from each other and forced to flow in an opposite direction. The electrical discharge causing the air to expand rapidly and produce a shock wave as thunder."

Item D1: From the information above (referring to case study on lightning provided), write down three things of lightning that could be compared to the three parts of a capacitor (scientific structure of a capacitor).

The following section from item D1 on the structure of a capacitor provides a snapshot of how teachers experienced a cognitive shift, most probably due to their exposure of DAIM.

Before DAIM (Individual responses)

The individual in the Case Study Group had to once again name the different parts that a capacitor consists of. At this stage, the 2 plates and the di-electric was identified by all the teachers in the Case Study Group. The di-electric was also referred to as the insulator which is also correct. There were no extended explanations given, only that a capacitor consists of 2 metal plates and a di-electric/insulator as prescribed by the school textbooks.

Some of the responses were as follow:

- T1:** *Di-electric and two parallel metal plates*
T2: *Twee plate en 'n isolator [two plates and an insulator]*
T3: *two parallel plates and a di-electric*
T4: *2 plates separated by an insulator*

Teachers **T1**, **T2**, **T3** and **T4** investigated the case study and found similarities between the structure of the scientific capacitor device and the phenomenon of lightning. According to CAT, this information is equipollent. An equipollent conception takes place when two competing ideas (science/non-science/indigenous) or worldviews exert comparably equal intellectual force on an individual.

After DAIM (Small Group discussions)

The Case Study Group was comparing the three parts of the capacitor with three elements of the atmosphere involved in the phenomenon of lightning. This comparison could be regarded as an equipollent/emergent viewpoint according to CAT and a summary of the small groups' responses is indicated in table 4.2.15 below:

Table 4.2.15 Small Group responses regarding the scientific structure of a capacitor versus the phenomenon of lightning

T1	T3
<p><i>Plate 1 of a capacitor (Negative Plate) compared to the Cloud, because electrons build up in the clouds;</i></p> <p><i>Plate 2 of a capacitor (Positive plate) compared to the Earth, because electrons goes from negative to positive;</i></p> <p><i>Die-electric material between the plates of a capacitor compared to the earth, because it keeps the charges apart</i></p>	<p><i>Plate 1 of a capacitor compared to the -Earth; Grounds: induced ground</i></p> <p><i>Plate 2 of a capacitor compared to the cloud ; Grounds- energy builds up in the clouds. Grounds: move through air from clouds to earth.</i></p> <p><i>Di-electric of a capacitor compared to the air</i></p>
T2	T4
<p><i>Plate 1 of a capacitor compared to the - clouds (negative); Grounds: charges are generated here/Buildup of electrons</i></p> <p><i>Plate 2 of a capacitor compared to the Ground (positive plate)</i></p> <p><i>Di-electric between the plates of a capacitor compared to the - Air - different from other insulators. I know charges flow through the air (Emergent/Equipollent)</i></p>	<p><i>Plate 1- Earth; Grounds: If lightning strikes, charges flow to the earth.</i></p> <p><i>Plate 2- Plate 2: clouds; Grounds: Clouds brush against each other, resulting in charges formed.,</i></p> <p><i>Di-electric- Air - different from other insulators. I know charges flow through the air (Emergent/Equipollent).</i></p>

Discussion

Their responses before DAIM and after DAIM were dominantly from a scientific worldview according to CAT. A conception becomes dominant when it is the most adaptable to a given situation. Apart from the above responses being equipollent according to CAT, it could also be regarded as emergent according to CAT, seeing that teachers were introduced to this comparison for the first time during the engagement of the above case study 2.

As for the small groups, they had to give feedback to one another in order for the whole class to take part in the discussions. During the whole class discussions, the

Case Study Group had to end up with a single agreement on the structure of the capacitor versus the phenomenon of lightning.

The Case Study Group teachers **T1, T2, T3 and T4** investigated the case study and came to the conclusion of similarities between the scientific structure of the capacitor device and the natural phenomenon of lightning. Each part of the capacitor is compared to each element in the atmosphere that is involved in the phenomenon of lightning as indicated in table 4.2.16

Table 4.2.16 Whole Class consensus reached by Case Study Group of teachers regarding the structure of a western capacitor compared to a natural phenomenon of Lightning

Scientific (Capacitor)	Natural Phenomenon (Lightning)
One of the plates in a capacitor being compared with the earth as explained in lightning.	The Earth in the phenomenon of lightning being compared with one of the plates in a capacitor.
The second plate of a capacitor is compared with the clouds in the phenomenon of lightning	The cloud in the phenomenon of lightning being compared with the plate in a capacitor.
The di- electric material between the plates that separates the plates could be compared with the air molecules between the clouds and the occurrence of lightning	The air molecules between the earth and the clouds during lightning being compared with the di- electric material between the two plates.

Discussion

The responses before DAIM in both items C1 and D1 (scientific capacitor compared to an indigenous capacitor and lightning) of the teachers show that none of the teachers gave any cause related to indigenous knowledge. All their explanations, although not always clear or accurate, were based on scientific knowledge. *Science knowledge to many learners became nothing more than declarative information to be memorized and reproduced when demanded especially during examinations (Jegade, 1996, p.6)*. The researcher is also referring to the fact that all the teachers indicated that the only function of the capacitor is to store charge, because that seemed to be the only information provided by the textbooks as mentioned before. Therefore for this

group of teachers, the scientific explanations and understanding of a capacitor were dominant over the indigenous explanations, according to CAT.

During the whole class discussions, the concept of the di-electric came up as a core point of discussion amongst the small groups. The characteristic of the di-electric was questioned amongst the teachers. The scientific explanation of the di-electric is an insulator; in other words, the di-electric is a non-conducting material between the two plates of a capacitor. The di-electric accomplishes three things which are;

- Solves mechanical problem of keeping the plates separated.
- Increase the maximum potential difference allowed between the plates
- Increase the capacitance of a given capacitor.

For this study, it is important to note that the whole group discussions were informed by science, and the rebuttals questioned the validity of the scientific explanation. This was exactly what happened during the engagements of the groups when they discussed whether a di-electric is an insulator when comparing the di-electric with the air molecules during the phenomenon of lightning. The reason for comparing air with the di-electric was that the Case Study Group was in agreement that air should always be seen as an insulator. The air found between the cloud and the ground during lightning is another reason for comparison to the di-electric found between the two plates of a capacitor.

Some of the members in the Case Study Group started to show evidence of contradicting themselves and could not understand why the air allows electrical particles to move through to cause the lightning effect if it is regarded as an insulator. As far as their knowledge was concerned an insulator is a non-conducting material.

Some of their responses were as follows:

Group 1 (T1 and T3) – *“air cannot be the di-electric so the di-electric is not an insulator.”*

Group 2 (T2 and T4) – *“air is the di-electric, because in nature air can acted as both a conductor and an as an insulator, air is a good insulator at low voltages, the di-electric is an insulator.”*

Discussion

It must be remembered that before any discussions took place as indicated in the responses of item A6, all the teachers in the Case Study Group had an agreed viewpoint of the di-electric to be an insulator with no one questioning whether the di-electric is in fact an insulator. When the comparisons were made as indicated above, there seemed to be a transformation, a change of position amongst some of the teachers, referring to the small group of teachers in Group 1. They started to question whether the di-electric of a capacitor is an insulator. The transcription of the video recordings indicated T3's question: *“di-electric - how can it be an insulator if charges move through the air to the ground to cause a shock?”* After many discussions, all of the teachers accepted the assimilated viewpoint of group 2 (T2 and T4) as truth. The fact that Group 1 accepted the viewpoint of Group 2, made the argument assimilated. A conception becomes assimilated when it capitulates to another more datable conception.

Summary for Research Question 2 findings

Based on the findings in the booklet and video transcriptions of the three DAIM lessons, it seemed that the DAIM significantly improved the teachers' conceptions of capacitors (Hewson, 1992). The mind shifting from one level to another level was clearly evident as indicated in the tables above. The findings also showed that DAIM did not only improve their conceptions, but also raised awareness among teachers regarding indigenous knowledge concepts to be used in the teaching of capacitors.

Vygotsky (1978) suggested that teaching should be more related to the social context of the child's learning process, which was exactly the case in this study.

In the light of the above findings, it concludes that DAIM was very effective in enhancing teachers' conceptual understanding and knowledge of capacitors. The following scientific/indigenous information on capacitors below was all emergent according to CAT and only became familiar to the teachers after they were exposed to the DAIM.

Scientific/ Indigenous conceptions of capacitors.

The structure of the capacitor

- The structure of the capacitor could be related to the structure of an indigenous capacitor (Indigenous/Emergent/Equipollent)
- The structure of the capacitor could be related to the natural phenomenon of lightning (Indigenous/Emergent/Equipollent)
- Better IK understanding in relation with scientific concepts of capacitors (Assimilated)
- Di-electric in nature acted as both an insulator and conductor (Scientific/Natural)

The function of a capacitor

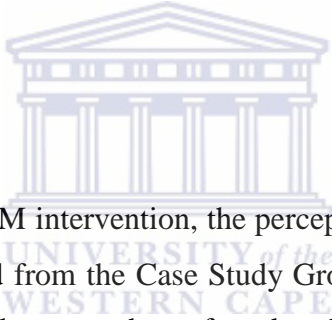
- The teachers learned that the only function of a capacitor is not only to store charge (misconception)/energy, but a capacitor can also create a phase angle difference to enable rotation in a single phase AC motor (Scientific)
- Capacitors used by farmers also serve as a protective device by saving their crops (Indigenous/ Emergent)
- A battery or any power supply is needed to charge capacitor (Scientific)

The application of a capacitor

- The LED is also polarity sensitive as the capacitor (Scientific)
- Discharge can take place with no power supply (Scientific)
- Capacitors play an important role in AC circuits and AC-induction motors
(Scientific)

4.3 Research Question 3: What are teachers' perceptions on the use of DAIM in teaching capacitors?

Introduction



At the end of the DAIM intervention, the perceptions regarding the implementation of DAIM were requested from the Case Study Group of teachers who formed part of this study. In this study, the researcher referred to this Case Study Group of teachers in some cases as Subjects or Case Study Group. Reflective journals in the form of Reflective Diaries were used to facilitate and assess reflection and reflective learning of the Case Study Group.

The Reflective Diary facilitates the development of the process of reflection and reflective learning during training. As an assessment method, the Reflective Diary provides evidence of understanding of content knowledge, reflection, professional judgment and application. According to Biggs (1999) and O'Rourke (1998), reflection diaries also enhance critical self-reflection and self-awareness. The evidence from the teachers' reported experience on DAIM and other information regarding their perceptions of DAIM shows that reflective diaries are a useful tool in facilitating reflection and reflective learning.

4.3.1 Experiences on the DAIM

The teachers experienced DAIM in a positive light and seemed to believe that DAIM could be workable in science lessons. According to the Case Study Group, they experienced DAIM not only to be a teaching methodology that encourages more structured group work discussions, but also creates a thinking space for self-discovery and intra- argumentation to occur (Glasgow, McNary& Hicks, 2006). Here the individual activity within the DAIM model (Figure 3.3) supports and ensures the above.

Table 4.3.1 Frequency distribution of the Case Study Group teachers' responses on DAIM experiences

Themes	Frequency	%
DAIM encourages group work discussion	2	50
DAIM improves thinking space to experience self-discovery	3	75
DAIM workable	4	100
DAIM not workable	0	0

Some of the Responses were:

T1: *The expansion of group work is essential. This study shows that sharing of group findings is very important.*

T2: *Meer DAIM aktiwiteite aan leerders te gee, sodat hulle dit self kan ontdek. Om gereeld in elke les aanbieding DAIM toe te pas [To provide learners with more.DAIM activities to discover things by themselves. Also to apply DAIM in each lesson].*

T3: *It was not a new concept. One did not think about it the way this method work, gives me one more teaching methodology. Small group to whole class discussion gives the student an opportunity to think about what they do as well as discuss it with their peers.*

T4: *DAIM very interesting. Learners will be forced to think and work on their own*

at first. Throughout the lesson, they will be actively cognitively involved. I think it would be very stimulating to the learners and they will also find out their strengths & weaknesses or lack of knowledge.

4.3.2 Suggestions on improving DAIM

All four of the Case Study Group teachers in this study could not mention any shortcomings with reference to DAIM and they seemed to believe that DAIM has all the characteristics to contribute to the improvement of the science results in the NSC examinations as confirmed by Erduran, (2004); Ogunniyi, (2004, 2006, 2007); Reddish and Steinberg, (1999); Wilson, (2010). The dominant response was that DAIM lessons should take place on a regular basis and should be extended to other subject disciplines like Mathematics and so on.

Table 4.3.2 Frequency of teachers' responses on improvement of DAIM

Themes	Frequency	%
More DAIM lessons to be presented on a regular basis	2	50
DAIM consist of all the concepts to improve science	1	25
DAIM to be used in other subjects apart from sciences	1	25
No improvement	4	100

Some of the Responses were:

- T1:** *I could not find any improvement yet on the DAIM concept, because it has all the concepts at improving science and learning in the classroom.*
- T2:** *My question is, except subjects like science, can DAIM be applied to abstract subjects like Mathematics, Computer practice, etc. I am sure it needs to be adapted for certain subjects- maybe researchers need to look into this*
- T3:** *DAIM should be use daily, no improvement*
- T4:** *No comment, I just love it.*

4.3.3 Knowledge of capacitors before and after DAIM

Initially the teachers did not have much knowledge of capacitors, but after the intervention, the teachers claimed to have a much better understanding of capacitors) especially when the discussion of the functions of the capacitor took place (Osborne et al., 2004). Two of the subjects claimed that their critical thinking definitely improved. After DAIM, the mechanical function of a capacitor in a single phase AC-induction motor was a totally emergent concept to them. The charge and the discharge of a capacitor became clearer when it was explained to them in terms of a familiar phenomenon of lightning. The subjects identified the similarities between the structure of a capacitor and lightning as indicated previously in Table 4.10. These subjects claimed that they gained more confidence to teach the topic of capacitors without any fear as confirmed in other studies (Kuhn, 2010; Walker and Zeidler, 2007).

Table 4.3.3 Frequency of teachers' responses (after DAIM) regarding their knowledge of capacitors

Themes	Frequency	%
Confident in teaching capacitors	4	100
Critical thinking improved	2	50
DAIM influence attitude	4	100

Some of the Responses were:

- T1:** *Before DAIM, I knew the capacitor store charge. After DAIM, I found out that the AC-inductor motor needs a capacitor to get moving in a certain direction.*
- T2:** *Before: Never knew capacitor enable rotation in a certain direction in an AC motor. Kennis was boekgebonde, [Grounds]: feite uit handbook [facts from text books] [After]: Meer inligting van besprekings ontvang [received more information from discussions].*
- T3:** *Before: Thought capacitors only store charge as a function. After: but now knows that it directs rotation in a single-phase induction motor. Before: Capacitors stores electricity from a current for later use. Grounds: I*

experienced that in computers. After: A capacitor is so much more than an energy stored; Grounds: Capacitors also change the rotation

- T4:** *Before: Did not know much about capacitors, but after many discussions, know now that capacitors don't only store charge, but also ensure rotation in a specific direction in a single-phase AC motor. After: The fact that you can make your own capacitor in an indigenous manner, never knew that. Before: Also did not quite understand how capacitors charge and discharge, After: but just through the explanation -of lightning, because I am also teaching Geography, so I understand the phenomenon of lightning quite well, made me understand how the capacitor discharged. Thanks. I am feeling confident now to teach capacitors, not scared as I used to be.*

4.3.4 DAIM's contribution to the understanding of capacitors

It was agreed upon by all the subjects in this study that conceptual understanding on capacitors improved since the DAIM provided an opportunity for arguments to occur. In other words, the subject gets an opportunity to think first and formulate his or her own perceptions on a particular issue. These discussions afterwards that took place first within the smaller and larger groups assisted the subject to gain more insight regarding capacitors and its applications.

Teaching by discussion/arguing is an extremely effective means of helping learners apply abstract ideas and think critically about what they are learning (The Penn State ID newsletter, 1992). These subjects agreed that their thinking process was enhanced through the discussions that took place. Their grounds were that they definitely knew more about capacitors than before. According to Brookfield and Preskill (1999), discussions help learners find their own voices and develop their own understanding of the subject matter.

The dominant response is that all the teachers indicated an improvement of their understanding of capacitors after being exposed to the intervention of DAIM as confirmed in other studies (Erduran, 2004; Ogunniyi, 2004, 2006, 2007; Reddish and Steinberg, 1999; Wilson, 2010). Their grounds were that their horizons were broadened for example referring to the function of a capacitor, which they used to believe has only one function as mentioned by the textbooks used at school level,

which is not the case. The capacitor has many functions whereby it acts as a protective device, a starter to a single-phase induction motor, stores energy and directs rotation in a single-phase induction motor and so on. The table 4.3.4 below indicates how teachers' understanding of capacitors was influenced due to the contribution of DAIM.

Table 4.3.4 Frequency of teachers' responses regarding DAIM's contribution towards understanding of capacitors

Themes	Frequency	%
Discussions supported by DAIM enhance understanding	4	100
Critical thinking improved	2	50
Obtained more knowledge on capacitors	3	75

Some of the Responses were:

- T1:** *Yes, we discussed arguments around capacitors and came to a common understanding.*
- T2:** *“Ja, deur die groepsbesprekings weet ek dat capacitors het nie net een funksie nie soos om te stoor nie, maar bepaal ook rigting van beweging [Yes, through discussions in groups, I came to learn that capacitors do not only have one function which is to store, but also determine the direction of movement]*
- T3:** *Yes, before the lesson, I had limited understanding, After DAIM; I realized that through debate with fellow educators, one's horizons are broaden. From listening to the different views, I got a better understanding of capacitors.*
- T4:** *On the application, yes*

4.3.5 DAIM's contribution towards the understanding of IK

Initially, the responses of the Case Study Group towards IK were very discouraging. They did not give much appreciation to IK. According to them, there was no room for cultural and indigenous influences. After DAIM, the subjects seemed to have a mind shift towards IK being included in sciences. All of the Case Study Group teachers (100%) agreed that the knowledge concerning IK was enhanced through DAIM. Those discussions resulted in them being able to obtain a better understanding of IK. The subjects also rediscovered the importance of integration of IK into the sciences lessons, because IK seemed to enhance understanding regarding capacitors as in this case.

Through DAIM, two different worldviews regarding capacitors were introduced (Emergent). The subjects found capacitors easy to understand after comparing the scientific knowledge of capacitors with indigenous knowledge of capacitors (Equipollent). As cited by Diwu (2013), studies by Erduran, Simon and Osbourne (2004) have shown that teaching strategies based on argumentation does enhance both teachers and learners' awareness of and understanding of the nature of science and IKS.

Table 4.3.5 Frequency of teachers' responses regarding DAIM's contribution towards the understanding of IK

Themes	Frequency	%
Able to compare two different thought systems	2	50
Discussions on capacitors as a protecting device on farm-help to understand and apply the work	2	50

Three of the four teachers were convinced that DAIM contributed in enhancing their knowledge on IK, while one teacher (T3) did not seem to be sure based on his response.

Some of the Responses were:

- T1:** *Yes, it can be used to save the crops against lightning. I didn't know about Marc's plan by constructing your own capacitor to save your crop as a farmer. After: knew now how to merge IK concepts in lesson.*
- T2:** *Ja, die samewerking en bespreking met ander het my 'n beter insig gegee. Die vergelykings van 'n capacitor met die natuur en hoe dit deur die plaasboer benut word, het my meerlaat dink dat IK belangrik is om beter te verstaan die konsep.”[Yes, the comparisons made with nature and how farmers used capacitors to safe their crops gave me more insight on the importance of IK in science concepts to enhance understanding].*
- T3:** *I somewhat get an understanding and view on IKS and capacitors.*
- T4:** *Yes understand it much better now, need more practice in IKS though. Yes, because through the discussions, I could actually hear what IK means. I thought of IK as knowledge of the witchdoctor... (Smiling) actually did not have a clue about IK, but after DAIM things started to make sense. Yes, what farmers did to protect their crop, actually interest me when discussions took place within the small and whole class groups.*

4.3.6 Use of DAIM as a teaching methodology

The subjects shared similar positive opinions regarding DAIM to be implemented as a teaching methodology:

- The dominant response was that they are all in agreement that DAIM could be workable in teaching challenging topics as in this study.

- The DAIM as a teaching methodology should also be introduced to other subjects like Mathematics. They emphasized that the learners would be able to develop independent thinking.
- DAIM would contribute to the learners' active involvement in their learning and taking ownership of it.
- DAIM should definitely be implemented across the board according to the teachers, because it seems to enhance communication skills.

Table 4.3.6 Frequency of teachers' responses regarding DAIM to be implemented as a teaching methodology

Themes	Frequency	%
DAIM to be implemented in science lessons	4	100
DAIM encourages interest in complex topics	4	100

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Some of the Responses were:

- T1:** *Yes, I definitely would do so, and also would like to DAIM being applied in other subjects like Maths.*
- T2:** *Ja, dit sal die leerders leer om meer effektief te kommunikeer. Hulpvaardighede sal beter ontwikkel. ” [Yes, it will teachers to study more effectively. Their skills would develop more effectively].*
- T3:** *Yes, I definitely would do so, and also would like to DAIM being applied in other subjects like Mathematics.*
- T4:** *Yes, I definitely would do so, and also would like to DAIM being applied in other subjects like Maths.*

Conclusion

Overall, the results of this analysis indicated that all of the teachers in this study felt positive about DAIM as a teaching method. The goal of DAIM is to justify one's standpoint or to refute someone else's standpoint. The teachers who took part in this study seemed to enjoy the three DAIM lessons that were conducted by the researcher. They claimed that science concepts would only be better understood if more discussions and arguments take place in science lessons (Ogunniyi, 2007). The teachers also requested that the DAIM should be accessible in other complex subjects' disciplines like Mathematics, Applied Computer Science and so on. Although Van Eemeren (2009) and his associates do not explicitly advocate argumentation for learning science, there is no reason why the concept of argumentation cannot be used in science education as a teaching method.



Chapter 5 Findings, Implications and Recommendations

5.0 Introduction

The main purpose of this study was to investigate what effect the Dialogical Argumentation Instruction Model (DAIM) will have on selected Western Cape teachers' understanding of capacitors. This study was done to raise teachers' interest in teaching complicated topics in physical sciences as well as to raise awareness regarding indigenous concepts that could be used in their teaching.

The detailed results presented in Chapter 4 indicated that this model could serve as a potentially useful method to achieve the above (raise awareness and interest in physical sciences and IKS). In this Chapter, some conclusions will be drawn from the study followed by some implications and recommendations which could be beneficial to curriculum advisers, policy makers and all other stakeholders involved in the development of science in education in South Africa.



5.1 Main findings

The main findings indicated that the teachers had difficulty in teaching the concept of capacitors to the learners (Nkuna, 2013). The teachers did not clearly understand the importance of capacitors being included in the curriculum and how it should be applied in their daily lives. As confirmed by the study of Nkuna (2013), the two teachers interviewed also indicated that they found it difficult to teach capacitors as it was a new topic they were not familiar with.

5.1.1 Research Question 1(RQ1)

What conceptions of capacitors do the teachers under study hold?

Summary of the findings in answer to RQ1

- The teachers held incorrect concepts of the structure of a capacitor
- The teachers' knowledge was mostly textbook bound
- The teachers showed a lack of knowledge regarding the components of a capacitor
- The teachers believed that a capacitor stores charge, which is a misconception.
- The teachers had a very poor understanding of electric motors and how capacitors are applied in electric motors.
- The teachers also did not understand how a capacitor charges and discharges.
- The teachers also lacked any indigenous knowledge regarding capacitors

5.1.1.1. Teachers' scientific concepts of a capacitor

a) Structure of a capacitor

The evidence in Chapter 4 indicated that an average of less than 50% of the teachers (Initial and Case Study Group) could recall what the scientific structure of the capacitor was. As this question was a low level question according to the taxonomy cognitive levels, but still the teachers could not recall the three parts of the capacitor. The teachers who answered correctly regarding the structure of capacitors indicated that their knowledge was obtained from the school textbook. Therefore, the comparison of the structure of a capacitor made to the indigenous knowledge does not only raise interest, but will also ensure that any learner's memory span will be extended.

According to Hatano (1998), knowledge is acquired by construction and not transmission alone. The teachers could have compared the different parts of the capacitor to something familiar to them in order to be reminded of the correct parts of the structure of the capacitor as done in this study. Unfortunately, the majority of physical sciences

teachers in South Africa could not do the above due to limited content background which has led to teachers' over-reliance on prescribed textbooks instead of exploring the NOS of the subject (Nkuna, 2013). This confirmed the findings in this study as to why teachers were so textbook bound before they were exposed to DAIM.

According to Rollnick, Bennet, Rhemtula, Dharsey and Ndlovu (2008), about 40% of physical sciences teachers in South Africa have a degree in many different disciplines other than physics and chemistry. Also as in this study, the teachers did not receive completed formal training in the physics discipline, but is expected to teach at grade 12 level.

b) Function of a capacitor

The only response from the teachers towards the function of a capacitor was that a capacitor stores charge which is not the case. No other function of the capacitor was indicated. According to Nkuna (2013),

'Capacitors don't really store charge at all. They allow negative charge to be transferred from one plate to the other, thus establishing an electric field between their plates but there is no net increase in the amount of charge on the capacitor's plates. After charging, the charge is exactly the same as it was before charging. The charge just moved around. What capacitors store is energy, not charge'

c) Application of a capacitor

As mentioned before, the NCS (DOE, 2006) for physical sciences expected teachers to introduce capacitors at grade 11 level. In grade 12, it is expected to see how capacitors could have a variety of uses in alternating current as well as to be introduced to inductors. In the Capacitor Assessment (CA) test, the researcher tested the grade 12 content knowledge of the Case Study Group and concluded the following:

- Initially, in the pre-test of the Capacitor Achievement (CA) test, the teachers showed evidence of having a very poor understanding of electric motors and how capacitors are applied in electric motors.
- In the post-test, it is evident that the teachers obtained a much better understanding of the relationship between capacitors and electric motors, specifically looking at single-phase induction motors.

The teachers evidently did not have a good understanding of the concepts of capacitors and electric motors. Teachers seemed not to understand how a capacitor could be applied to an electric motor. The teachers also did not understand how a capacitor charges and discharges. The applications of a capacitor only became clear to them after training. The teachers appeared to show evidence of effective learning because they demonstrated their understanding of capacitors in a real life context as confirmed by Sendur (2012).

5.1.1.2 Teachers' indigenous conceptions of a capacitor

The teachers had no indigenous conceptions of a capacitor and the little they knew about capacitors was dominantly science-based and not necessarily correct. The teachers made it clear that most of their knowledge on capacitors was based on the school textbooks. No formal training of capacitors was provided to them when it first formed part of the curriculum. According to Rollnick (2008), inadequate training of teachers in physical sciences has led to poor teaching of this subject.

All of the non-scientific knowledge of the teachers was obtained during the exposure of the DAIM interventions. The teachers, who were exposed to the non-scientific knowledge through DAIM, developed a better understanding towards the structure and function of capacitors as confirmed by Riffel (2013).

5.1.2 Research Question 2(RQ2)

What effect does DAIM have on the subject teachers' scientific and indigenous conceptions of capacitors?

The following summarises the main findings in answer to RQ2:

- Teachers seemed to be more confident in talking about the concept of capacitors without confusion.
- Teachers did not have any trouble understanding how a capacitor as a modern component could fit in with the rest of the components in an electric circuit.
- Misconceptions regarding capacitors were clearly dealt with in the discussions, for example capacitors do not always have a parallel shape, capacitors that do not store charge as the word “charge” has many meanings as indicated in 2.2 and so on. According to Tobin, Tippins, and Gallard (1994), the role of the teacher is that of a mediator of learning, rather than a transmitter of knowledge (cited by Mulhall, Berry, and Loughran ,2003).
- The teachers fully agreed that strategies such as the DAIM should be put in place to help them overcome their misconceptions.
- The study has clearly shown that teachers underwent a paradigm shift after being introduced to DAIM as a teaching methodology.
- DAIM enhanced the understanding of capacitors among the teachers. This was clearly evident when measured by the different levels of thinking according to TAP.
- DAIM encouraged awareness of possible IK concepts that could be related to capacitors.

5.1.3 Research Question 3(RQ3)

What are the subject teachers' perceptions on the use of DAIM in the teaching of capacitors?

The following summary discusses the main findings in answer to RQ3:

- Teachers seemed very enthusiastic about DAIM.
- They were also eager for DAIM to be implemented in their physical sciences lessons.
- DAIM, according to the teachers, enhanced their understanding on capacitors and gave them broader knowledge regarding concepts.
- DAIM is an excellent model to encourage discussions and to improve communication skills.
- DAIM develops critical thinkers and independent learners.
- The teachers requested for the use of DAIM in subjects such as Mathematics and Computer Sciences. There is just a need for researching DAIM in other subjects.
- DAIM encourages two different thought systems, i.e. indigenous worldview versus the scientific worldview of concepts.
- At the beginning, teachers felt that the integration of IK is unnecessary and time consuming.
- Teachers underwent a paradigm shift with reference to IK after they were introduced to the DAIM intervention. Teachers felt more comfortable as they became knowledgeable about how to relate the operation of a capacitor with either a natural phenomenon or indigenous knowledge.
- Teachers showed appreciation for IKS.
- This study has confirmed a desperate call for teachers to adjust their teaching and learning.
- Reflection is a meaningful way of approaching learning about teaching so that a better understanding of teaching, and teaching about teaching, might develop.

5.2 Implications of argumentation in science lessons

The implication of teachers arguing and discussing in science lessons gave them the opportunity to experience scientific practices to be grounded in and applied to contexts that were familiar to them. This was exactly what the teachers experienced during the lesson and they could easily relate it to a familiar context.

Through argumentation, learners would become active teachers in the construction and production of scientific knowledge (Diwu, 2010). Through these discussions and inputs, the teachers learned to take full responsibility for their learning. According to Watson (1924/1930) learning occurred when a new stimulus is repeated before another stimulus that already evokes a given response (Cited by Phye, 1997). Different cultures get embraced when there is social interaction.

The skills of presenting cogent, logical, rational arguments learned in the science classroom can be applied outside the school environment, developing good citizenship in the process.

Argumentation could play an important part in decision making (Rieke, Sillars and Peterson, 1999). When a problem needs to be solved, decisions should not only be made by the specialists, but also by the people who are faced with the problem.

As argumentation is a study of reasons according to Zarefsky (2005), the learners and teachers should be able to justify their acts and through their discussions, they could influence the thoughts or actions of others.

Argumentation is a form of discourse that must be appropriated by children and explicitly taught through suitable instruction, task structuring and modelling (Mason, 1996). After several training sessions on the modelling of an argumentation lesson on capacitors, teachers started to realise the importance of reasoning and discussions that must take place in science lessons. These discussions lead teachers to acknowledge the multiplicity in beliefs among each other. They also became more convinced that more learning and comprehension of the subject matter resulted from these discussions. In

other words, the more active the teacher is in the lesson, the more the cognitive skills would be developed as confirmed by Riffles (2013).

5.3 Recommendations

The time has arrived for South African education authorities to take ownership of the current state of the science education system in South Africa. Despite all the resources provided to only a small percentage of the schools, there is still a major challenge to be addressed, namely the lack of training in science integrated lessons with indigenous knowledge systems as the curriculum requires.

Currently, there is a great need for South African science teachers to change their teaching methodology and to move away from the traditional teaching method. Teachers are expected to approach science holistically and the only way to accomplish this is probably by presenting argumentation science lessons. The learners should be allowed to freely express themselves and take responsibility for their own learning. They should first be given the opportunity to apply intra-argumentation, whereby they have discussions with themselves and later on share their opinions with the rest of the members of the groups as cited by Patronis, Potari and Spiliotopoulou (1999).

According to Folesdale (1986), “rationality consists firstly of taking the best choice from a set of opinions, whereby what counts as the best is a matter of negotiation” (Krummheuer, p.748).

It is important that the teachers in the discussions try to identify the best opinions in order to reach consensus as Toulmin indicated in his model of argumentation. As argumentation lessons are more practically orientated, it will not only enhance the cognitive skills, but will have a great effect on the domains of the affective (attitude) and psychomotor (feelings) skills of both the learners and the teachers. They will definitely learn to value each other’s opinions and also embrace one another’s cultures. Through the application of DAIM, learners would become more open-minded and would acquire the skill of questioning on a regular basis. In this way, South Africa would produce more independent learners who will have a huge impact on the economic development of the

country. This approach to teaching is desperately needed in South Africa to give our economy.

IKS should not be neglected because society's contribution is valuable. The lack of involvement of society is one of the causes of concern in the development of education in South Africa, especially in science education. The curriculum is already set in a way that the community of a specific area should be involved in the teaching and learning of sciences. In the case of New Zealand, the Maori elders entered the school to teach the learners to build a Maori oven as part of their curriculum. *"The onus of the success of science education does not only depend on the teachers, but also involves both the community and the education authorities,"* as the deputy minister of basic education, Mr Mohammed Enver Surtie, quoted at a press conference. Our science teachers should become culturally competent teachers who use the cultures of their learners in class as the building blocks of teaching and learning. In other words, our teachers must be aware of how to use the different cultures of the learners in their class to improve the teaching and learning process. This awareness could also assist the teacher in facilitating relationships and professional growth.

According to Hikitia (2008), culturally competent teachers get to know the learner and work to ensure that the learning environment, learning partnerships and learning discussions acknowledge and respect the learners' culture(s). Prospective science teachers should also be encouraged to become researchers in order to avoid any misconceptions regarding particular topics in the science curriculum.

Our education authorities should recognise these misconceptions in the topics of the science curriculum and curriculum advisers should be able to guide teachers in terms of these misconceptions. These misconceptions can be identified in the learners' responses in the national senior examination and be highlighted in textbooks as well. As mentioned in Chapter 2, a capacitor, according to the western perspective, is a device that stores charge. A charge has so many meanings which could lead to a misconception among the learners. Although teachers had content training on capacitors, it is important for education authorities that re-training takes place as new teachers enter the system on a

regular basis. *If science and IK have to be integrated, it would be necessary for an evaluation of both in official examinations, since the school system seems to be so much focused on examination results as the main means of evaluating success* (cited by Angaama, 2012).

The ultimate aim of the researcher's study is to see that all the teachers across the whole of South Africa be exposed to the DAIM as a teaching methodology, not only to encourage discussions in sciences lessons, but also to integrate indigenous knowledge systems into science lessons. As a nation, we must value and recognise to lost knowledge.

Teachers also stated in Hewson and Ogunniyi's study (2008) that there is a need for professional development if DAIM as a teaching strategy should be introduced into South African schools. The teacher training programmes must produce teachers conversant with the epistemological and methodological similarities as well as differences between science and IK (Ogunniyi, 2004; Onwu & Ogunniyi, 2006). In other words, at the end of the programme, teachers must be very knowledgeable about the nature of sciences (NOS) and the nature of indigenous knowledge systems (IKS) and how to integrate the two thought systems into their science lessons.

Final Comments

The lessons learned from this study are worth highlighting. This researcher gained many experiences regarding the research process. Initially, it was a very complex and frustrating experience, especially in the light of unpredictable and unforeseen changes in situations and events. For example, the teachers involved in the Initial and Case Study Groups were from the same province (Western Cape), but from different districts within the Western Cape.

On a personal level, the loss of the researcher's father (Patrick Michael Goodman) and a colleague (Gabriel Van Schalkwyk) who assisted me in the analysis of the capacitor,

was devastating but perseverance prevailed. Despite all the above constraints, the researcher enjoyed the excitement of the journey and the learning experience in working with so many different personalities.

The researcher also learned that patience was an essential key in the completion of this study. The following quote from Prof Ogunniyi was a wonderful drive throughout every challenge: *“What is worth doing is worth doing well.”*



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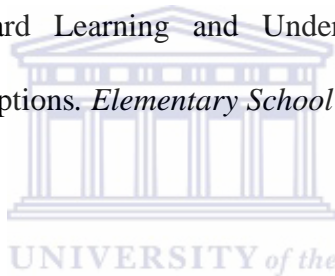
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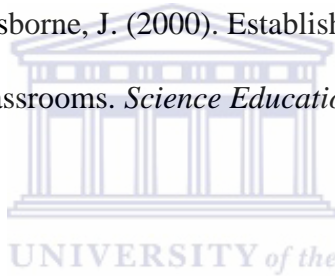
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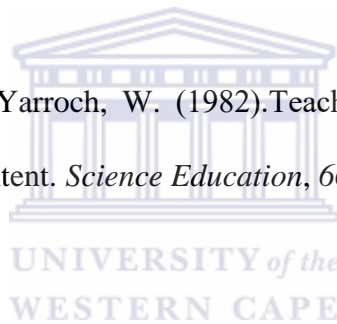
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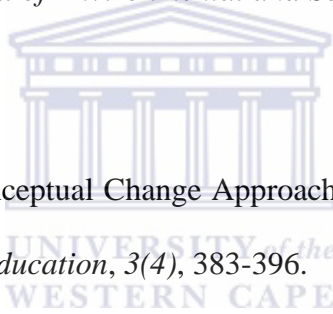
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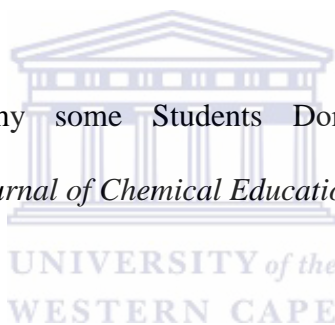
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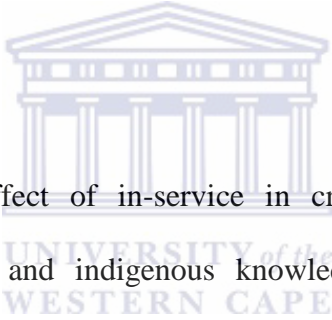


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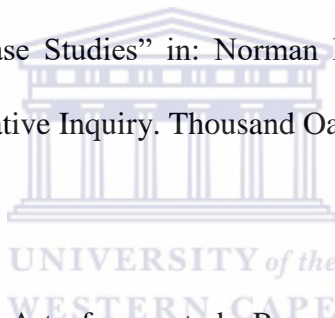
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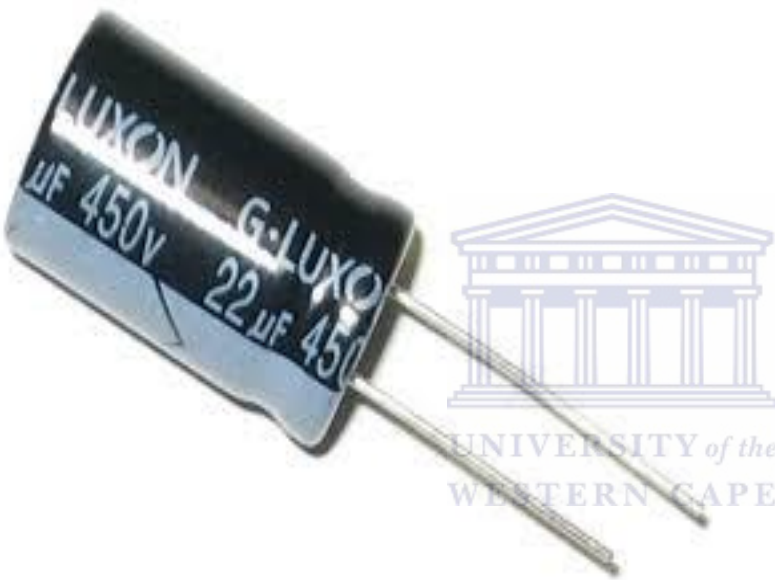
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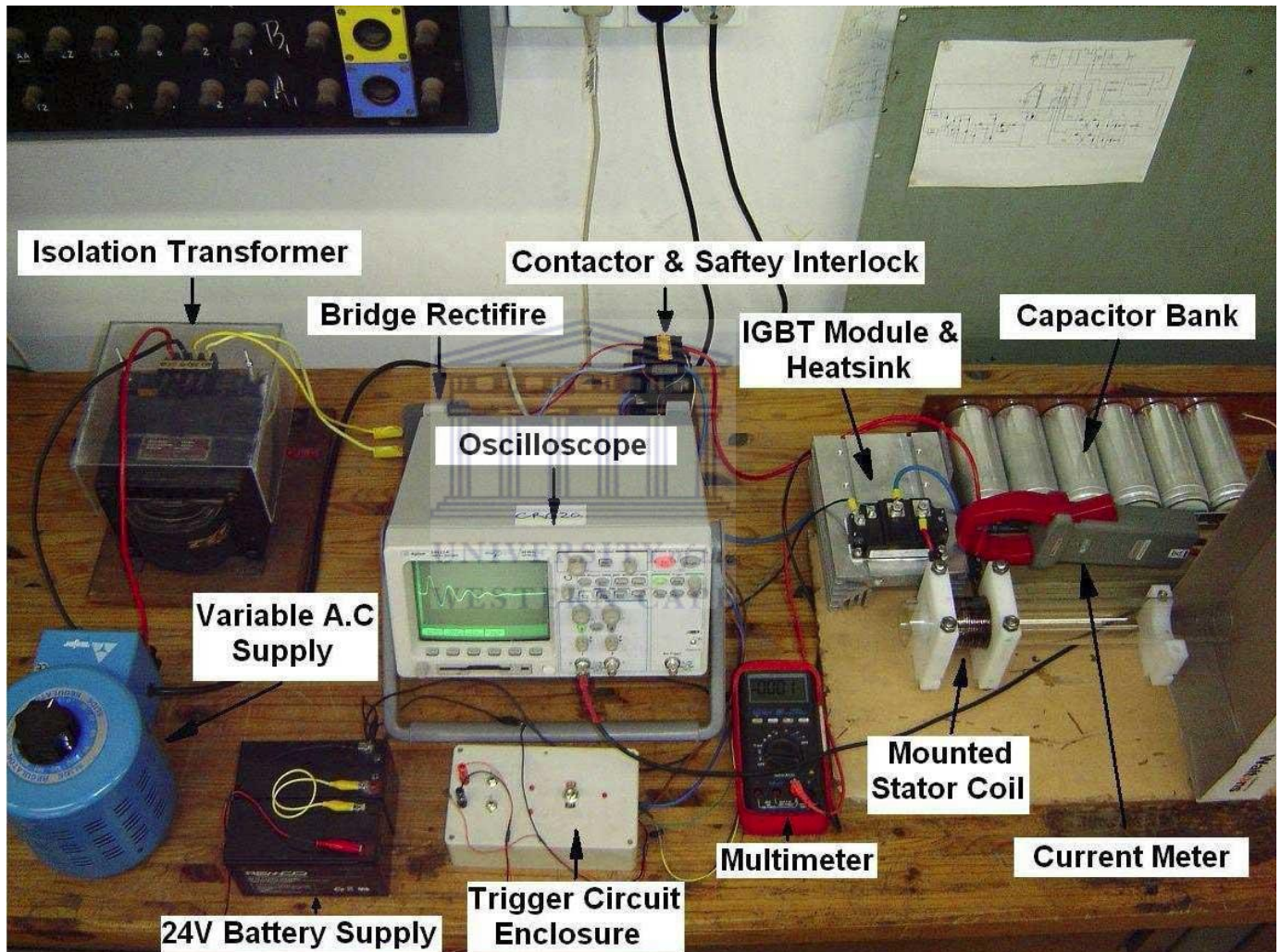
Appendix 1

DIALOGICAL ARGUMENTATION INSTRUCTION METHODOLOGY(DAIM)

CAPACITORS WORKSHOP



COMPILED BY: LYNN GOODMAN

GRADE 12MODULE 5, TERM 3**A) ELECTRICAL MOTORS (UNIT 2)****AC Induction Motor**

Source: Daniels, B (2008), University of cape Town, South Africa

Appendix 1.1**Capacitor Assessment (CA) TEST**

A1) What is an electric motor? What is the reason for your answer?

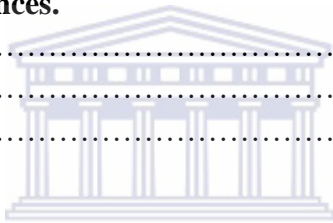
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A2) Name two types of electrical motors

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A3) Name one type of AC motor that assist in minimizing electrical noise and electrical sparks in electrical appliances.

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A4) What device is needed to get the induction motor started? Name it.

What is the reasons/grounds for your answer?

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A5) Explain how the world first came in contact with capacitors.

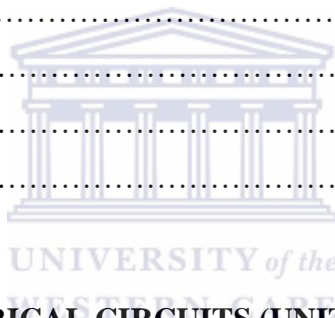
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A6) Name the parts of any capacitor. Name the source of your information.

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A7) Write down any other information about capacitors that you would like to know or share at a later stage within your group.

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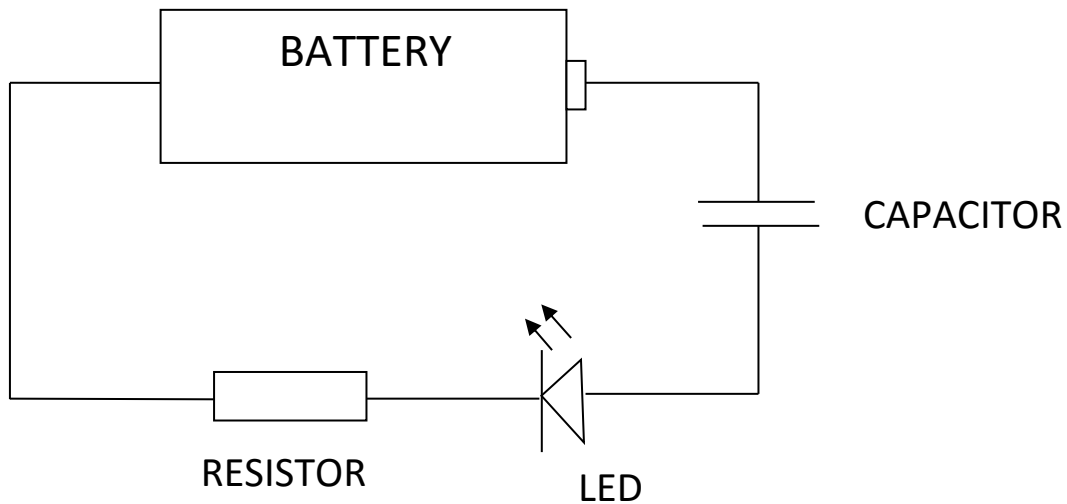
Appendix 1.2

B) DAIM LESSON 1 – ELECTRICAL CIRCUITS (UNIT 1)

B. 1) INDIVIDUAL ASSESSMENT


A LED AND RESISTOR are connected to the BATTERY and the CAPACITOR as shown in Figure 1.

Figure 1



B1.1 What is the function of a capacitor in the circuit? **What is/are your ground (s) for your answer?**

Table 1

Claim	Grounds [evidence + warrant]
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B1.2) Name any natural phenomenon that a capacitor could be compared to? **What is/are your ground (s) for your answer?**

Table 2

Claim	Grounds [evidence + warrant]

B1.3) Will the LED light up if you switch the LED in an opposite direction?

Table 3

Claim	Grounds [evidence + warrant]

B1.4) What will happen to the LED when the battery is removed from the closed circuit and only the capacitor is present in the closed circuit? What is/are your ground (s) for your answer?

Table 4.

Claim	Grounds [evidence + warrant]




B.2 SMALL GROUP EVALUATION (*Build the circuit (figure 1) and small groups discuss individual claims and grounds and compromise by compiling joint claims and grounds.*)

Group Number :.....

B1.1 – B1.4	Claims	Grounds [evidence + warrant]

B.3 WHOLE CLASS EVALUATION(*Group leaders make a summary of the input of all the different groups' input*) **OK**

Group Numbers	Claims		Grounds [evidence + warrant]
1	B1.1		
	B1.2		
	B1.3		
	B1.4		
2	B1.1		
	B1.2		
	B1.3		
	B1.4		

3	B1.1		
	B1.2		
	B1.3		
	B1.4		
4	B1.1		
	B1.2		

	B1.3		
	B1.4		
5	B1.1		
	B1.2		
	B1.3		
	B1.4		
6	B1.1		
	B1.2		
	B1.3		
	B1.4		

COUNTER CLAIMS

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REBUTTALS

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The logo of the University of the Western Cape is centered on the page. It features a classical building with a pediment and columns, with the text "UNIVERSITY of the WESTERN CAPE" below it.

Appendix 1.3

C) LESSON 2 - CASE STUDY: CAPACITORS AS A PROTECTING DEVICE

CAPACITORS

The first device for storing charge or a **capacitor** was discovered in the winter of 1745-46 by two electricians working independently:

Firstly Dr. Ewald Georg von Kleist a scientist from Poland built a device, consisted of a medicine bottle; partly filled with water and sealed with a cork. A nail was then pushed through the cork into the water. Now holding the bottle in one hand, the nail was brought in contact with the terminal of an electrostatic machine which allowed it to acquire charge for some time. Then, when Dr. Von Kleist touched the nail to remove it from the stopper while still holding the bottle,

the separated charges were able to reunite by flowing through his body, and he received a bitter shock, which later went on to become one of the biggest boons for mankind.

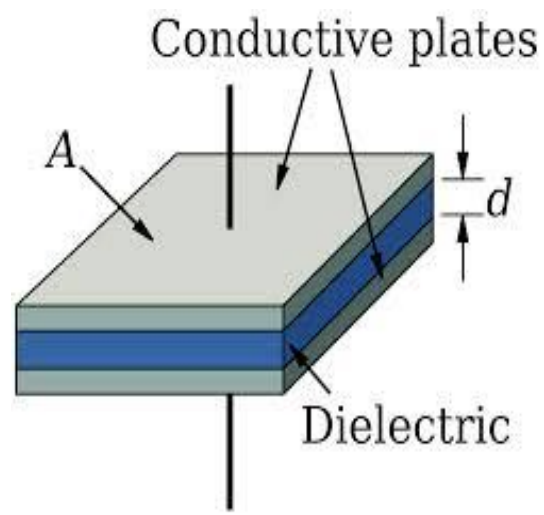
Simultaneously; another scientist from Holland, Sir Pieter Van Musschenbroek built his own device, and the experiences with it were almost the same as von Kleist's, but with three major exceptions.

Firstly, a visiting student Andreas Cunaeus to Pieter van's laboratory made the shocking discovery, not van Musschenbroek himself. Secondly, he made many significant improvements to the device; one of them being, removal of water and then wrapping the jar with metallic foil, inside out. And thirdly, he wrote to his colleagues to tell them all about his new discovery. It was from this point that the world came to know about capacitors, and later on several papers were published and scientists all over the globe studied about the **capacitance** of an electrical circuit at large, to develop a modern day capacitor that we encounter these days.

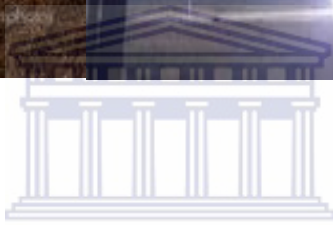
So, to store more energy in a capacitor, the voltage across the element must be increased. This essentially means that more electrons will be added to the negative plate, which is at the expense of electrons being taken away from the positive plate, thus necessitating a flow of current from the positive to negative direction.

Conversely, the reverse is also true, as to release energy from a capacitor; the voltage across it must be reduced sufficiently. This means some of the excess electrons on the negative plate must be returned to the positive plate, thus reducing the value of current flowing through the element.

Source: <http://electrical4u.com/what-is-capacitor-and-what-is-dielectric/>



The farm



Galvanized steel



Copper



Many, many years ago, Marc and Louise lived on the upper east side of Cape Town. After a few years of living in the city, they have decided to move to the rural area close to Wellington, just outside of Cape Town. Marc became a real farmer and it was expected of him to grow some crops. Marc noticed that their soil was in a terrible state and their stony fields were unsuitable for growing crops. He also noticed that the area suddenly underwent loads of lightning strokes which was very unlikely in the area. The lightning was the main purpose behind all the damages. He realised that the high frequency electron energy needed to be dispersed quickly in the earth body .

“What to do!” the farmer cried out loudly. He soon came up with a plan, which was as follows:

MARC’S PLAN

Due to the constant lightning strokes in the area, Marc decided to connect a galvanized steel rod and a copper rod parallel (*next to each other*)into the soil, large spacing between the rods to reduce the overall inductance. Each rod was surrounded with soil and was resistively separated from the other.

C1 INDIVIDUAL– By reading Marc’s Plan, tabulate the similarities of the three different parts of a western capacitor compared to the indigenous capacitor (Marc’s capacitor) used by farmers

STRUCTURAL SIMILARITIES	
CAPACITORS	MARC’S CAPACITOR
Plate 1	CLAIM: GROUND:
Plate 2	CLAIM: GROUND:
Di-electric	CLAIM: GROUND:

Counter claims and/or rebuttals

1.....

2.....

3.....

C 2 SMALL GROUP EVALUATION OK

(please indicate your group number below)

Group number



C2.1) In your group, discuss all the individual claims and grounds as indicated in C1 and reach consensus if possible on the scientific structure of a capacitor versus the capacitors constructed by farmers as a protecting device against lightning.

Group number	Claim	Grounds [evidence + warrant]

C2.2) Discuss within your group how the first capacitor existed.

Group number	Claim	Grounds [evidence + warrant]

C.2.3) In your group discuss why the farmer added the galvanized steel and not just pure iron to the steel.

Group number	Claim	Grounds [evidence + warrant]



C.2.4) In your group, discuss how this capacitor of Marc could perform its function as a storing device.


Group number	Claim	Grounds [evidence + warrant]


C.2.5) In your group, discuss how this capacitor of Marc could perform its function as a protecting device.

Group number	Claim	Grounds [evidence + warrant]

C3 WHOLE CLASS EVALUATION- *Group leaders make a summary of all the groups' input on C2 of the different groups.*

Group Numbers	Question	Claims	Grounds [evidence + warrant]
1	C2.1		
	C2.2		
	C2.3		
	C2.4		
	C2.5		
2	C2.1		
	C2.2		
	C2.3		
	C2.4		
	C2.5		

3	C2.1 C2.2 C2.3 C2.4 C2.5		
4	C2.1 C2.2 C2.3 C2.4 C2.5	 <p>The logo of the University of the Western Cape, featuring a classical building with columns and a pediment, with the text "UNIVERSITY of the WESTERN CAPE" below it.</p>	
5	C2.1 C2.2 C2.3		

	C2.4 C2.5		
6	C2.1 C2.2 C2.3 C2.4 C2.5		

COUNTER CLAIMS

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REBUTTAL

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Appendix 1.4

LESSON 3- CASE STUDY: LIGHTNING- *Read the information below and discuss the different parts of a capacitor and compared it to the phenomenon of lightning*



Source: <http://cosmicconvergence.org/?p=1109>

Lightning is an atmospheric discharge of electricity usually during a rainstorm at times. The enormous energy of lightning breaks nitrogen molecules and enables their atoms to combine with oxygen in the air forming nitrogen oxides. These dissolve in rain, forming nitrates, that are carried to the earth. Lightning plays an important role in the nitrogen cycle, returning nitrogen to the soil that is lost by denitrifying bacteria. So lightning indirectly affects photosynthesis, by "fertilizing" plants allowing them to grow greener (they have more chlorophyll) and thus are better photosynthesis, the net effect of which is that they grow faster.

Lightning jumps between a part of a cloud having one electrical charge and the ground or another part of the cloud having the opposite charge. The electrical charge of the cloud is the sum of all the charges of the droplets of water of which the cloud is composed. As these minute charges leap toward an opposite charge, they flow together. The formation of lightning can be regarded as an example of how a capacitor operates. The first process in the generation of lightning is charge separation. One theory states that opposite charges are driven apart and energy is stored in the electric field between them. The comparison is made where the two plates of the capacitor is seen as the cloud and the earth. Between them two, an electrical charge occurs.

The separation of charge and accumulation occurs until there is sufficient electric potential to initiate lightning discharges. A strong electric field forms. As a thundercloud moves over the earth's surface, an equal but opposite charge is induced in the Earth below. The induced ground charge follows the movement of the cloud. When the electric field becomes strong enough, an electrical discharge between the clouds and ground occurs. During the strike electrons and positive ions of portions of air molecules are pulled away from each other and forced to flow in an opposite direction. The electrical discharge causing the air to expand rapidly and produce a shock wave as thunder.

A lightning bolt is a kind of canal through which electrical charges flow to an opposite pole; its branches are smaller canals that collect the charges. In daily life, the application of capacitors is very common. TV sets, refrigerators, computers, air conditioners, washing machines and so on. Capacitors are needed

Name:

D1) INDIVIDUAL- From the information above, write down three things of lightning that could be compared to the three parts of a capacitor (referring to the scientific structure of the capacitor).

STRUCTURAL SIMILARITIES	
CAPACITORS	LIGHTNING
Plate 1	CLAIM: REASONS:
Plate 2	CLAIM: REASONS:
Di-electric	CLAIM: REASONS:

COUNTER CLAIMS AND / REBUTTALS


1.....

2.....

3.....

D2) SMALL GROUP



D2.1) *Each member of group discusses their comparisons made in terms of the similarities between capacitors and Lightning. A joint comparison is written down as the claim with grounds.*

Group number	Claim	Grounds [evidence + warrant]
	 UNIVERSITY of the WESTERN CAPE	

D2.2) Within your group, discuss with grounds the applications of capacitors, in other words where it had been used in everyday life.

Group number	Claim	Grounds [evidence + warrant]

D3) WHOLE CLASS EVALUATION- *Group leaders make a summary of all the groups' input from D2.*

Group Numbers	Question	Claims	Grounds [evidence + warrant]
1	D2.1 D2.2		
2	D2.1 D2.2		
3	D2.1 D2.2		
4	D2.1 D2.2		
5	D2.1 D2.2		
6	D2.1 D2.2		

COUNTER CLAIMS

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REBUTTALS

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Appendix 1.5

E) REFLECTION- Please give a detailed reflection on the following below:

E.1) How did you experience the DAIM teaching method?

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E.2) Any suggestions to improve the DAIM?

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E.3) How can you compare your knowledge on capacitors before argumentation with the one after?

Claims before DAIM	Grounds	Claims after DAIM	Grounds

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(Answer the following question only if you obtained a better understanding in capacitors as you have stated in the previous question)

E.4) Did DAIM contribute in you obtaining a better understanding of capacitors? Why?

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(Answer the following question only if you obtained a better understanding in IKS as you have stated in the previous question)

E.5) Did DAIM contribute in you obtaining a better understanding in IKS on capacitors?

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**E.6) Would you make use of or recommend the DAIM to teach topics in Physical sciences?
Please give reasons.**

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THANK YOU FOR PARTICIPATING.

GOD BLESS



Appendix 2

Date: 09 January 2015

Dear Physical sciences teachers

My name is Lynn Goodman and I am currently in the final process of a research study. This study entails a teaching model to teach Physical sciences, especially challenging topics. The topic I am referring to is **a grade 12 topic, Electricity and Magnetism, specifically looking at Electrical Motors and Electric circuits.**

I would like to invite you to a workshop whereby this teaching model would be tested on the topics as mentioned above. **The main focus of the workshop is the teaching model used.** Therefore, the input and the contribution of all Physical sciences teachers are required. It is vital for all of the Physical sciences teachers to make a contribution towards the development of Science Education in South Africa.

I am aware that much training was done with teachers, but never a teaching model such as this one had been introduced. **This model encourages discussions in sciences in order to prepare our learners holistically.**

The workshop needs to take place anytime from mid- January until beginning of February 2015. I only need one session with the teachers, perhaps on a **Saturday morning.** Light refreshments will be served. **Further logistics arrangements will be further discussed** with the **teachers who indicated that they are interested** in taken part in this study.

The identity of the institutions will not be disclosed and the teachers' rights, anonymity and dignity will be respected. The findings of this research project will also be communicated to the WCED for the purpose of information. It is my hope that the findings will prove to be useful and informative for curriculum developers and Physical sciences teachers.

My wish is that many teachers attend, I can guarantee you, it won't be a waste of your time, because your input is of utmost importance.

Looking forward to your response.

Thanking you.

Lynn Goodman

Physical sciences Education Researcher

University of the Western Cape (UWC)

Cell: 0725227269

Email: lynnleegoodman63@gmail.com



Appendix 3

Director of School of Science & Mathematics Education

Lynn Goodman

Tel: 0219383157/0725227269

Email: lynnleegoodman63@gmail.com

04 December 2011

Dr. AT Wyngaard

Western Cape Education Department (WCED)

Private Bag x9114

Cape Town

8000

Tel. 021 476 9272

Fax. 086 590 2282

awyngaar@pgwc.gov.za



An application to conduct research in the WCED

I am a Masters in Science Education student at the University of the Western Cape (UWC) and wish to request your permission to conduct my research in ten schools. The topic of my research is: “Effects of a Dialogical Argumentation Instruction on science teachers’ understanding of capacitors in selected Western Cape Schools. A Dialogical Argumentation Instruction (DAI) which I will use is an enquiry-based teaching strategy developed at the School of Science and

Mathematics Education attempts to promote critical thinking among learners in their study of science. It provides learners the opportunity to express their views, clear their doubts and even change their minds to accept a more scientifically valid understanding of the various phenomena they study in the science classroom. As recommended in the new science curriculum, learners work in small groups and co-construct ideas together as they make claims and support them with evidence, while others make counter-claims. In this study I will closely work with teachers first by introducing the DAI methodology to them in order to make the teaching of capacitors much clearer to the students. Thereafter, the methodology will be taken into the classroom. It is hoped that this study will be of much benefit to the teachers as well as learners of Physical sciences.

The identity of the institutions will not be disclosed and the teachers, learners' rights, anonymity and dignity will be respected. The findings of this research project will also be communicated to the WCED for the purpose of information. It is my hope that the findings will prove to be useful and informative for curriculum developers and educators.

Fifteen willing schools from the Northern District will be randomly chosen.

Please find attached the following documents. My research proposal, which has been approved by the UWC Ethical clearance by UWC

Thanking you in advance.

Yours faithfully,

.....

L.Goodman

.....

Supervisor: Prof. M Ogunniyi

Appendix 4



UNIVERSITY OF THE WESTERN CAPE

School of Science and Mathematics Education

lville 7535 Republic of South Africa

40/2442

Fax: (021) 9593358

**UNIVERSITY of the
WESTERN CAPE** www.uwc.ac.za

24/03/2011

The Director

Department of Education

Western Province

Cape Town



Dear Sir /Madam.

Re: Permission to conduct research at 15 schools in the Northern District of Cape Town

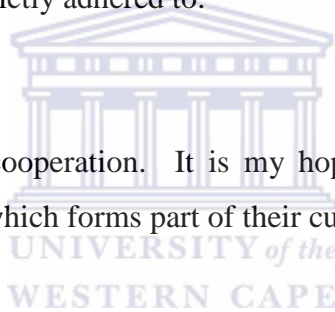
Ms Lynn Goodman (Student Number 3178454), is a registered Masters student in the School Science and Mathematics Education of the University of the Western Cape. Her research topic

deals with the effects of a dialogical argumentation instruction on sciences teachers' understanding of capacitors.

The proposal has been approved by the Senate of the University of the Western Cape. Kindly assist her in every way possible to meet this academic requirement by granting her permission to collect the required data from any willing Secondary school in the Northern district of Cape Town.

The data collected will be for the purpose of research only and all the ethical considerations related to confidentiality will be strictly adhered to.

Thank you in advance for your cooperation. It is my hope that the study will enhance the learners' understanding of a topic which forms part of their current Sciences Curriculum.



Yours sincerely,

A handwritten signature in blue ink, appearing to read "M.A. Ogunniyi", written over a horizontal line.

Professor M .B .Ogunniyi.

Appendix 5

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20111208-0036

ENQUIRIES: Dr A T Wyngaard

Miss Lynn Goodman
Education Faculty
UWC
Bellville



Dear Miss

RESEARCH PROPOSAL: Effects of a Dialogical Argumentation Instruction on science teachers' understanding of capacitors in selected Western Cape Schools.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.

5. The Study is to be conducted from **19 January 2015 till 28 February 2015**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000



We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

Directorate: Research

DATE: 21 November 2014

Appendix 6

ATTENTION: Principal / Physical sciencesgrade11 teacher

TOPIC: Physical sciences Research Thesis

Dear Principal

This letter serves to ask for your permission regarding my research in trying out a new teaching methodology w.r.t. Physical sciences in general. I am currently in the process of doing a deeper study in terms of finding different teaching methodologies that might be contributing to the improvement of Physical sciences at school level. In order for me to perform this research, I am desperately in need of Physical sciencesgrade 11/12 teachers and their students to participate in this study. The names of teachers, schools and students will be strictly confidential .The teaching methodology I am looking at is called 'Dialogical Argumentation' and the concept/topic relates to Capacitors. Through this type of methodology, we are trying to get the students to interact more in the subject matter and take more responsibility for their own learning. It is important for students to develop a passion for Physical sciences and this is what we hope to achieve. I have chosen your school to be part of this study, but only if you and the Physical sciences teacher is **willing to participate.(not obligated)**

What is expected of your school and the teacher?

The teacher needs to attend only one workshop session with me. This session include a lesson that will be performed by me. The selectedteachers will act as the learners.

Secondly, the teacher then needs to go back to his/her particular grade 11 class to perform the lesson with students. During this session, I will be present in order to make a video recording of the lesson. During these sessions questionnaires will be handed to students to complete and interview sessions will be performed with some students. These sessions will perhaps only require one or two visits from me to your school.

I have full permission from WCED to perform research and collecting data from the schools. Please find the attached letter send to me by WCED. I promise that I will not allow the research to have an influence on the other learning areas of the student or will not interrupt the daily tasks of the particular teacher involved. I would greatly appreciated it if you could discuss this with your grade 11/12 Physical sciences teacher. It will mean a great deal to me if your school can be part of this project. The time frame of collecting all the data will be from **16 January until 30 March 2011.**Please indicate via email or fax if your school is willing to participate.

Hoping to hear from you soon.

Thanking you.

L. Goodman

Curriculum Adviser: Physical sciences (FET/GET)

DATE: 2011-12-09

