INVESTIGATING GRADE 10 LEARNERS' ACHIEVEMENTS IN PHOTOSYNTHESIS USING CONCEPTUAL CHANGE MODEL

by

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DEDICATION

To Magdeline, Boipelo, Oarabile and Oreabetse

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DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Education in Science Education has not previously been submitted by me for a degree at this or any other University; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

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ABSTRACT

A deep level approach to learning leads to quality learning outcomes. Teachers should use appropriate teaching strategies to encourage learners to use deep level approaches to learning. The Conceptual Change Model (CCM) approach is one such strategy for the teaching of science concepts. Deep level approaches are a necessity when dealing with a difficult science concept like photosynthesis. The purpose of this study was to investigate Grade 10 learners' achievements in photosynthesis using the CCM approach in order to minimize misconceptions and develop a broader and deeper understanding of the photosynthesis process in the high school context in a semi-rural South African school. The learners' attitudes towards the CCM approach in the teaching of Life Sciences were explored. This study aimed to answer the following main question: what are the achievements of Grade 10 learners' in photosynthesis as core knowledge?

The CCM approach included worksheets based on all five steps of the CCM process: commit to an outcome, expose beliefs, confront beliefs, accommodate the concept and extend the concept. The sample consisted of 78 Grade 10 learners. The research was carried out with a quasi-experimental/control group design and lasted for six weeks. The achievement test and questionnaires were used as instruments to collect data. The analyses of results show that experimental and control group's pre-test academic achievement scores were similar and there was no significant difference between them ($p < 0.05$), but when the academic achievement of the post-test results of the EG and CG were analyzed, it was clear that there is a significant difference. The results from post-tests suggest that learners from the EG, taught using the CCM approach, show significantly greater achievements in photosynthesis than learners from the CG. In addition, learners from EG show a positive attitude towards Life Sciences after CCM teaching approach, but not from the CG taught using traditional approach. These findings have implications for a science teacher and recommendations are made to improve the teaching of photosynthesis as core knowledge.

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Chapter 1

1.0 Introduction

1.1 Introduction

Photosynthesis is one of the most difficult concepts taught in high school (Russel et al., 2004). It was taught in grade 12 in the 550 Curriculum South Africa and is now in Grade 10 in the new National Curriculum Statement (NCS). Generally, learners start with the basics of photosynthesis in the lower primary school and continue with it in the Senior Phase. It is a topic that forms the basis of botany in the GET band. It is a very important topic for a learner studying or intending to study botany at tertiary level (Russel et al., 2004).

Despite its central importance in providing biochemical energy, fixed carbon and oxygen for all life on earth, it remains an area which learners find uninteresting and difficult to understand. Photosynthesis presents a problem to educators too since molecules involved are so small, actually visualising this process remains a mystery (Russel et al., 2004). The actual results of photosynthesis are also hard to analyse since plants grow at seemingly slow rates. The difficulty is also compounded by lack of resources in some public schools. There are no laboratory equipments for practical work in most schools and this makes it rather difficult to provide effective, hands-on teaching of photosynthesis and the large classes pose yet another challenge in schools. Despite all these, there are also conceptual challenges surrounding the understanding of Photosynthesis. These challenges (or learners' beliefs) emanate from misconceptions that are associated with the broadness and complexity of the topic. Misconceptions often persist in learners' understanding of photosynthesis even after being taught in a traditional lesson (Haslam & Treagust, 1987; Lonergan, 2000; Ebert-May et al., 2003). These may, among others, include beliefs like:

- plants get most of their food from the soil (which is why they need fertilizer);
- Photosynthesis is the simple conversion of CO_2 and water to carbohydrates and O_2;
- plants photosynthesize during the day and respire at night;
- Chlorophyll molecules in the light harvesting complexes transfer excited electrons to the reaction centre and;
- plants are green because they absorb green light.

For teaching to be effective, educators need to know more about these misconceptions in advance. Knowing misconceptions will assist the educator to prepare some form of intervention to break down the learning barrier. As learners construct meaning, they may alter their views and adapt a new stance. This change of stance constitutes the constructivist theory of learning (Hershey, 2004). One major problem, however, is when learners try to construct meaning based on incorrect existing ideas. Educators must first make sure that they understand the concept themselves in order to avoid reinforcing the existing misconceptions. A selective and effective intervention would minimize misconceptions in the Life Sciences classes. This study, therefore, proposes the use of the Conceptual Change Model (CCM) approach to deal with learners' misconception about photosynthesis. The central concern of this study is to investigate Grade 10 learners' achievements in the core knowledge photosynthesis using the CCM approach.

1.2 Background

High school learners, including some science educators, have misconceptions related to Life Sciences concepts such as classification of living things, ecology, cells and continuity and change (Driver, et al., 1994). Research has shown that learners hold many ideas about scientific concepts before instruction, some of which may be in conflict with the accepted scientific ideas (Grayson, 1995). Among these are misconceptions that arise from misinterpreted experiences, undifferentiated concepts, and those from instruction as well as textbooks. If the above mentioned misconceptions are ignored, effective learning of science concepts might not take place (Grayson, 1995). The researcher based on his teaching or class room experience noticed that learners have misconceptions on the flow of energy during photosynthesis process. For instance, learners believe that plants get their food from the soil and support their view by citing fertilizers placed in the soil for improved food production. They think that photosynthesis occurs only during the day and plants respire at night. They believe that the simple conversion of carbon dioxide and water to carbohydrate and oxygen is all that is needed for the process of photosynthesis to take place. Also, learners believe that plants are green because they absorb green light from the sunlight (Pers. Obser.). These misconceptions that learners bring to science classrooms are the product of their first hand experience, and to them these misconceptions are common sense of what they have been told through the media, books and other forms of instruction (Stepans, 1994). Misconceptions are widely spread, deeply rooted and are often immune to change (Driver et al., 1986). According to Wichmann et al. (2003), learners are likely to resist giving up an existing concept in favour of a new concept. Furthermore, learners’ misconceptions vary in their resistance to conceptual change depending on their robustness (Stepans, 1994; Driver et al., 1994). In view of all of the above the researcher decided to explore ways in which he could assist learners to develop a better understanding of the photosynthesis process. To achieve this outcome, the researcher decided to use CCM not only to broaden the learners’ knowledge, but also to give educators alternative ways of teaching Life Sciences concept in a more meaningful way that would dramatically minimise misconceptions in the science classroom.

1.3 Motivation for the study

This study is inspired by the following seven sources:

1. Broadie (2006) found that very few educators in South Africa are able to implement the new curriculum dictates. They still use the traditional approach to teaching. The educators mainly focus on how to deliver knowledge and the lesson presentation is centred on the content of the course. Learners are treated as sponges, ready to absorb knowledge (Xiaoyan, 2003). The current curriculum in South Africa encourages a learner-centred teaching approach where educators are expected to take learners’ ideas into account and seriously engage with them in debates. This approach encourages increased participation, communication, justification and explanation from learners. Educators are encouraged to hold back with their own scientific ideas in order to facilitate learners’ ideas and thinking.

2. The discovery by Stepans (1994) indicates that methods used in science classrooms are distanced from research in science education. Educators and textbook writers do not acknowledge learners’ personal mental models as a starting point for instruction. Science classes involve disjointed and disconnected concepts, which do not help learners to make sense of the world. Testing focused on benchmarks in the curriculum rather than on aiding learning (Stepans, 1994). Also, from the researcher’s personal experience the main goal of Life Sciences is to help learners to pass examinations and gain university entrance marks. Every stakeholder: learners, educators, parents, education officials (circuit managers, subject advisors, educational center managers and other education and regional and provincial managers) value this aspect more

than other forms of teaching and learning. Educators are therefore encouraged to prepare learners to pass examinations with little emphasis on conceptual change. They use chalk and talk teaching styles, regurgitation and recall of factual knowledge (Prophet, 1990; Koosmile, 2005; Kasanda et al., 2003). According to Stepans very few learners, if any, benefit from this teaching approach. Therefore, it is important for educators to explore alternative approaches to instruction. These approaches should emphasise hands-on activities, as well as group and whole class discussion (Grayson, 1995).

3. The findings by Hershey (2004) indicate that most Life Sciences educators are ill prepared to teach botany, and therefore cannot readily recognise errors in literature and textbooks. Learners' misconceptions are reinforced due to ignorance. So Life Sciences educators must focus on the misconceptions in order to recognise when literature and/or textbooks are incorrect. The only way to overcome these misconceptions is to have educators prepare more comprehensive analysis of what they are teaching. The overall trend of eliminating misconceptions seems to be experiential learning. A learner-centred approach requires learners to go beyond the mere memorization of facts and terminology an understanding of the scientific explanation of phenomena. In this approach learners will be engaged in critical thinking, problem solving and decision making within contexts that are relevant to their day-to-day life.

4. The problem, as given in the background, normally experienced by high school learners is the conceptual understanding of the photosynthesis process (Haslam et al., 1987).

5. The necessity to enhance learners' conceptual understanding of this photosynthesis in high school context (Barker et al., 1989).

6. The need to find out the effectiveness of CCM in enhancing the learner conception of photosynthesis.

7. The lack of interest of learners in science, which leads to poor performance and discipline related issues (Schommer, 1993).

1.4 The purpose of the study

The purpose of this study is to compare Grade 10 learners' achievements in photosynthesis using the Conceptual Change Model (CCM) approach and that obtained using traditional teaching approach. The CCM was used in order to minimize the already established misconceptions and to develop a broader and deeper understanding of photosynthesis process in high school context in Mpumalanga province in South Africa. Also to identify learners' attitudes towards science after a teaching approach is completed.

1.5 Research questions

Main question

This study answered this main question; what are the achievements of Grade 10 learners' in photosynthesis as core knowledge?

Sub-questions

This main question was answered by addressing the following sub-questions:

1. Are there any significant differences in achievements between post-test of control and experimental group?
2. Are there any significant differences between post-test and pre-test achievements of the experimental as well as the control group?
3. Is there any significant difference in achievements of boys and girls in both experimental and control group?
4. What attitudes do learners have towards Life Sciences before and after instruction in both the experimental and control group?

1.6 Significance of the study

Apart from the study of Ebenezer et al., (2010:3) “most of the reform-based studies have used quantitative approaches (Chang & Mao, 1999; Eryilmaz, 2002; Marx et al., 2004) but rarely have both quantitative and qualitative approaches (Sungur et al., 2001) been applied to investigate the effectiveness of conceptual change interventions on learners’ achievement”. In this study, both qualitative and quantitative approaches have been used in order to understand the effect of an intervention. The study adds to the existing knowledge regarding the use of conceptual change interventions in order to foster reforms in science education in South Africa and possibly beyond her boarders. Thus, this study provides an alternative approach to the teaching of complex topic like photosynthesis in Life Sciences. It will also help learners to develop a better understanding of photosynthesis as a concept. It is hoped that the experience gained through this study is useful in motivating learners involved in this study not only to study photosynthesis, but to employ a similar strategy to other complex topics in Life Sciences. Finally, this study contributes to the future research on the teaching of complex Life Sciences topics using other forms of conceptual change models that employ both qualitative and quantitative approaches.

1.7 Conceptual framework

The Conceptual Change Model is an alternative approach that is used in this study to teach learners the photosynthesis process. It incorporates experiential learning. It recognises learners’ prior knowledge of the concept under study. Building on these fundamental concepts, other theorists have articulated a theory that explains and describes the "substantive dimensions of the process by which people's central, organizing concepts change from one set of concepts to another set, incompatible with the first" (Posner et al., 1982: 211), a "conceptual change" learning model. The central commitment of the conceptual change learning model is that learning is a rational activity that can be defined as coming to comprehend and accept ideas because they are seen as intelligible and rational; the "aha" experience is of the utmost importance in learning (Hewson, 1992). This approach has its roots in the constructivism theory.

In general constructivism is based on the philosophy that knowledge is not something that can be transferred from one person to another, but instead it must be built by an individual (Jones, 1997). Constructivism in its many forms has become a familiar view of learning among science educators (Tobin & Tippins, 1993). From Piaget's (1964) work, assimilation has been identified with constructivism and denotes the fitting of new experiences into existing mental schemes. Accommodation, a related term, describes the changing of mental schemes that are unable to explain one's new experiences. Although individuals construct their own understandings, it is not done in isolation but in a social context (Maypole & Davies, 2001). Constructivism relies on learners sharing and discussing their own interpretation of the world around them (Brooks & Brooks, 1999). This view of learning acknowledges that learning is a social activity in which learners are involved in constructing consensual meaning through discussions and negotiations. During these discussions, learners can identify and articulate their own views, exchange ideas and reflect on other learners' views, reflect critically on their own views, and when necessary, reorganise their own views and negotiate shared meanings (Kearney et al., 2001).

Learning and teaching are inseparable. The NCS expects learners to take responsibility of their own learning. But this presupposes that the educator plays a role of facilitator by providing an enabling environment. The educator should use teaching methods that will make the lesson interesting and encourage learners' creativity and thinking. For the purpose of this study CCM is used as teaching approach to achieve the above mentioned outcome. More details of this theoretical constructs in which this study is situated are presented in chapter 2.

1.8 Limitations

The findings of this study should be interpreted with caution given its limitations. The study used only two samples from two high schools in the same rural area accessible to the researcher, which of course, cannot be regarded as a representative sample of Grade 10 learners from all high schools in the country. It would have been better if the selected samples were coming from urban, squatter camps, rural and townships schools from the same province. Generalization is not advised when interpreting results of this study. This study was pursued over a short period of time and as such it gives a snap shot view of the problem and not the holistic picture in one school set-up. The timing of the data collection during the third quarter when educators were preparing their learners for the trial and end-of-year examination was also a limiting factor. Consequently, the researcher was only allowed to use a maximum of four weeks to collect data and instead of the intended minimum of six weeks, including two weeks of acclimatization.

1.9 Definition of terms

Constructivism: It emphasizes learning and not teaching. The constructivist view of learning suggests that learners construct their own knowledge, strongly influenced by what they already know. It recognises the fact that learners come to class with prior knowledge. This knowledge has been gained from previous interaction with others i.e. educators and peers in formal schooling in earlier grades, parents, siblings and the community. Constructivism encourages educators to recognise their learners' strongly held preconceptions and to provide experiences that will help them build on their current knowledge of the world (Duit & Confrey, 1996).

Social Constructivism: This view of learning acknowledges that learning is a social activity in which learners are involved in constructing consensual meaning through discussions and negotiations. During these discussions, learners can identify and articulate their own views, exchange ideas and reflect on other learners' views, reflect critically on their own views, and when necessary, reorganise their own views and negotiate shared meanings (Kearney et al., 2001). Although individuals construct their own understandings, it is not done in isolation but in a social context.

Meaningful learning: It is a process of assimilation where new knowledge is linked to existing cognitive structures. Individuals learn meaningfully by choosing to relate new knowledge to relevant concepts and propositions they already know. According to Ausubel (1963), the essential features of meaningful learning is that it embodies a distinctive kind of learning process in which a learner employs a "set" to incorporate within his cognitive structure, in a non-arbitrary, non-verbatim fashion, potentially meaningful materials which are sub-sumable by established entities within a structure.

Learner-centred approach: An approach to learning and teaching that views learning as the active construction of meaning and teaching as the act of guiding and facilitating. This approach sees knowledge as being ever changing and built on prior experience. The approach in sciences provides opportunities to learners to practise critical and creative thinking, problem solving and decision making. These involve the use of skills and processes such as recall, application, analysis, synthesis, prediction and evaluation, all of which contribute to the development and enhancement of conceptual understanding.

Educator-centred approach: approach to teaching wherein most class time is spent with the educator lecturing and the learners watching and listening. The learners work individually on assessment tasks and cooperation is discouraged. The educator mainly focuses on how to deliver knowledge and the lecture is centred on the content of the subject. Learners are treated as sponge, ready to absorb knowledge. The goal of learning is to pass examinations. According to Pearsall (1992), the traditional approach to teaching often leads to a surface level approach to learning.

Conceptual change: The process of replacing a naïve or flawed understanding with a scientifically acceptable understanding. Conceptual change refers to the reorganising of current conceptual knowledge in the face of conflicting new information (Hoang, 2007).

Conceptual Change Model: The Conceptual Change Model (CCM) places learners in an environment that encourages them to confront their own preconceptions and those of their classmates, and then work toward resolution and conceptual change (Stepans, 1996). The interpretation of learner responses as driven by alternative conceptions suggests that learning may involve changing a person's conceptions in addition to adding new knowledge to what is already there. This view was developed into a model of learning by Posner et al., (1982) and expanded by Hewson (1982).

Alternative conceptions: Alternative conceptions or misconceptions might also be referred to as preconceived notions, non-scientific beliefs, naïve theories, mixed conceptions or conceptual misunderstandings. Basically, in sciences these are cases in which something a person knows and believes does not match what is scientifically correct. Hancock defined a "misconception" as "… any unfounded belief that does not embody the element of fear, good luck, faith, or supernatural intervention" (Hancock, 1940). Hancock considered misconceptions to arise from faulty reasoning. Driver and Easley (1978) contend that semantics indicate the writer's philosophical position, saying that Ausubel talks of "preconceptions" which are ideas expressed that do not have the status of generalised understanding that are characteristics of the conceptual knowledge. However those who use the term, misconception, indicate an obvious connotation of a wrong idea or an incorrectly assimilated formal model or theory. And, those persons who use alternative conceptions indicate that pupils developed autonomous frameworks conceptualising their experience of the physical world. Most people who hold misconceptions are not aware that their ideas are incorrect. When they are simply told they are wrong, they often have a hard time giving up their misconceptions. This becomes harder if they have had a misconception for a long time. What is more concerning about misconceptions is that we continue to build knowledge on our current understandings. Possessing misconceptions can have serious impacts on our learning.

1.10 Concluding Remarks

The problem of the study, its purpose and research questions were introduced in this chapter. It is essential that that the entire plan of this study is provided at this juncture to give an idea of what the rest of the chapters focused on.

Chapter Two centres on conceptual foundation of the Conceptual Change Model (CCM). It explains the meaning, origin and varieties of constructivist's experiences such as constructivism, social constructivism, meaningful learning as opposed to rote learning, conceptual change (both the interpretations and model of learning) and alternative conceptions (meaning and causes). It presents in detail the six stages that should be followed when implementing Conceptual Change Model. Furthermore it discusses the learners' misconceptions and their causes. The chapter ends by emphasising the importance of prior knowledge when teaching and proposes the strategy that covers it in science teaching.

Chapter three presents the research approach, plan of sampling procedure, and instruments. The material of teaching and data collection procedure are given. It describes data analysis and ethical considerations. Chapter four presents data analysis techniques and results of the study, consisting of the results of the achievement tests and questionnaire from EG and CG. It presents the results of the inferential and descriptive analysis and endeavours to answer research questions with the evidence from tables and graphs. It concludes with summary of results. Discussion of findings, summary of results, and conclusion are discussed in chapter five. In addition, the implications of the results and suggestions for further research are presented. The chapter ends with closing remarks.

Chapter 2

2.0 Literature Review

2.1 Introduction

When children start school and throughout their primary, middle and high school years they already have preformed ideas about how the world works (Stepans, 1994). These ideas come from within formal schooling or from daily interaction with others in our society, i.e. our parents, siblings, friends, educators and others (Köse & Usak, 2006). Everyone of our learners brings to the classroom his or her ideas about how the world works. Learners' ideas may or may not be scientifically valid (Driver et al., 1994). However, as they interact with the educators and textbooks, they ultimately construct, deconstruct and modify their own understanding based on their learning experience (Driver et al., 1994). Research has shown that teaching is unlikely to be effective unless educators and designers of learning materials take into account learners' misconceptions (Driver et al., 1994). The success or otherwise of instruction to a large extent, depends on the relevance of what is taught in their daily lives.

The new curriculum in most countries promotes scientific literacy as a goal (Hoang, 2007). At the end of schooling, science graduates should have achieved excellence and a high degree of scientific literacy. Many learners feel inadequate about their understanding of science phenomena. This is a result of science classrooms that are distanced from research in science education (Stephans, 1994). Research indicates that learners come to a class with their own personal theories about how things work and about science phenomena. Most of the time learners' personal views do not coincide with scientific explanations. But schools do not help learners' change their naïve ideas and misconceptions. Textbook writers do not acknowledge learners' personal mental models as a starting point for instruction (Stepans, 1994). For learners to develop scientific literacy, educational literature supports the approach that learners must go through a process and a shift in understanding (Stepans, 1994; Hoang, 2007). In this process, a flawed/naive understanding is replaced with a scientifically acceptable idea, a course of action which is called the "Conceptual Change". This shift is necessary for conceptual understanding to occur. It is high time that educators and textbook writers acknowledge the role of meaningful learning in teaching Science.

2.2 Constructivism

In general, constructivism is based on the philosophy that knowledge is not something that can be transferred from one person to another, but instead it must be built by an individual (Jones, 1997). The constructivist view of learning suggests that learners construct their own knowledge, strongly influenced by what they already know. It recognises the fact that learners come to class with prior knowledge. This knowledge has been gained from previous interaction with educators and peers in formal schooling in earlier grades, parents, siblings and friends at home. Constructivism encourages educators to recognise learners' strongly held preconceptions and to provide experiences that will help them build on their current knowledge of the world (Duit & Confrey, 1996).

Maypole and Davies (2001) have observed that constructivism encompasses a disparate array of philosophical, psychological and epistemological orientations. One key distinction within this broad theoretical 'camp' is that between cognitive and social constructivism. Cognitive constructivism is based on Piaget's (1977) model, which emphasises the interaction between the individual and their environment in constructing meaningful knowledge, whereas social constructivism-attributed to the work of Vigosky (1978), emphasises the importance of a learner learning through interaction with the educator and other learners (Jadallah, 2000; Maypole & Davies, 2001). The teaching approach discussed in this report subscribes to social constructivism. Hence, the emphasis in the CCM is on building the social context for learning and on facilitating learner learning through small group activity and encouragement of high levels of peer- to- peer and learner- to- educator interaction.

2.3 Social Constructivism

Piaget, Bruner, Ausubel, Vygotsky and Feuerstein, all emphasise the importance of prior knowledge learning experience as the basis for further learning. This study is situated in the socio-constructivist theory influenced mostly by Vygotsky (Jadallah, 2000; Maypole & Davies, 2001). Vygotsky sees teachers as facilitators of the learning process and learners as active constructors of knowledge. Vygotsky's (1978) approach to cognitive development as social constructivism, works on the assumption that action is mediated and cannot be separated from the milieu in which it is carried out. This view of learning acknowledges that learning is a social activity in which learners are involved in constructing consensual meaning through discussions and negotiations (Gedik et al., 2002). During these discussions, learners can identify and articulate their own views, exchange ideas and reflect on other learners' views, reflect critically on their own views, and when necessary, reorganise their own views and negotiate shared meanings (Kearney, 2001). Although individuals construct their own understandings, it is not done in isolation but in a social context. As purported above, there is an active individual and an active environment. CCM teaching approach provides opportunity for both in the teaching of sciences and the learning of difficult science concepts.

One of the purposes of science education is to have learners learn concepts meaningfully and to use concepts in their daily lives (Yuruk & Cakir, 2004). In order to achieve the above-mentioned purpose a model of learning that uses social interaction like small group activity and demonstrative experiments is recommended. In the CCM learners become aware of their existing misconceptions through questions and demonstrations. The demonstrations and discussions enable learners to comprehend scientific facts and combine them with their prior knowledge. Therefore, demonstrative experiments based on conceptual change are an effective method to reduce and prevent misconceptions (Gedik et al., 2002). Moreover small group activity based on a conceptual change strategy centralises learners and makes them explorers and constructors of knowledge; understanding necessary to simplify the teaching of concepts (Cayci et al., 2007). Learners build new concepts by interacting with their peers in order to help them complete a task. It is the educator's duty to create a favourable environment, by engaging learners in activities that are interesting and that will promote meaningful learning. Those activities should therefore use both demonstrative experiments and small group activity which are the heart of CCM.

2.4 Meaningful Learning versus Rote Learning

Earlier studies indicated two contrasting views of approaches to learning: rote (surface) and meaningful (deep) learning. Meaningful learning is well documented in literature. Ausubel, developed a theory of learning which distinguishes rote learning from meaningful learning (Ausubel, 1968). According to Ausubel, meaningful learning takes place during the internalisation process when symbolically expressed ideas are incorporated into some specifically relevant structures of already existing knowledge. Ausubel, like Piaget sees meaningful learning as a process of assimilation where knowledge is linked to existing cognitive structures. He sees rote learning as involving drilling and memorisation of facts and concepts for the sole purpose of recalling them for a test or examination and as he purports this is stored in the short term memory. (A reason, why) learners grapple with complex and often confusing concepts that do not conform to their existing ideas and explanation but simply serve to confuse them further. So, there is a need to examine alternative approaches to instruction which can improve, not only learners understanding of concepts, but also their performance in tests. Only a small group benefit from the traditional approach of being presented the product of scientific work and imagination in the form of rules, laws and generalisations (Stepans, 1994). Such approaches create in learners a feeling of helplessness. It forces them to merely memorise the definitions, rules, laws and formulas and they hope that it will all go away as soon as exams are over.

Studies exploring the learning approaches in relation to learners' achievement reported that learners with meaningful learning approaches accomplished more meaningful understanding of science concepts than those with rote learning approaches (BouJaoude & Guiliano, 1994; BouJaoude et al, 2004; Cavallo, 1996; Cavallo & Schafer, 1994). In an earlier study, BouJaoude (1992) reported that learners who learned by rote had less understanding and more misconceptions concerning chemistry concepts than meaningful learners. Similarly the work of Cavallo and Schafer (1994) demonstrated that learners with meaningful learning approaches accomplished more meaningful understanding of genetics concepts than those with rote learning approaches. All together, studies focusing on the learning approaches have suggested that there is a statistically significant association between learners' learning approaches and their science achievements.

The new curriculum in South Africa emphasises the implementation of learner-based teaching strategies in the teaching of life sciences, which grows from research. According to the research, this kind of learning can occur when educators provide experiences that acknowledge and directly challenge naïve conceptions. It is the desire or need to resolve this conflict which creates in the learner a motivation to learn. Out of this conflict, conceptual change can emerge.

2.5 Conceptual Change

(a) Interpretations of Conceptual Change

According to Hewson (1992), when referring to conceptual change, it is helpful to recognise that the word "change" is used in different ways. He gives the following four different scenarios to illustrate how change can be used in a given situation. Firstly, he gives a scenario where one might talk as in a fairy tale, of a princess kissing a frog who as a consequence, changes into a "prince". In this case there is only one entity before and a different one after the change. The frog is no more, there is only the prince. Here change means extinction of the former state. Secondly, he gives an example of an election for political office with the incumbent being defeated by the challenger; there has been a change of mayor position. The incumbent loses status, while the challenger gains it. In this case, there is no extinction; change means an exchange of one entity for another (Hewson, 1992) thirdly, he gives an example of a home that started as a small four-roomed cottage and was later extended by adding a wing at either end. When water and electricity became available, a bathroom and kitchen were attached. It is still the same home: change here means extension (Hewson, 1992). Using three scenarios he uses the problem of a learner who holds one view ("a table supports a book by being in the way") in contrast to the canonical view ("a table supports a book by exerting an upward force on it").

Change as in the first example above, extinction does not seem an appropriate characterisation of this change. There is no sense in view has disappeared to be replaced by other, learners will by and large, remember both views. Change as in the second example, exchange, seems a much better characterisation of what has been reported. It is change of this kind that is evoked for most people on hearing conceptual change. Conceptual change therefore refers to the reorganising of current conceptual knowledge in the face of conflicting new information (Hoang, 2007). Posner et al. (1982) and Strike and Posner (1985) point out that in order to bring about conceptual change in learners with respect to concept, these conditions below are necessary:

- The learners must be dissatisfied with their existing views;
- The new conception must appear somewhat plausible;

- The new conception must be attractive; and
- The new conception must have explanatory and predictive power.

This model provides an interesting premise on how individual learners may change their understanding of a concept and outlines the importance of prior knowledge for this change to occur. If science teaching should provide a rational and accessible basis for conceptual change, it must provide an opportunity for learners' prior knowledge to be heard. One approach that was developed in consideration of the above-mentioned fact is the Conceptual Change Model.

The conceptual change approach has frequently been used recently. It includes several applications. Those applications include analogies and explanatory models, conceptual change texts, concept maps, hands on activities, information processing skills, learners' written answers, and computer aided instruction, group work, demonstrative experiments and discussions.

The first way to deal with learners misconceptions is to be aware of them. Educators must be aware of learners' prior knowledge and possible misconceptions. During lesson preparations misconceptions should be incorporated into the lesson. These will allow learners to learn concepts meaningfully rather than memorising them. Life Science is a more interrelated science field with respect to concepts it covers compared to other sciences. Learners find it easier to memorise than to learn concepts meaningfully. The most apparent example of this can be seen in the subject of photosynthesis and plant respiration. Especially in these studies that were performed on photosynthesis and respiration, subjects reveal misconceptions are very frequent (Haslam & Treagust, 1987; Anderson et al., 1990; Amir & Tamir, 1994; Tekkaya & Balci, 2003; Cepni et al., 2006; Kose et al., 2006).

Tekkaya and Balci (2003) carried out a study that aimed to determine the misconceptions of high school learners regarding the concept of photosynthesis and respiration in plants. These researchers observed that most of the learners had the idea that "photosynthesis is a gas alteration process, energy is produced after photosynthesis and photosynthesis is the reverse of respiration" which is scientifically invalid.

Cepni et al. (2006) conducted a study to reveal the cognitive development, misconceptions and attitude of learners about the photosynthesis concept. They concluded that making use of Computer Assisted Instruction Material (CAIM) was very crucial for attaining the application and comprehension levels of cognition in teaching photosynthesis. However, they observed that CAIM did not substantially change the misconception of learners about photosynthesis.

Kose et al, (2006) investigated the effect of concept changing texts for reducing the misconceptions of pre-service educators in the concept of photosynthesis and respiration in plants. The authors observed that most pre-service educators had misconceptions about photosynthesis and respiration in plants. It was concluded that concept changing texts were efficient in the comprehension of photosynthesis and respiration in plants and in reducing misconceptions of pre-service educators.

(b) The Conceptual Change Model

Changing learners' conception is a big task. As Hewson, (1992) purports, the interpretation of learner responses as driven by alternative conception suggests that learning may involve changing a person's conception in addition to adding new knowledge to what is already there. The development of the teaching approach of the Conceptual Change Model is the result of the work by many science educators, educators and researchers of education. Some of those who contributed to the development and implementation of the Conceptual Change Model are listed below: Eaton, Anderson and Smith (1993), Clement (1987), Duit (1987), Feher and Rice (1988), Gilbert, Osborne, and Fensham (1982) and Stepans (1988). There are two major components to the CCM (Hewson, 1992). The first of these components is the condition that should be met (or no longer met) in order for a person to experience conceptual change. The extent to which the conception meets the conditions is whether a new conception is intelligible (knowing what it means), plausible (believing it to be true) and fruitful (finding it useful) necessary to experience conceptual change, is termed the status of a person's conception. The second component is the person's conceptual ecology that provides the context in which the conceptual change occurs, that influences the change and gives it meaning. Learners use their existing knowledge (i.e. their conceptual ecology) to determine whether different conditions are met, that is whether a new conception is intelligible (knowing what it means) plausible (believing it to be true) and fruitful (finding it useful) (Hewson, 1992). If the new conception is all three, learning proceeds without difficulty. If, however, the new conception conflicts with the existing conceptions, then it cannot become plausible or fruitful until the learner becomes dissatisfied with the old conceptions. A central prediction of the CCM is that conceptual changes do not occur without concomitant changes in relative status of the changing conception (Hewson, 1992). Learning a new conception means its status raises, i.e. learners understand it, accept it, and see that it is useful (Hewson, 1992). If the new conception conflicts with the existing conception, i.e. one that already has status for the learner, it cannot be accepted until the status for existing conception is lowered. This only happens, according to the CCM if the learner who holds the conception has a reason to be dissatisfied with the so called concept. As emphasised by Stepans (1994) CCM places learners in an environment that encourages them to confront their own alternative conceptions and those of their classmates, and then work toward resolution and conceptual change.

CCM actively engages learners through predicting outcomes, verbalising and sharing their own ideas as well as listening to each other (Vosniadou, 2001). Learners plan investigations, collect data and interpret observations together and finally construct models (Tabak et al., 1995). This promotes conceptual change and develops positive attitudes towards science learning (Dekkers & Thijs, 1998). In order to implement CCM, the following steps are adopted from Stepans (1994) and are followed in this study:

- Commit to an outcome: the researcher will help learners become aware of their own beliefs with respect to a concept by posing a question about science concepts or presenting a challenge or by learners calling on learners to make predictions about the outcome.
- Expose beliefs: the educator will allow learners to share their ideas with others in small groups so that they expose their beliefs and become aware of others’ beliefs.
- Confront beliefs: at this stage learners will be allowed to test their ideas by manipulating materials and their beliefs on photosynthesis might be challenged.
- Accommodate the concept: at this stage learners will begin to resolve the conflict that may exist between their beliefs and what is observed.
- Extend the concept: the learners will be asked to bring their own examples on how the concept is connected to other situations, including their daily lives.
- Go beyond: at this stage learners will be encouraged to continue thinking about the concept and pose additional questions and problems of interest to them.

2.6 Alternative conceptions

Alternative conceptions or misconceptions also known as preconceptions, to name but a few denote learner understandings of scientific concepts that are not aligned with the current understanding of scientists. Although the studies initiated by Driver and her colleagues have produced an impressive literature on learner alternative conceptions in general, the field of research into alternative conceptions in Life Sciences is still emerging compared with efforts in the Physical Sciences (Duit, 2004). Wandersee et al. (1994) describes much of the literature as focused on four areas of Life Sciences, namely, concepts of life, animals and plants, the human body and continuity of living things including reproduction, genetics, and evolution. It is also worth noting, that much of the literature available has investigated conceptions in very young learners, addressing concepts of life, plants and animals. Only in the late 1980s and 1990s have researchers focused their attention on alternative conceptions of high school learners and investigated more biochemical concepts, such as cellular respiration, photosynthesis, cell division and transpiration. Although topics such as cellular respiration and photosynthesis have been studied by multiple groups and using multiple methodologies, learners' alternative conceptions for most topics remain poorly understood. This study is an effort to add to literature on how to deal with learners' alternative conceptions on photosynthesis.

Causes of alternative conceptions

Misconceptions are formed in a variety of ways. Children come to school already holding beliefs about how things happen, and have expectations based on passed experiences which enable them to predict the future. That is, children hold ideas that were developed before and during their early school years, and these ideas may be compounded by the educator and/or the textbook. Lack of content knowledge by subject educators perpetuates learners' misconceptions. If educators do not understand Life Sciences concepts, how can they teach our learners? In South Africa, most science educators at secondary school level are under-qualified, thus exacerbating the problem (Broadie, 2006). In addition, these educators are ill equipped to deal with learners' alternative conceptions and preconceptions that they bring into science classes. The current curriculum in South Africa is underpinned by the constructivist theory and emphasises the independent construction of knowledge by learners and the educator as facilitator of learning. Educators should thus be aware of alternative conceptions that learners bring to the science class which prevents meaningful learning to take place. One of the most common sources of misconceptions is the fact that our everyday language is often at odds with science; commonly used vernacular does not match the precise language (terminology) used by scientists.

Fisher (1985) purports that misconceptions serve the needs of the persons who hold them and those erroneous ideas may come from strong word association, confusion, conflict or lack of knowledge. According to him, alternative conceptions have the following characteristics:

- They are at variance with the conceptions held by experts in the field.
- A single misconception, or small number of misconceptions, tends to be pervasive (shared by many different individuals).
- Many misconceptions are highly resistant to change or alteration, at least by traditional teaching methods.
- Misconceptions sometimes involve alternative belief systems comprised of logically linked sets or propositions that prevents learners from acquiring knowledge in systematic ways.
- Some misconceptions have historical precedence: that is, some erroneous ideas put forth by learners today mirror ideas championed by early leaders in the field.

Therefore an educator who expects to simply point out learners' mistakes to them will be met with little success. This is because, as stated earlier, misconceptions are not easily given up. The first step is to be aware of and 'diagnose' learners' misconceptions. Then employ a conceptual strategy that will help you deal with learners' misconceptions. For the purposes of this study the Conceptual Change Model is adopted.

2.7 Conclusion

Teaching toward conceptual understanding often sounds deceptively simple, while in reality it presents a host of significant challenges both in theory and in practice. Few if any learners come to the Life Sciences classroom without significant prior knowledge of the subject. It is therefore the responsibility of educators to find out what they already know or do not know, what they are confused about, and how their preconceptions about the world do or do not fit the new information they are attempting to learn. The instruction given to learners if it is to be understood by learners above and beyond memorisation, requires that educators take into account learners' prior knowledge and support learners in integrating new knowledge with their existing knowledge. Therefore, teaching strategies that simply cover the material and present a list of new ideas without engaging learners in their own metacognitive analysis are counter-productive. An inquiry-based science teaching strategy like CCM is therefore productive and imitates what scientists do in laboratories in trying to understand how living things work.

Chapter 3

3.0 Research design and Methodology

3.1 Introduction

The purpose of this chapter is to explain the research approach, plan sampling procedures, data collection and management. A suitable research design should be chosen to answer the research questions. The study investigated Grade 10 learners' achievements in photosynthesis using CCM in selected schools in the Moretele sub-region of the Nkangala Region, Mpumalanga Province, South Africa.

3.2 Research Design

The study used both quantitative and qualitative approaches. The quantitative study utilised a non-equivalent pre-test, post-test control group design (Campbell et al., 1963). Of the two groups one was designated as the experimental group (EG) and the other the control group (CG). Because we were unable to assign the learners randomly to the groups due to the constraints of the context, this study was quasi-experimental in nature. The pre-test, post-test CG design was chosen for this study because the study wanted to find out which method would yield better learners' achievements'. The paradigm of the research design, a non equivalent pretest-posttest control group, was as follows:

EG	O_1	X_1	O_2
CG	O_3	X_2	O_4

EG represents the Experimental Group, using CCM approach (X_1) while CG represents the Control Group, using the Traditional Approach (X_2). O's refer to the tests, pre-test and post-test in sequential order for each group. Qualitative approach used questionnaires to determine perceptions and attitudes of learners towards the use of the CCM in learning concepts regarding photosynthesis.

3.3 The sample

The sample of this study comprised a total of 78 grade 10 Life Sciences learners from two neighbouring high schools in Nkangala Region of Mpumalanga Province in South Africa. The schools were selected because they were all situated in the same rural region, which meant that the subjects were likely to have been exposed to similar socio-economic conditions and were probably familiar with the traditional practices found in that particular socio-cultural environment. The learners' ages ranged from 13 to 15 years, with a mean of 14. The sample was drawn by a purposive sampling technique from two separate schools: one Life Sciences class of 39 learners (8 boys and 31 girls) and another Life Sciences class of 39 learners (14 boys and 25 girls) with similar environment. One class formed the Experimental Group which was taught using CCM, while another class formed the CG and was taught through Traditional Approach.

3.4 Instruments

Three types of instruments were used in this study: achievement test (AT), a questionnaire and learning materials for both the Control and Experimental Groups (Appendices A and B). The AT which was used as both pre- and post-tests consisted of 11 questions; 5 true or false questions, five multiple choice question and 1 structured question. The pre-test was administered before the intervention to identify learners' misconceptions about photosynthesis. After the intervention, a post-test was used to explore learners' concepts associated with photosynthesis in order to determine how their understanding had changed due to the CCM intervention. Both tests covered most aspects of photosynthesis investigated in the two groups. In order to determiner learners' perceptions and attitudes, a questionnaire of 16 items on a 5-point Likert Scale ranging from 1 (strongly agree) to 5 (strongly disagree) was used in addition to the pre- and post-tests (Hake, 2001; Randler, 2006). The questionnaire was administered to learners during Life Sciences period on the very last day of the study. The questionnaire was divided into two sections: Section A was about learners' perceptions and Section B was about learners' attitudes towards the teaching approach. Four experts (2 subject advisors in Life Sciences and 2 experienced Life Sciences educators) were consulted for content validity of the instruments. For reliability of the questionnaire and the achievement test (AT), these instruments were piloted with 20 Grade 10 learners from another high school in the same vicinity which was not part of this study. The Cronbach alpha were 0.92 and 0.82 for the questionnaire and the AT, respectively. This suggests that the questionnaire and the AT had a good and acceptable reliability to be used for the study.

3.5 The development of the teaching materials

The teaching materials developed for this study were aimed at (a) increasing scientific conceptions of learners (b) helping learners to correlate scientific knowledge with their existing conceptions (c) using learners' reconstructed knowledge to describe and explain phenomena. In order to achieve the above-mentioned aims, the developed materials were prepared by examining a number of related resources such as life sciences textbooks, study guides, learning channel videos and work schedules developed by subject specialists. These teaching materials were also checked for content depth, magnitude and time devoted to teaching photosynthesis in Grade 12. A total of seven worksheets and five hands-on activities were developed which aimed at remedying learners' misconceptions identified by the researcher. Also, three video clips were used as part of the teaching materials. These need to have been checked by educators to ascertain face validity (See Appendices attached).

3.6 Data Collection

This study was conducted over a period of six weeks. In order to alter learners' misconceptions, six stages of the CCM, as discussed in Chapter 2, were used. The study utilised the experimental design (pre- and post-testing design). The EG was taught using the CCM approach, while the CG was taught using the traditional approach. In the EG the educator facilitated learners' activities through the first six stages of the CCM. Learners were allowed to make presentations in groups and submitted worksheets of their activities. The educator evaluated each group based on their presentations and worksheets. In the control group, where the traditional approach was utilized, the textbook method; whole class discussion and lecturing were mainly employed for instructional purposes. In this approach, the underlying principle is that knowledge resides with the educator, and it was the educator's responsibility to transfer this knowledge to learners. Learners became passive recipients of the information given by the educator.

3.7 Data Analysis

Data analysis techniques

This research adopted both quantitative and qualitative data analysis techniques. All the quantitative data collected were entered in SPSS program, version 17. Two statistical techniques were used in the analysis, namely descriptive statistics and inferential statistics.

3.7.1 Descriptive statistics

Descriptive statistics were used to obtain the difference between means, standard deviations of the scores for each group on each dependent variable.

3.7.1.1 Mean

The means for the experimental and control groups were used in determining whether the group who received CCM instructional approach, performed better than their counterparts who received traditional instruction.

3.7.1.2 Standard Deviation

The standard deviation provides indication of the degree of variability of the scores in the experimental and control groups. This study assumed that the standard deviations of the groups are equal or near equal. For this study, the differences of the experimental and control groups were verified using the t-tests. If the t-test is significant at 0.05 alpha levels, this rejects the assumption that variances of experimental and control groups are not equal. On the other hand, a calculated p-value exceeding 0.05 suggests that the variances for experimental and control groups are equal, and this would imply that the assumption of homogeneity of variances is tenable.

3.7.2 Inferential statistics

In order to find the effect of the intervention (CCM) on the understanding of photosynthesis, ANCOVA was used. ANCOVA was used to compare group means of post test scores between the EG and CG. ANCOVA, using pre-test as covariate, statistically controlled for the differences of the pre-test so that post differences would not be due to initial differences prior to treatment. All statistical tests were evaluated at $p < 0.05$ level of confidence. A t-test was used to determine if there were significant differences in pre- and post-tests for both experimental and control groups (Dugard and Todman, 1995).

Data from the questionnaires were analysed using descriptive statistics (frequencies, percentages, and means) of each item and grouped into the following themes: 1) opinions about the role of CCM in the acquisition of knowledge and skills; 2) opinions about the role of CCM practical work in acquiring and developing procedural knowledge and investigation skills; and 3) opinions about attitude towards the CCM on the teaching of photosynthesis.

3.8 Ethical Considerations

The schools management teams (including the principals and head of department of sciences), the Grade 10 class educators and Life Sciences educators were asked permission to conduct study in their schools. Given the problems that learners and educators have with this Life Sciences complex topic, educators and learners in both schools welcomed the researcher. The quasi-experimental design used in this study implies that a particular group will be subjected to the CCM while another group is subjected to the traditional approach and denied the innovative approach. This was a special concern mentioned by the principal where the CCM was not used. To achieve equity and fair play the two groups were exposed to the innovative approach, though the CG was exposed to the approach at a later stage. For purposes of anonymity the two schools and the participants where the study took place could not be named.

3.9 Conclusion

This chapter focused on the selection of the research design and methodology. An approach using quantitative and qualitative methods was explained. The methods where achievement test and a questionnaire were used to collect data were explained. Ethical considerations and limitations of the study were also given. As explained above data analysis used SPSS, version 17. The findings of the inquiry are presented and discussed in Chapter 4.

Chapter 4

4.0 Results

4.1 Introduction

The previous chapter described the research approach, plan, sampling procedures, data collection and management of data. In this chapter the techniques for data analysis and results are presented.

4.2. Presentation of Results

i. **Homogeneity of groups before the treatment**

The study was conducted on two groups: the experimental and control groups. Learners' prior knowledge and level of achievements were identified from the pre-test. The learners' achievements will be reported in two groups: experimental and control.

The results of the pre-test for both the control and experimental groups are shown (See Table 1) below side by side as raw scores out of a total of 15.

Table 1: Pre-test scores of both the control and experimental groups

	Control Group (CG)	Experimental Group (EG)
Numbers	**Mark Obtained**	**Mark Obtained**
1.	2	0
2.	0	6
3.	4	2
4.	2	4
5.	2	5
6.	3	2
7.	1	2
8.	2	4
9.	4	2
10.	5	4
11.	2	3
12.	4	2
13.	3	4
14.	2	6
15.	6	0
16.	3	5
17.	1	2
18.	6	4
19.	2	4
20.	2	1

21.	1	4
22.	1	4
23.	1	2
24.	2	3
25.	1	2
26.	2	3
27.	2	2
28.	4	3
29.	3	1
30.	2	4
31.	0	6
32.	3	4
33.	2	1
34.	3	2
35.	5	3
36.	1	2
37.	2	1
38.	3	2
39.	4	4

In order to test whether there is a difference among variables of groups, an independent sample t-test was conducted. The values of the mean scores, standard deviation, t-values are listed in Table 2 below.

Table 2: T-test and achievement scores of pre-test for Control and Experimental groups.

Group	**Count**	**Mean Score**	**SD**	**df**	**T-test**	***p***
Control	39	2.51	1.46	76	- 1.27	0.10
Experimental	39	2.94	1.56			

The Independent t-test analysis showed that there was no statistically significant difference between the pre-test achievement scores of the control and the experimental groups (t = -1.27; p>0.05). The achievement test scores of the learners EG before the treatment (X= 2.94) was higher than the CG learners' score (X=2.51), but this small difference is not significant to the 95% confidence interval. This result shows that Grade 10 learners' conceptions on photosynthesis in plants are at same level of understanding before the intervention.

4.3.2 Are there any significant differences between the post-test scores of the control and experimental groups?

The results of the post-test for both the control and experimental groups are shown, in Table 3 below, side by side as raw scores out of a total 15.

Table 3: Post test scores of the control and experimental groups

Learners' Numbers	Control Group (CG)	Experimental Group (EG)
	Marks obtained	Marks obtained
1	4	8
2	4	15
3	5	13
4	4	15
5	4	10
6	8	15
7	3	9
8	4	9
9	2	11
10	3	14
11	4	10
12	3	10
13	4	8
14	6	11
15	4	2
16	5	2
17	3	4
18	3	5
19	3	9
20	8	3
21	4	4
22	4	9
23	4	2
24	4	5
25	6	9
26	3	8
27	3	4
28	7	7
29	7	2
30	3	8
31	0	8
32	2	7
33	2	7
34	5	4
35	7	1
36	4	4
37	5	5
38	6	2
39	5	7

A t-test was also used to compare post-test scores of the groups after intervention. The result of the independent sample t-test scores is presented in Table 4

Table 4: Control and experimental groups post-test achievement scores on photosynthesis in plants and independent t-test scores

Group	Count	Mean Score	SD	df	T-test	*p*
Control	39	4.23	1.71	76	-4.51	0.00
Experimental	39	7.33	3.94			

As represented in Table 4, there is a significant difference between the post-test achievement scores of the EC and EG (t = -4.509; p <0.05). The means and variances for the control and experimental groups are also reported in Table 2. The mean score of the EG was 7.33 which is higher than the CG mean score of 4.23. This result may suggest that the treatment used on the EG considerably enhanced learners' achievement. The results show that the CCM approach may reduce the misconceptions of Grade 10 learners regarding photosynthesis in plants.

4.3.3 Are there any significant differences between post-test and pre-test achievements of the experimental as well as the control group?

A t-test analysis was also used to compare the results of the pre- and post- tests of the EG. The results of this comparison are shown in Table 5 below:

Table 5: T test results of pre- and post-tests in the experimental group (* Significant at p < 0.05).

Group	Count	Mean Score	SD	df	T-test	*P*
Control	39	2.94	1.56	76	-6.46	0.00
Experimental	39	7.33	3.94			

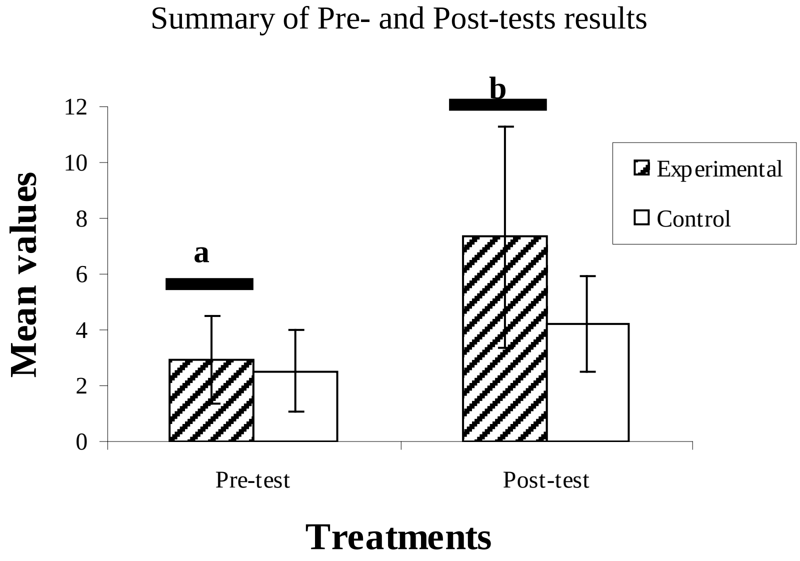
Table 5 indicates that there is a significant difference between the pre-test and post-test scores in the experimental group's achievement scores {(t= -6.46; p<0.05). The mean score of the learners' pre-test scores is 2.94, and the post-test score is 7.33. Conversely, there were no significant differences between pre-test and post-test for the control group (p<0.05). These results show that the intervention used on the EG drastically enhanced learners' achievements. Based on this data it can be concluded that the CCM approach positively affected the conceptual understanding of learners on photosynthesis as a topic. Analysis of Covariance was also used to assess the effect of each treatment on the learners' understanding of photosynthesis in plants. The independent variable was intervention, the dependent variable was the learners' understanding measured by post-test scores. In this study the pre-test scores, which are found to be highly related to the learners' understanding of science concepts, were used as covariates (Soyibo & Hudson, 2000).

Table 6: ANCOVA summary of post-test: pre-test as covariate

Source	SS	Df	F	P
Pre-test	23, 57	1	2.82	0.09
Post-test	125.14	1	14,65	0.00
Error	657.79			

Table 6 contains the summary of ANCOVA, comparing the mean scores of the performance of learners from each group to the post-test scores. The analysis indicates a significant treatment effect, F (1, 76) = 14, 65, p < 0.05 in favour of the EG. Figure 1 below further summarises the results as mean scores of pre-test and post test. It clearly gives the visual picture of the results of Tables 1 - 4.

Figure 1: Results of study as the mean scores for Pre- and Post-tests for experimental and control group.



The range of post test scores for the CG was from 0 to 7 with a mean of 4.23 while the same for the EG was from 1 to 15 with a mean of 7.33 (Figure 1). The F-value of 14.65 ($p<0.05$) for treatment recorded in Table 6, shows that there is a statistically significant difference in performance between the experimental and control groups. Therefore, by comparing the means of the post test scores, this study found that learners in the EG (Mean = 7.33 ± 3.94) gained more than their counterparts in the CG (Mean = 4.23 ± 1.71). The results reveal that the learners in the EG, who were taught through the Conceptual Change Model approach, achieved higher post test scores than the learners in the CG who were taught through the traditional approach.

4.3.4 Is there any statistically significant difference in the achievements of boys and girls?

Tables 7 – 12 compare achievement scores of the boys and girls.

Table 7: T-tests of pre-test achievement scores for girls in the CG and EG

Group	Count	Mean Score	SD	df	T-test	*p*
Control	25	2.68	1.72	48	-0.43	0.33
Experimental	25	2.88	1.56			

As evidenced in table 7, the independent t-test analysis shows that there was no statistically significant difference ($t = -0.43$, $p > 0.05$) between the mean scores of the experimental (2.88) and control groups (2.68) on the pre-test achievement table of girls.

Table 8: T-test of pre-test achievement scores for boys in the control and experimental groups.

Group	**Count**	**Mean Score**	**SD**	**df**	**T-test**	***p***
Control	8	2.5	0.75	14	-0.34	0.37
Experimental	8	2.75	1.90			

As evidenced in table 8, the independent t-test analysis shows there was no statistically significant difference ($t = -0.\ 34$, $p < 0.05$) between the mean scores of the experimental (2.5) and control (2.75) groups on the pre tests achievement table of boys

Table 9: T-test of post-test achievement scores for girls in the CG and EG.

Group	**Count**	**Mean Score**	**SD**	**df**	**T-test**	***p***
Control	25	4.20	1.91	48	-3.13	0.00
Experimental	25	7.16	4.32			

Table 10: T-test of post-test scores of boys for the CG and EG.

Group	**Count**	**Mean Score**	**SD**	**df**	**T-test**	***p***
Control	8	4.86	1.36	14	-1.66	0.059
Experimental	8	7.38	4.03			

A t-test was also used to compare post-test scores of the control and experimental groups of boys and girls as given in tables 9 and 10. Table 9 shows that the girls' achievement scores were statistically significant different (t = -3.13, p <0.05). Whereas, Table 10 shows that the boys' achievement scores show that there was no statistically significant difference (t = -1.66, p> 0, 05) regarding the experimental and control groups.

Table 11: Achievement scores of the pre- and post-tests of the boys in the EG.

Group	**Count**	**Mean Score**	**SD**	**df**	**T-test**	***P***
Pre-test	8	2.75	1.91	14	-2.93	0.05
Post-test	8	7.38	4.03			

Table 12: Achievement mean scores of the pre- and post-tests and t-test of the girls in the EG.

Group	**Count**	**Mean Score**	**SD**	**df**	**T-test**	***P***
Pre-test	25	2.88	1.56	48	-4.66	0.00
Post-test	25	7.16	4.03			

To further justify the assertion that girls performed better than boys the EG is pre- and post-tests for both genders were analysed. It was found that there was no statistically significant difference (t = -2.93, p> 0.05) with a mean of 2.75 for the pre-test and 7.38 for boys in the EG. The statistically significant difference (t = - 4.66, p< 0.05) with a mean of the pre-test of 2.88 and 7.16 for the post-test for girls in the EG. It can, therefore, be concluded that boys in the EG (using the CCM approach) performed much better than the traditional group.

4.3.5 What attitudes do learners have towards Life Sciences after instruction?

Results of the Conceptual Change Model approach

This section deals specifically with the results obtained through the questionnaire. The results of the questionnaire have been discussed separately for each section. For Section A learners were asked to rank their opinions about their perception of their own learning and for Section B their attitude towards the CCM as an approach of teaching and learning photosynthesis.

SECTION A

The data set reflected in this section indicated that most of the respondents were positive when judging from themes: confidence and critical thinking skills. Theme 1 referred to as confidence about the role of CCM in the acquisition of knowledge and skills. Thus, learners were confident that they can apply the information gained from the lessons to answer questions given in different situations (77%); to diagnose and dispel misconceptions about photosynthesis in cells (72%); and to understand where plants get their food (88%).

Theme 2 referred to as critical thinking about the role of CCM practical work in acquiring and developing procedural knowledge. Also, in investigation skills, learners were confident and able: to think systematically and critically after doing experiments (84%); to read, understand and interpret different situations (84%); to use experimental techniques and tools to answer questions given under photosynthesis (80%); to analyse and interpret the result from experiments (79%); to plan and perform a few experiments on their own (87%); to record and organise data from experiments (77%); to make accurate observations and describe the events as they unfold; and to apply observation skills in experiments (72%).

SECTION B

Theme 3 learners were asked to rate their positive attitudes regarding the change of their attitudes towards the CCM on the teaching of photosynthesis. The data reflected in this section showed that most learners were quite happy with the kind of teaching approach used in teaching photosynthesis in plants and had positive attitudes toward science. As indicated by the results from section B of table 13, learners' attitudes towards the CCM changed as indicated by the 95%, 90%, 72% and 87%, respectively.

Table 13: A & B Showing the Likert results regarding learners' attitudes towards CCM teaching approach.

SECTION A

Item	**Strongly disagree OR Disagree**		**Not sure**		**Strongly agree OR Agree**	
	No	**%**	**No**	**%**	**No**	**%**
1. I can apply the information gained from these lessons to answer questions given in different situations.	5	13	4	10	30	77
2. I am able to diagnose and dispel misconceptions about photosynthesis in cells.	6	15	5	13	28	72
3. I understand where plants get their food.	2	5	3	8	35	88
4. I am able to think systematically and critically after these experiments.	3	8	3	8	33	84
5. These activities helped me to read, understand and interpret different situations.	4	10	2	5	33	84
6. These activities helped me to use experimental techniques and tools to answer questions given under this topic.	4	10	4	10	31	80
7. The activities also helped me to analyse and interpret the result from experiments.	3	8	5	13	31	79
8. I am now able to plan and perform a	2	5	3	8	34	87

few experiments on my own.						
9. I am able to record and organise data from experiments.	3	8	3	8	33	84
10. I can make accurate observations and describe the events as the unfold.	4	10	5	13	30	77
11. Doing these activities developed me to apply my observation skills in experiments.	4	10	7	18	28	72

SECTION B

1. Motivates and creates interest in life sciences.	0	0	2	5	37	95
2. Promotes the spirit of tolerance and curiosity in learning life sciences.	1	3	3	8	35	90
3. Helps to develop positive attitudes towards life sciences.	2	5	2	5	35	90
4. Helps to develop logical reasoning.	4	10	7	18	28	72
5. Practical work helps us to understand the subject content better than when we study without practical work.	2	5	3	8	34	87

Results of traditional teaching approach

The results for traditional approach are also discussed separately for each section. For Section A learners were asked to rank their opinions about learning of science and for and Section B their attitude towards the traditional teaching approach when learning photosynthesis.

SECTION A

The data set reflected in this section indicated that most of the respondents were negative when judging from themes: confidence and critical thinking skills. Theme 1 referred to as confidence about the role of traditional approach in the acquisition of knowledge and skills. Thus, the majority of learners strongly disagreed that they can apply the information gained from the lessons to answer questions given in different situations (38%). Unexpectedly most learners were certain that they were able to diagnose and dispel misconceptions about photosynthesis in cells (41%). I suspect that the statement was not well understood by learners. Though majority again still disagreed that they understand where plants get their food (41%).

Theme 2 referred to as critical thinking about the role of practical work in acquiring and developing procedural knowledge. Also, in investigation skills, learners were doubtful: to think systematically and critically after doing experiments (62%); to read, understand and interpret different situations (67%); to use experimental techniques and tools to answer questions given under photosynthesis (72%); to analyse and interpret the result from experiments (69%); to plan and perform a few experiments on their own (80%); to record and organise data from experiments (74%); to make accurate observations and describe the events as they unfold (64%); and to apply observation skills in experiments (67%).

SECTION B

In theme 3 learners were asked to rate their positive attitudes regarding the change of their attitudes towards photosynthesis when taught with the traditional teaching approach. The data reflected in this section showed that most learners were quite discontented with the kind of teaching approach used in teaching photosynthesis in plants and had negative attitudes toward science. As indicated below by the results from section B of table 14, learners' attitudes towards the traditional teaching approach indicated low percentage as compared to the CCM approach i.e. 7%, 26%, 10%, 31% and 7%, respectively.

Table 14: A & B Showing the Likert results regarding learners' attitudes towards traditional teaching approach.

SECTION A

Item	Strongly disagree OR Disagree		Not sure		Strongly agree OR Agree	
	No	**%**	**No**	**%**	**No**	**%**
1. I can apply the information gained from these lessons to answer questions given in different situations.	15	38	12	31	12	31
2. I am able to diagnose and dispel misconceptions about photosynthesis in cells.	13	33	10	26	16	41
3. I understand where plants get their food.	16	41	11	28	12	31
4. I am able to think systematically and critically after these experiments.	24	62	12	31	3	7
5. These activities helped me to read, understand and interpret different situations.	26	66	9	23	4	10
6. These activities helped me to use experimental techniques and tools to answer questions given under this topic.	28	72	8	21	3	7
7. The activities also helped me to analyse and interpret the result from experiments.	27	69	8	21	4	10
8. I am now able to plan and perform a few experiments on my own.	31	80	4	10	4	10
9. I am able to record and organise data from experiments.	29	74	5	13	5	13
10. I can make accurate observations	25	64	10	26	4	10

and describe the events as the unfold.						
11. Doing these activities developed me to apply my observation skills in experiments.	26	67	11	28	2	5

SECTION B

1. Motivates and creates interest in life sciences.	26	67	10	26	3	7
2. Promotes the spirit of tolerance and curiosity in learning life sciences.	23	59	6	15	10	26
3. Helps to develop positive attitudes towards life sciences.	28	72	7	18	4	10
4. Helps to develop logical reasoning.	27	69	0	0	12	31
5. Practical work helps us to understand the subject content better than when we study without practical work.	27	69	8	21	3	7

4.3 Concluding Remarks

This chapter has presented the findings of the analysis of data obtained from achievement tests and questionnaires. These data were related to the learners understanding of the concept of photosynthesis before the intervention and after the intervention. The data was also related to the learners' attitudes towards the use of CCM in the teaching of science concepts. The following is a summary of these findings:

- The results show that the level of understanding that Grade 10 learners had at the beginning of the intervention in both EG and CG was similar in both groups.
- After the intervention the results suggest that the intervention used on EG considerably enhanced learners achievement and may have significantly reduced the misconceptions learners had about synthesis of food in plants.
- This further attested for by mean scores for the pretest and posttests for the EG and CG (Figure 1).

- For gender the results reveal no significant differences in the achievement of boys and girls, before the intervention and after the intervention.
- The intervention using CCM in teaching science concepts such as photosynthesis seemed relevant method to minimize learners' misconception.
- On the question of confidence, critical thinking skills and attitude, the EG learners have positive attitudes towards the subject being taught as compared to CG learners.

It can therefore be concluded that after the exposure to a series of lessons on photosynthesis, targeting conceptions were found to be more intelligible and plausible to learners in the EG in comparison to their counterparts in the CG. It appears that both groups experienced some form of conceptual change, while the former significantly outperformed the latter in because of the higher achivements compared to control group. The next chapter discusses the results presented in this chapter by relating the findings to the previous studies, justification of this study and CCM as a method of teaching

Chapter 5

5.0 Discussion and Conclusion

5.1 Introduction

In Chapter 1 the main research question, sub-questions and purpose were given. It was shown by several researchers that the misconceptions that learners bring to the science classrooms are met with resistance to change (Wichmann et al., 2003). These misconceptions are the product of learners' first hand experience and become common sense by way of what they have been told by others through the media, books and other forms of instruction (Stepans, 1994). These misconceptions are widely spread and deeply rooted and hence, difficult to change. The CCM approach was chosen in this study as a relevant method to minimise these misconceptions. The CCM approach shifts the focus of activity from the educator to the learners. The CCM approach has repeatedly been shown to be superior to the traditional educator-centred approach of instruction, a conclusion that applies, whether the assessed outcome is short-term mastery, long-term retention, or depth of understanding of course material; acquisition of critical thinking or creative problem-solving skills, formation of positive attitudes toward the subject being taught, or level of confidence in knowledge or skills.

Therefore, this study investigates the effect of the CCM method of teaching photosynthesis on the learner's ability to reconstruct ideas and their attitudes towards this method of teaching. This chapter discusses the results presented in Chapter 4 by relating the findings to the previous studies, justifications of this study, and the CCM as method of teaching photosynthesis. The implications of my findings and suggestions for further research are also discussed. The chapter concludes with closing remarks.

5.2 Discussion

Educators play a very significant role in the realization of correct or acceptable scientific concepts. The more acceptable teaching methods of today place emphasis on the learner instead of the educator. This is vindicated in the National Curriculum Statement (NCS) in South Africa where the emphasis is on the learner-centred approach, which requires learners to take responsibility for their own learning; to be more active in the classroom and participate at all levels (Department of Education, 2005).

In South Africa traditional teaching methods still takes the centre stage in the presentation of science lessons (Broadie, 2006). In the traditional teaching method, educator-centred approaches dominate the teaching process. The educator gives information to learners and the learners' responsibility is to learn the information that is given by the educator. In the traditional approach to teaching, most class time is spent with the educator lecturing and the learners watching and listening. The learners work individually on assignments, and cooperative work is discouraged (Xiaoyan, 2003). On the other hand, learner-centred teaching methods shift the focus of activity from the educator to the learners. These methods include *active learning*, in which learners solve problems, answer questions, formulate questions of their own, discuss, explain, debate, or brainstorm during class; *cooperative learning*, in which learners work in teams on problems and projects under conditions that assure both positive interdependence and individual accountability; and *inductive teaching and learning*, in which learners are first presented with challenges (questions or problems) and learn the course material in the context of addressing the challenges. In learner-centred approaches, the role of an educator and learner should be compatible with the constructivist learning theory (Xiaoyan, 2003).

Constructivists believe that the knowledge which learners discover by themselves is more enduring than the knowledge transmitted to them by the educator or someone else. Constructivism recognizes that learning is a cognitive process involving construction and reconstruction of ideas. Constructivism recognizes the learner is a meaning-maker rather than a passive recipient of factual knowledge (Kearney, 2001). Fundamentally, the constructivist approach to teaching recognizes that the conditions that inspire conceptual change are internally induced (Duit et al., 1996). Inducing this change necessitates a shift of ownership from the educator to the learners.

5.3 Summary of results

The analyses of results of this study show that the experimental group and control group's pre-test academic achievement scores are similar and there was no significant difference between them ($p < 0.05$). However, when the academic achievements of the post-test results for the EG and CG were analyzed, it was clear that there is a significant difference. The range of post- test scores for the CG was from 0 to 7 with a mean of 4.23 while the same scores for the experimental group was from 1 to 15 with a mean of 7.33 (Table 5 & Figure 1). The results of ANCOVA recorded in Table 6 showed that there was a statistically significant difference in performance between the EG and CG. Therefore, by comparing the means of the post-test scores, this study found that learners in the EG (Mean = 7.33 ± 3.94 SD) gained more than their counterparts in the CG (Mean = 4.23 ± 1.71 SD). The results revealed that the academic achievements of the EG learners, taught through the conceptual change model approach, achieved higher post-test scores than the CG taught through the traditional approach. The results of this study are compatible with results of other studies like Smith et al., (1993) and Kose et al., (2006). All of the above mentioned researchers found that learners in classes, where educators use CCM approach, performed better in post-tests than those learners who were taught through traditional methods.

For instance, Driver, et al., (1994) identified the following misconceptions: plants get their food from the environment rather than manufacturing it internally and soil supplies most of the raw materials for photosynthesis, water and minerals are food for plants and soil is the plant's food which is the reason why people put food (fertilizer) in the soil for plants to eat. During lesson presentation and classroom discussion with learners all of the above-mentioned misconceptions were confirmed. The pre-test results show that 80% of learners in the class had similar misconceptions (Table 2). The t-test analysis showed that there was no statistically significant differences between the pre-test achievement scores of the CG and the EG ($t = -1.27$; $p>0.05$). Achievement test scores of the EG before the treatment ($X= 2.94 \pm 1.56$) was higher than the CG score ($X=2.51 \pm 1.46$) (with total marks out of 15), but this small difference is not significant at the 95% confidence interval. These misconceptions are due to the fact that when children start school and throughout their school years, they have already preformed ideas about how the natural world works (Stepans, 1994). Some of these misconceptions are the ideas coming from the instructional setting or from their experiences outside the school (Grayson, 1995).

In another study, Köse and Uşak (2006) found that most of the pre-service educators had some misconceptions about certain concepts like, "photosynthesis occurs only in green plants", "photosynthesis is a gas exchange process", "green plants respire only during the night when there is no light" and "respiration occurs only in the leaf of plants". The main reasons for these misconceptions are: learners' previous knowledge, the difference of scientific jargon and daily conversations and course textbooks. Thus the CCM approach used in this study was deemed to be more effective than traditional approaches in the elimination of the above mentioned misconceptions regarding photosynthesis in plants.

In the study conducted by Cibik et al. (2008), an investigation was done on the effect of the use of group work and demonstration experiments based on the conceptual change approach in the elimination of misconceptions about the subject of photosynthesis and respiration in plants in pre-service science educators at Gazi University in Turkey. The study used the pre-test and post-test results of the control and EGs to compare the effectiveness of both the conceptual change approach and the traditional approach in the teaching of photosynthesis and respiration. After instruction the results revealed that conceptual change instruction dealt with learners' misconceptions and produced significantly greater achievement in the understanding of concepts of photosynthesis and respiration in plants. The results from the study are also consistent with the study of Cibik et al. (2008) in that the conceptual change approach is more successful and reduces the misconceptions held by learners. When the results of Cibik's study were analyzed, the EG and EC's pre-test academic achievement scores were close to each other, and there was no significant differences between them ($p < 0.01$), which suggests that at the beginning of the study the two groups had similar capabilities as far as the content was concerned.

On the other hand, the academic achievements from post-test results of EG and CG reveal that there was a significant difference. Therefore, the academic achievements of the EG that took in the course using the CCM approach achieved higher post-test results than the CG using the traditional approach. Also, group work and demonstrative experiments based on the CCM approach seem to be very effective in eliminating the EGs' misconceptions in photosynthesis and respiration in plants in the science laboratory application course. The underlying reason is that the strategies applied in the CCM explain misconceptions between scientific information and existing information.

The analysis of results from Table 7-12 in Chapter 4 revealed a significant difference between the performance of boys and that of girls, in favour of girls in the EG. This study's findings agree with the study of Yenilmez, et al. (2006) study entitled 'Enhancing Learners'

Understanding of Photosynthesis and Respiration in Plants through Conceptual Change Approach' done in an urban area in Turkey to the Grade eighth learners, which found that the performance of females was better than that of males after the treatment, but the interaction of the treatment with gender difference was not significant for the learning of concepts.

From the analysis of the questionnaires as well as the marking of learners' worksheets in the EG, it seemed clear that the CCM approach employed during the intervention (treatment) in this study had a significant positive impact on the learners' understanding of the concept of photosynthesis and their attitudes towards Life Sciences. Table 13, A & B show that learners' perceptions ranged from 72-87% (Mean 80.4 ± 5.5 SD), while the attitudes ranged from 72 to 95 (Mean 86.4 ± 8.5 SD) which suggests that learners found the CCM approach to be useful in helping them to understand concepts and also to be useful to help them think out of the box because it challenges their thinking process. The CCM approach is viewed positively by learners who describe it as enjoyable, interactive, relevant, practical and holistic. They liked the CCM approach because it encouraged them to discuss issues with the educator and among themselves. Consequently, through CCM approach learners developed interpersonal skills. This is in agreement with Barraket's (2005) study which concluded that the use of learner-centred techniques facilitated a strong social context for learning. Both the learner-centred teaching used by Barraket (2005) and that of the CCM process used in this study encouraged active and experiential engagement of learners with the subject matter. The CCM approach has the potential to be extremely effective, in terms of learner satisfaction and class performance as demonstrated in this study (Table 13 Section B). The high percentage scores on the positive side of the Likert scale suggested that the learners responded positively to the CCM approach, at least in this study. The high percentage scores on the negative side of the likert scale (Table 14 Section B) suggest that learners in the Traditional Teaching approach were not happy about this way of teaching. Also, their achievements were lower than those from the EG.

5.4 Implications of this study

Although the results of this study concur with the findings of previous studies that constructivist teaching approaches are more effective than the traditional teaching approaches in facilitating leaners' performance and achievements in the teaching of photosynthesis, it is important to note that the CCM approach is not a panacea to all ills. The CCM approach demands commitment on the part of learners and educators alike. As demanded by the new curriculum in South Africa, educators play the role of facilitators while learners take responsibility for their own learning. In line with the NCS, educators should give learners activities that challenge their preconceptions and allow them to modify their knowledge in the light of new evidence.

Looking at the data provided in Chapter 4, it is evident that learners from EG seemed to have made a significant attempt to make sense of the concepts involved in this study. They even did their best in debating and trying to understand photosynthesis as well as in attempting to use the CCM approach as a learning tool. While the constructivist perspective focuses primarily on the actions of learners in constructing or developing information, educators, curriculum developers and textbook writers also influence learning outcomes. These professionals need to select and organise learning materials in such a way that learners can easily access such materials. Resources like photocopiers, paper, ink, extra textbooks and science apparatus are a 'must-have' in schools which implement the CCM approach. The CCM may be a resource to Life Sciences educators who seek to improve their teaching methods. It is a teaching approach that is relevant to the NCS and indeed relevant to Curriculum Assessment Policy Statements (CAPS) in South Africa.

This study provides evidence that the CCM approach has a significant effect on improved attitudes towards Life Sciences. If learners are given an authentic problem that is challenging and real, they will be even more motivated to learn and to enjoy the learning process immensely. At the beginning of the study the learners had a poor understanding of photosynthesis concepts. However, in view of the outcomes of this study, it is appropriate to suggest that the CCM approach could serve as a useful means to motivate learners in developing a positive attitude towards their studies. Learners' achievements improve as a result of their conceptual understanding; they might become more confident to study for meaningful learning experiences (Horton et al., 1993).

5.5 Suggestions for further research

The findings from this study are localized to a specific topic and a specific situation; the inquiry was performed in two public schools in a semi-rural part of Mpumalanga province in South Africa during a limited period of time. However, I believe that the intervention and the results gained from this study will influence any improved design of the school-based curriculum in science education. I therefore, propose that further research should investigate the following areas:

- The effect of CCM in public schools in the rural and urban areas of South Africa and independent schools. These contexts may highlight different challenges that could verify the findings of this study.
- The effect of CCM on teaching of other life sciences concepts other than photosynthesis.

5.6 Concluding Remarks

Learners come to science classrooms with preconceptions. These preconceptions are at variance with scientific conceptions and resist efforts by educators to change them. The traditional teaching approach proved ineffective in changing learners' non-scientific ideas. The Constructivist teaching approach using the CCM proved to be effective as evidenced in this study. Underpinning this approach is the view that learners' misconceptions can be modified if learners, rather than the educators take responsibility for their own learning. South African educators should accept this new role of learners and change their format of presenting lessons. Educators should play the role of facilitators and strive to give learners opportunities that will further challenge their misconceptions. CCM inspires a reform in the approach to Life Sciences teaching in South Africa. Thus, the paradigm shifts from the traditional approach, to the constructivist approach where other models in addition to CCM can be explored.

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APPENDIX A

ACHIEVEMENT-TEST

Question 1 (5 marks)

Use either **TRUE** or **FALSE** in responding to statements below:

1.1 Plants get food from soil. People put food (fertilizers) in the soil for plants to eat.

1.2 Plant growth material (mass) comes from soil.

1.3 Plants breathe in carbon dioxide and drink water.

1.4 Sunlight, carbon dioxide, water and minerals (fertilizers) are food for plants.

1.5 Plants manufacture their food internally.

Question 2 (5 marks)

Multiple-choice questions

Various possibilities are suggested as answers to the following questions. Indicate the correct answer.

2.1 Photosynthesis takes place in …

A: Autotrophic organisms B: Primary consumers C: Decomposers D: Heterotrophic organisms

2.2 Which of the following is **not** needed for photosynthesis to occur?

A: Water B: Oxygen C: Chlorophyll D: Carbon dioxide

2.3 Photosynthesis is process in which plants produce …

A: Carbohydrates and oxygen B: Sugar and carbon dioxide C: Starch and carbon dioxide D: Chlorophyll and radiant energy

2.4 Which of the following atmospheric gases will disappear first if all chlorophyll containing plants were to be removed from earth?

A: Nitrogen B: Carbon dioxide C: Oxygen D: Water vapour

2.5 For photosynthesis to occur, a plant requires …

A: Water, oxygen, light and chlorophyll B: Chlorophyll, light, carbon dioxide and oxygen C: Carbon dioxide, light, chlorophyll and water D: light, darkness, oxygen and carbon dioxide

Question 3 (5 marks)

3.1 In the seventeenth century John Baptista Van Helmont carried out one of the first experiments relating to the synthesis of food in plants. He placed $200\,lb\ (\pm 90kg)$ dried earth in a vessel in which he planted a $5\,lb(\pm 2{,}25kg)$ willow tree. He covered the opening of the vessel with an iron plate to prevent dust from entering and he watered the soil with rainwater. After five years he found that the willow tree weighed $169lb30oz\ \ (\pm 73{,}7kg)$ and the soil has lost $20oz(\pm 0{,}56g)$. Explain what lead to the increase in body mass of the plant.

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APPENDIX B

QUESTIONNAIRE

Key: 1 strongly disagrees (SD); 2 disagree (D); 3 not sure (NS); 4 agree (A);

5 strongly agree (SA)

Section A: Learners' perception of their own learning (Circle the right choice)

Item	SD	D	NS	A	SA
1. I can apply the information gained from these lessons to answer questions given in different situations.	1	2	3	4	5
2. I am able to diagnose and dispel misconceptions about photosynthesis in cells.	1	2	3	4	5
3. I am able to understand where plants get their food.	1	2	3	4	5
4. I am able to think systematically and critically after having done these experiments.	1	2	3	4	5
5. These activities were useful in helping me read, understand and interpret different situations.	1	2	3	4	5
6. These activities helped me to use experimental techniques and tools.	1	2	3	4	5
7. They also helped me to analyze and interpret results of observations and experiments.	1	2	3	4	5
8. I am now able to plan and perform experiments on my own.	1	2	3	4	5
9. I am able to record and organize the data of experiments.	1	2	3	4	5
10. I can make accurate observations and describe the events as they unfold.	1	2	3	4	5

11. Doing these activities developed my skill to apply results of observation and experimentation.	1	2	3	4	5

Section B: Attitude towards Conceptual Change Model/Traditional Teaching Approach as a way of teaching and learning photosynthesis.

12. Motivates and creates interest in life science.	1	2	3	4	5
13. Promotes the spirit of tolerance and curiosity in learning life sciences.	1	2	3	4	5
14. Helps to develop positive attitudes towards life sciences.	1	2	3	4	5
15. Helps to develop logical and reasoning method of thought.	1	2	3	4	5
16. Practical work helps us to understand the theory better.	1	2	3	4	5

APPENDIX C

TEACHERS' NOTES

Common misconceptions about plants regarding obtaining and using energy

Berthelsen, B. (1999). Students Naïve Conceptions in Life Science. ***MSTA Journal*****, 44(1) (Spring'99), pp. 13-19. http://www.msta-mich.org**

1. Plants obtain their energy directly from the sun.
2. Plants have multiple sources of food (heterotrophic as well as autotrophic).
3. Carbon dioxide, water, and minerals are food.
4. Plants feed by absorbing food through their roots.
5. Plants use heat from the sun as a source of energy for photosynthesis
6. Sunlight is a food.
7. Sunlight is composed of molecules.
8. Sunlight is "consumed" in photosynthesis.
9. Plants absorb water through their leaves.
10. Plants produce oxygen for our benefit.

The Conceptual Change Model

From: Stepans, J. (1996). ***Targeting Students' Misconceptions: Physical Science Concepts using the Conceptual Change Model.*** **Idea Factory, Riverview, Florida.**

The Conceptual Change Model places students in an environment that encourages them to confront their own preconceptions and those of their classmates, and then work toward resolution and conceptual change. The six stages are:

1. Students become aware of their own preconceptions about a concept by thinking making predictions (*committing to an outcome*) before any activity begins.
   Where do plants get their food? Individually write your answers on a piece paper

2. Students *expose their beliefs* by sharing them: initially in small groups and then with the entire class.

Discuss your answers in your group?

3. Students *confront their beliefs* by testing and discussing them in small groups.
   Is your answer correct? If not, what is wrong with your ideas? How do plants make their own food? Summarise your ideas in your group and choose one person to present the group's ideas to the class.

4. Students work toward *resolving conflicts* (if any) between their ideas (based on the revealed preconceptions and class discussion) and their observations, thereby *accommodating the new concept.*
   Report back to the class on your group's ideas about how plants make their own food. Once the whole class has reported back, discuss the ideas presented by the different groups. Do you want to change any of your ideas now that you have listened to the other groups? If your ideas on how plants make their food have changed, write them down.
5. Students *extend* the concept by trying to *make connections* between the concept learned in the classroom and other situations, including their daily lives.
   You are given notes on scientific ideas about photosynthesis and discovery about photosynthesis. Read the information given and make a table to compare historical ideas about photosynthesis with the current ideas about photosynthesis.
6. Students are encouraged to *go beyond*, i.e. pursue additional questions and problems of their choice related to the concept.
   A sunflower plant with a mass of 80g was placed in 800g of dry, fertile soil and allowed to grow for five weeks. The plant was placed in sunlight and watered every second day in the afternoon. The area where the plant was kept was in the open and well supplied with fresh air. After five weeks, the mass of the plant and soil were measured. The sunflower plant weighed 160g.
   (i) Do you think the soil mass decreased after five weeks? If yes, by how many grams?
   (ii) Explain what lead to the increase in body mass of the plant during the five weeks.

Learners' Worksheets

Worksheet 1: <u>Ideas about photosynthesis</u> (Group)

1. Where do plants get their food? Individually write your answers on a piece paper.
2. Discuss your answers in your group?
3. Is your answer correct? If not, what is wrong with your ideas? How do plants make their own food? Summarise your ideas in your group and choose one person to present the group's ideas to the class.
4. Report back to the class on your group's ideas about how plants make their own food. Once the whole class has reported back, discuss the ideas presented by the different groups. Do you want to change any of your ideas now that you have listened to the other groups? If your ideas on how plants make their food have changed, write them down.

Worksheet 2: <u>Comparison of historical and current ideas about photosynthesis</u> (Individual)

1. Refer to the given notes on scientific ideas about photosynthesis and discovery about photosynthesis. Read the information given and make a table to compare historical ideas about photosynthesis with the current ideas about photosynthesis.

2. A sunflower plant with a mass of 80g was placed in 800g of dry, fertile soil and allowed to grow for five weeks. The plant was placed in sunlight and watered every second day in the afternoon. The area where the plant was kept was in the open and well supplied with fresh air. After five weeks, the mass of the plant and soil were measured. The sunflower plant was 160g.

   (i) Do you think the soil mass decreased after five weeks? If yes, by how many grams?

   (ii) Explain what lead to the increase in body mass of the plant during the five weeks.

Worksheet 3: <u>Investigation on the kind of organic food plants make during photosynthesis process</u> (Group)

1. What kind of food do you think plants make? Write down your answer.
2. Discuss your answer in your group and plan an investigation to answer your question. Use the information provided to help plan your investigation.
3. Write down your scientific report with all steps from hypothesis to conclusion.
4. Present your group report to the whole class.

Information needed for this investigation.

Important points to consider when planning your investigation:

- What is your hypothesis for the investigation?
- What parts of the plant are you going to test for the presence of organic food?
- What food are you going to test for?
- If your results are likely to involve a colour change, how will you see this if the plant parts you use are coloured themselves?
- How can remove colour from the plant if you need to?
- How will you know that photosynthesis has taken place in the plants you are testing?

Your plan should reflect the following points:

- The kind of organic food plants make.
- The method of testing for the kind of food manufactured by plants.
- Tests to be used to check for correctness of results which may include control.
- Apparatus needed for the investigation**.**
- **Note: Research as a group how to remove the green pigment, chlorophyll, from leaves. Write a step-by-step method of removing chlorophyll from leaves.**

Other worksheets were done on the following investigation:

1. Investigate if light is needed for photosynthesis (Group)
2. Analysis of the effects of light (Pair)
3. Investigation if plants need chlorophyll for photosynthesis (group)
4. Analysis of the importance of chlorophyll (individual)
5. Investigation if plants need carbon dioxide for photosynthesis (group)
6. Analysis of the effects of carbon dioxide concentration on photosynthesis (pair)
7. Demonstrate that plants give off oxygen during photosynthesis (group)
8. Lecture on the process of photosynthesis (including video clips)

Assessment strategy used during lessons: teacher assessment, informal assessment, peer assessment, self assessment and formal summative assessment**.**