CONCEPTUAL UNDERSTANDING OF PHOTOSYNTHESIS

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DECLARATION

I, **NOMPUMELELO VENENTIA MHLAMVU** declare that the dissertation for the degree of **Masters in Education** at the University of Zululand hereby submitted has not been submitted by me for a degree at this or any other university, that is my own work in design and execution and all material contained herein has been duly acknowledged.

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ABSTRACT

CONCEPTUAL UNDERSTANDING OF PHOTOSYNTHESIS

The purpose of this study was to investigate possible reasons for the high failure rate in Biology, particularly under the topic “Photosynthesis”. Photosynthesis is a biological process which is critical for producing food for all living organisms. A test was used as a tool for collecting data. The test consisted of six questions taken from previous grade twelve final examination papers. The questions were analysed to determine the cognitive demands according to Blooms taxonomy. The questions were found to be integrated and tested lower and higher order cognitive levels according to Bloom’s taxonomy. The learners achievement scores showed that the test discriminated well among those learners who studied well and those who did not know their work. The sample was drawn from six high schools of Mthunzini circuit, in northern KwaZulu-Natal. To test whether there were significant differences in achievement scores among the six schools, a statistical Package for Social Sciences was used.

Poor performance in the structured questions showed that language was a major barrier in expressing the learners ideas. Examples of incoherent sentences written by learners were captured in the main study. English as a medium of instruction affects the ability of the learners to answer questions. Looking at the learners responses, it is evident that language is a barrier to those students who cannot discuss in the target language (TL) of instruction which is English. Some students with better English competence were able to express themselves in the instructional language, and this gave them a chance of explaining their observations clearly and accurately. The poor performance at the level of 29% in lower order questions, showed how poorly the learners are mastering their work. Question 5 an application level question was the most poorly done with 66% learners achieving between 0-10%. The learners failed completely to plot a graph, they failed to use information given to identify correct axes on which to plot the independent and dependent variables. There was therefore also a problem of mathematical literacy which should make sure that every learner can handle a simple graph question.

Learners who had chosen careers for which Biology is a requirement, performed better than their peers. Career choices seemed to be a factor in motivating learners to strive to do well. There were no significant differences in the achievement scores between boys and girls at 95 confidence levels. In one of the more conceptual questions the girls did better than boys at the range of 61-70% while at the range 71-80% only the girls featured. The efforts by the government to encourage girl children to do well may be beginning to pay off. It is also an achievement that the overall study showed the girls performing as well as the boys.

The study provides a window which shows what is happening in our Black schools and a challenge for the government to look for ways of assisting, in particular, poverty stricken schools and also supplying such schools with well qualified teachers. The schools may also need to spend more time on task instead of allowing learners to mill around doing nothing.

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This work is dedicated to my children and my grandchild as well as my beloved husband Mr. AT Zikhali who provided me with love and support throughout my studies. Their sacrifices and perseverance were a great contribution to my education as a whole. May the Almighty God always be with my parents for laying the foundation of my success and not forgetting Mr LG Mhlamvu who contributed a lot in my proffession.

TABLE OF CONTENTS

CHAPTER TWO

2.0 LITERATURE REVIEW

CHAPTER THREE

3.0 RESEARCH METHODS

CHAPTER FOUR

4.0 DATA ANALYSIS AND INTERPRETATION

CHAPTER FIVE

5.0 SUMMARY, RECOMMENDATION AND CONCLUSSION

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

Conceptual understanding of photosynthesis

CHAPTER ONE

1.0 ORIENTATION

1.1 INTRODUCTION

The performance of high school students in the matriculation examinations has been very low and a matter of concern to the public. The fact that it has been criticised by all sectors of society raised my interest as a Biology educator to study the reasons behind the learners' poor performance in grade twelve, as doing well in grade twelve is usually one's ticket to a better education and a better life.

The study explores the results of learners' performance with regard to photosynthesis and suggests ways and procedures to help the learners to perform at their maximum level. The targeted group consisted of grade 12 schools in the Mthunzini district of KwaZulu-Natal. The release of 2008 matriculation examination results, for example, was followed by public outrage as expressed in the newspapers especially concerning poor performance in mathematics and the sciences, but also in other subjects. For instance, Gudluza writing in the *Sowetan* of 7 January 2009 stated that the poor results arose from teachers' poor grasp of Outcomes-Based Education (OBE). Govender, writing about matriculation results in the *Sunday Times* of 4 January 2009 the heading "The Blame Game" stated that inadequate training of educators in OBE was responsible for all the matriculants who failed in the Eastern Cape. Poor teaching because of inadequate teaching methods and a lack of sound content mastery seemed to be cited as the main causes for poor results in the matriculation examination.

The pass rate in Black schools is generally known to be very low across all subjects, except the vernacular language. It therefore seems important to conduct research to discover where the learning problems for especially Black learners are situated in terms of the different topics covered by the various curricula. This study specifically set out to study the performance of matriculation candidates on one important topic taught in Biology, namely **photosynthesis**, a process by which food is made for all living organisms. The topic was targeted because of its conceptual difficulty and its suitability in revealing whether students are able to understand a topic that combines biochemistry with practical work and requires them to think not only at a lower cognitive level, but also to analyse, synthesise and evaluate information given.

1.2 BACKGROUND OF THE STUDY

Magi (1993) states that the following problems in African education have generated frustration and anger in the African communities: lack of control and effective administration, unequal allocation of finance and resources, the explosion in the number of pupils without proper classroom accommodation, the suspect quality and relevance of education, and a high failure rate in matriculation examinations, particularly in science subjects. According to Magi, the poor performance rate of learners is to a great extent due to the fact that the Department of Education demands that educators should pass the learners without taking into consideration the different environmental factors that affect them. These factors will be interrogated more fully at a later stage in this study. An attempt was made to employ a multilevel analysis to examine factors at school and home level that influence learners' performance in mastering the subject of photosynthesis.

Muwanga (2007) stresses the importance of learning science in a hands-on fashion, and as photosynthesis is a science topic that can be illustrated in a practical way, practical work is indicated. Muwanga also believes that science teaching must take place in the laboratory, and in this regard there is no controversy. Science belongs there as naturally as cooking belongs in a kitchen and gardening in a garden. He explains that, for science teaching to be effective, the laboratory must be used for practical work. Practical work gives learners time to share ideas and to discuss issues and concepts pertaining to the practical work that they are doing. Both doing and discussion help them to learn better than just passively listening to a teacher. The central idea of constructivism is that, rather than describing or copying the understandings of others, learners must construct their own understanding. Driver (1983) advocates a shift in the focus of instruction from mechanical drill and practice towards teaching for understanding with an emphasis on hands-on inquiry-oriented strategies designed to promote students' conceptual knowledge by building on prior understandings, active engagement with subject matter, and content and application of knowledge to real world situations. Life Sciences are good in that the concepts that are learned are directly applicable to real life situations. The problem arises when educators do not problematise practical work but give students practicals that are very similar to a domestic science student's recipes.

Good learner performance (as indicated by a maximum pass rate), greatly depends on a number of factors. Educators should have adequate facilities and a thorough knowledge of the subject matter and the history of how the subject has been taught at the school in question; they should also be able to motivate learners to dedicate themselves to their learning. Social factors are also important in understanding the process of conceptual change. Learning is not so much an individual activity than a social activity, where meanings are shaped through discussion and negotiation between peers and between pupils and teachers. Moreover, science classrooms are complex social systems within a wider system of schooling. Teaching children in such an environment requires careful consideration of these social and cultural influences on their learning. Some learners are not competent enough to use English in understanding processes and systems. The sensitivity of the educator in demystifying terms helps learners to assimilate scientific language (for instance the equation of photosynthesis) is important. The benefit of practical work lies in the opportunities it gives the learners to engage one another and the educator as they perform the experiments.

1.3 STATEMENT OF THE PROBLEM

Learners have a high failure rate in Biology, particularly with regard to the topic photosynthesis. The researcher, as one of the external examination markers, observed that photosynthesis is one of the topics is which most learners failed. This motivated the researcher to find out what aspects of photosynthesis posed conceptual problems for learners. The results would then be used to improve the teaching of photosynthesis in the schools involved in the study.

Robinson (2004) in their paper, "Photosynthesis in Siloco: overcoming the challenges of Photosynthesis Education using a multimedia CD-Rom", state that photosynthesis remains one of the most challenging topics, largely because of its conceptual difficulty, the difficulties that students have in visualising the process and limitations to the practical demonstration of photosynthesis due to the fact that available equipment is either unreliable or antiquated.

The researcher feels that there is a lack of motivation in Biology learners when it comes to practical topics such as photosynthesis. This is due to various reasons, which this study hopes to explore and unravel. The researcher also intends to identify the areas of study in Biology which Black learners find particularly difficult to master. The study intends to explore the misconceptions that students have about photosynthesis and to find out whether they can handle questions at higher cognitive levels. If they are found to be unable to do so, the study intends to explore reasons for this situation in existing literature and to find out what other educators have done to try to solve some of the problems. The study also intends to arouse interest in educators who have accepted that learners are poor performers in this specific topic, so that they can realise that the facilitation of the topic can be improved by varied methods of teaching that target the development of particular skills.

Lonergan (2000) states that students tend to have more misconceptions about photosynthesis than other Biology topics. According to Hershey (1992), Science is, in general, under represented in high schools and undergraduate courses and often receives a poor response, especially from students enrolled in biomedical-type courses. Photosynthesis is also a conceptually difficult topic, which spans several disciplines (biophysics, biochemistry, and ecophysiology) and organisational levels (molecules, cells, organisms, ecosystems). Due to problems of relevance and conceptual difficulty, major misconceptions often persist in learners' understanding of photosynthesis. Learners have a saying that plants are boring. The researcher is concerned about this misconception and this is one of the most important motivations for this study.

1.4 MOTIVATION OF THE STUDY

Practical work is a means of pupils' skills development, but more importantly it is a purposeful way of learning about working in a laboratory. When learners learn Biology as a science subject, they learn to understand the world; they have a holistic picture of what is life. Biology, like other branches of science subjects, is based on systematic observations, hypothesis, predictions and observational and experimental tests. The external world, not internal conviction, is the testing ground for science theories. The study attempts to reveal the relationship between practical work and the learner's performance. The topic photosynthesis offers many of opportunities for learners to do practical work and experience what it means to work like a scientist. Photosynthesis being a process which makes it possible for food to be manufactured should be an interesting and relevant topic to all students. The question is how competent the educators are in presenting the topic, or whether they are challenged by the topic to the extent that they are able to **demystify** the challenging aspects of the topic for the learners.

Biology is a science subject which channels learners towards a number of important careers such as medicine, radiography, botany, biology education, etc. Having goals to enter these professions is not enough; learners need motivation to be helped to achieve their goals in biology. This study serves as an attempt to find out what learners' achievement scores are in this topic. Although such studies have been done abroad, this study is unique because it targets students whose home language is not English, the medium of instruction. It also targets students who find themselves in a relatively new curriculum that is based on the philosophy behind Outcomes-based Education (OBE). It is therefore important to find out how students cope with this difficult topic in the new South African Education system of education.

1.5 AIMS AND OBJECTIVES

The aim of the study was to investigate the performance of grade 12 learners in the Biology topic, "photosynthesis." The research attempted to:

1.5.1 Establish how learners perform in a photosynthesis diagnostic test.

1.5.2 Find out whether the availability of facilities and resources affect learners' performance with regard to photosynthesis.

1.5.3 Investigate whether the location of the school affected the learners' performance with regard to the topic.

1.5.4 Find out whether gender affected the learners' performance.

1.5.5 Determine whether English as a medium of instruction affected the ability of learners to answer questions correctly and with understanding.

1.5.6 To find out whether the career interests of the learners affected their performance.

1.6 OPERATIONAL DEFINITIONS OF TERMS

1.6.1 Photosynthesis

In this study photosynthesis refers to a process by which green plants use sunlight, carbon dioxide and water to make their own food. According to Dekker (1989), photosynthesis occurs mainly in green plants. Photosynthesis is the only process in nature by which the radiant energy of the sun becomes available as potential chemical energy for all the reactions that constitute metabolism. A simple equation of photosynthesis according to Mader (2004) is written as follows:

$$6C0_2 + 12H_20 + \text{light energy} \rightarrow C_6H_{12}0_6 + 60_2 + 6H_20$$

Photosynthesis involves the utilisation of sunlight by plants, as well as by the cyanobacteria to convert two inorganic substances, namely carbon dioxide and water, into carbohydrates, with the liberation of oxygen. Pigments such as chlorophyll *a* and *b* in the chloroplast of plant cells act as the energy converters in this reaction. Photosynthesis is a very cost effective process which harnesses sunlight energy to drive the synthesis of carbohydrates. The issue of solar energy is now seen as something that has to be encouraged in our normal lives because both oil and electricity have become extremely expensive. For instance, in South Africa Eskom, the electricity company, is willing to help people who want to install solar panels in order to heat water instead of using their electricity driven geysers.

Hall and Rao (1994) define photosynthesis, literally, as building up or assembly by light. In common terms, photosynthesis is the process by which plants synthesise organic compounds from inorganic raw materials in the presence of sunlight.

1.6.2 Science

In this study the word ‘science’ refers to the activity of scientists, to the knowledge held (as published material) and to the institutions that practice science. Science is an extension of everyday observations on the nature of the world; it attempts to provide models and to theorise about how things happen. It seeks consensus. It is not essentially good or evil, but can be used to either end. Systematic experimentation and reasoning, induction and deduction, form the core of the scientific method. Science seeks to present nature in the form of laws to which a number of different observations can be fitted. Science is not a static body of dogma. With time models get replaced by new models that fit a wider range of phenomena. Such replacement may be so gradual or the changes can be so radical that we speak of a conceptual revolution Brown (1986). Martin and Sexton (1997) state that when science is taught holistically, it produces an effective learner and this arises from including three important parts of science: **attitude**, **process and knowledge**. They furthermore state that any one part emphasized at the expense of the other two leaves the learners' experience incomplete, hence affecting their academic performance.

1.6.3 Concept

In this study 'concept' means an idea or mental picture of a group or class of object, formed by combining all their aspects (Oxford dictionary 1999). A slight extension by Martin and Sexton (1997) define the word "concept" as a general idea or understanding that is derived from specific experiences; a thought or notion, an idea.

1.7 DELIMITATION OF THE STUDY

Delimitation basically refers to limitation in the field of the study (Sibaya, 1997). In this study the delimitation is as follows:

- The schools that participated use different textbooks with different presentations. Some textbooks contain certain misconceptions and errors that reflect poor editorship, while others contain content at a lower level than what is desirable at FET level.
- The schools are also different in the sense that they are situated in different places and have different resources.
- The learners have been taught by different educators with different teaching experiences and different qualifications, thus different mastery of the content and different effectiveness in teaching.

1.8 ORGANISATION OF THE STUDY

Chapter one outlines the aim of the study and provides the statement of the problem. This chapter also states the motive behind the study and its aim and objectives.

Chapter two outlines the literature review of photosynthesis, the importance of photosynthesis, and the views of learners about the learning of photosynthesis. It also outlines the role of practical work in teaching science subjects. Furthermore, theories of teaching and learning are discussed in relation to the present curriculum (OBE), with particular reference to the teaching and learning of photosynthesis.

Chapter three discusses the method that was followed to investigate conceptual understanding of photosynthesis in the schools. It explains the "how," "where" and "when" of the research.

Chapter four provides an analysis of responses received from learners. The results are presented numerically, while the data is presented graphically. The analysis focuses on learners' backgrounds, gender, career interests and achievements scores and well as the medium of instruction and the facilities available to them.

Chapter five outlines the entire study, summarises the findings and makes recommendations about how the results of this study could contribute to improving the teaching/learning of photosynthesis in grade twelve.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND OF PHOTOSYNTHESIS

One of the shortcomings of teaching science in schools is the failure of educators to teach about some history of the science concepts they teach, in order to give learners insight into how the concepts evolved over time. The history of the people involved in the development of science helps the students to know that science is a product of high level thinking by ordinary people. A very wild view of what scientists are is captured by Martin and Sexton (1997) who cite that learners think scientists "are middle aged white males who wear lab coats and glasses. Their peculiar facial features are indicative of their generally deranged behaviour. They work indoors, alone, perhaps underground, surrounded by smoking test tubes and other pieces of technology. An air of secrecy and danger surrounds their work". This is a distorted image of a scientist which shows that in school learners do not have opportunities to work like scientists so that they learn first-hand at their own level what scientists do. A common belief is that learners are as inquisitive and stimulated by investigations as scientists are, but the curiosity and the motivation to explore the world is somehow killed at school.

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The history of the origins of photosynthesis forms interesting reading which can give learners a background to this topic. In the early half of the seventeenth century, the Flemish physician van Helmont grew a willow tree in a bucket of soil, feeding the soil with rain water only, Hall (1994). He observed that after 5 years the tree had grown to a considerable size; however the amount of soil in the bucket had not diminished significantly. Van Helmont naturally concluded that the material of the tree came from the water used to wet the soil. In 1727 the English botanist Stephen Hales observed that plants used mainly *air* as the nutrient during their growth on his book, "Vegetable Staticks". Between 1771 and 1777 the English chemist Joseph Priestley (who was one of the discoverers of oxygen) conducted a series of experiments on combustion and respiration Hall (1994). He came to the conclusion that green plants were able to reverse the respiratory processes of animals. Priestley burnt a candle in an enclosed volume of air and showed that the resultant air could no longer support burning. A mouse kept in the residual air died. A green spring of mint however, continued to live in the residual air for weeks. At the end of this time Priestley found that a candle could burn in the reactivated air and a mouse could breathe in it. We now know that the burning candle used up the *oxygen* of the enclosed air, which was replenished by the photosynthesis of the green mint. The history captured in this section consists of ideas that learners can debate in order to understand why a green plant would make a difference in the air present in an enclosed container where there is a living small mammal. Such debates in the classroom would also promote language development for learners who are not first language speakers of English.

A few years later (in 1779) the Dutch physician, Jan Ingenhousz, discovered that plants evolved oxygen *only in sunlight* and also that only the *green* parts of the plant carried out this process (Hall & Rao, 1994). What has been discussed in this paragraph is some interesting history of how some stages in the process of photosynthesis have been discovered. This is part of history of science that is never discussed in many classrooms, but which would give context to what is being studied. This history would help students to understand where science comes from; it would also show that science has a culture. The history of science also shows how different people have collaborated to give us a complete picture of what happens during photosynthesis. It also gives one characteristic of science, that is, it is empirical and consists of knowledge that should be shared among peers. This is unlike indigenous knowledge which is generally not shared openly with peers and this is the culture from which the learners come.

In 1782, Senebier, a Swiss minister, confirmed the findings of Ingenhousz and observed further that plants used as nourishment *carbon dioxides* dissolved in water. Early in the nineteenth century another, Swiss scholar, de Saussure, studied the quantitative relationship between the CO_2 taken up by a plant and the amount of organic matter and O_2 produced and came to the conclusion that *water* was also consumed by plants during assimilation of CO_2 (Hall & Rao, 1994). In 1817 two French chemists, Pelletier and Caventou, isolated the green substance in leaves and named it *chlorophyll.* Another milestone in the history of photosynthesis was the enunciation in 1845 by Robert Mayer, a German physician, that plants transform energy of sunlight into chemical *energy.* By the middle of the last century the phenomenon of photosynthesis could be represented by the relationship shown below (Hall & Rao, 1994).

$$CO_2 + H_2O + \text{light} \xrightarrow{\text{green}} O_2 + \text{organic matter} + \text{chemical energy}$$

Accurate determinations of the ratio of CO_2 consumed to O_2 evolved during photosynthesis were carried out by the French plant physiologist. He found in 1864 that the photosynthetic ratio-the volume of O_2 evolved to the volume of CO_2 used up – is almost unity. In the same year, the German botanist Sachs (who also discovered plant respiration) demonstrated the formation of starch grains during photosynthesis. Sachs kept some green leaves in the dark for some hours to deplete them of their starch content (Hall & Rao, 1994). He then exposed one half of a starch depleted leaf to light and left the other half in the dark. After some time the whole leaf was exposed to iodine vapour. The illuminated portion of the leaf turned dark violet due to the formation of starch – iodine complex; the other half did not show any colour change Hall and Rao (1994). These early experiments gave rise to the experiments done in schools where they show that light is necessary for starch to form in leaves.

The direct connection between oxygen evolution and chloroplasts of green leaves, and also the correspondence between the action spectrum of photosynthesis and the absorption spectrum of chlorophyll were demonstrated by the German botanist Engelmann in the 1880 (Hall & Rao, 1994). He placed a filament of the green alga *Spirogyra,* with its spirally arranged chloroplasts, on a microscope slide together with a suspension of oxygen requiring, motile bacteria. The slide was kept in a closed chamber in the absence of air and illuminated. Motile bacteria would move towards regions of greater O_2 concentration. After a period of illumination the slide was examined under a microscope and the bacterial population counted. Engelmann found that the bacteria were concentrated around the green bands of the alga filament Hall and Rao (1994).

2.2 WHY PHOTOSYNTHESIS IS IMPORTANT?

All forms of life in this universe require energy for growth and maintenance, algae, higher plants and certain types of bacteria capture this energy directly from the solar radiation and utilize the energy for the synthesis of essential food materials. Mader (2004) states that life on earth is solar powered. The chloroplasts of plants capture light energy that has traveled 160 million kilometers from the sun to convert it to chemical energy stored in sugar and other organic molecules. Described accurately plants should be called photoautotrophic because they use light as a source of energy to synthesize organic substances.

During photosynthesis, carbon dioxide is absorbed and oxygen released. Oxygen is required by organisms when they carry on cellular registration. According to Campbell and Reecel (1995) oxygen released in photosynthesis also rises high in the atmosphere and forms the ozone shield that protects terrestrial organisms from the damaging effects of the ultraviolet rays of the sun. Animals cannot use sunlight directly as a source of energy; they obtain the energy by eating plants or by eating other animals which have eaten plants. Thus the ultimate source of all metabolic energy in our planet is the sun, and photosynthesis is essential for maintaining all forms of life on earth (Hall & Rao, 1994).

2.3 WHY PHOTOSYNTHESIS SHOULD BE TAUGHT?

The majority of the world's people live by growing plant or processing their products, and thus depend on the productivity of plants or processing their biomass production in terrestrial environment must therefore continue to rise as long as it remains necessary to meet the demands of a growing world population. Increased food production is an essential part of overall biomass production in a world where 600 million people are estimated today to be seriously undernourished and hungry; nearly three-quarter of the world's population, biomass production is also their main source of fuel, clothing fiber and building materials. Uneven distribution of fossil energy resources and their increasing costs indicate that competition between rich and poor for existing and potentially new plant resources will inevitable intensify (Beable *et al.*, 1994). Planting trees is encouraged by the government and environmentalists because it helps clear the air of carbon dioxide, which is poisonous to many organisms and contributes to global warming.

2.4 INCREASING AVAILABILITY OF OXYGEN

The carbon dioxide content of the atmosphere remained almost constant for millennia inspite of its depletion during photosynthesis; however, there has been a 27% increase since the industrial revolution in the last century, resulting in the so-called *greenhouse effect*. All plants and animals carry out the process of respiration (in mitochondria) whereby O_2 is taken from the atmosphere by living tissue to convert carbohydrates and other tissue to CO_2 and water, with the simultaneous liberation of energy. The energy is stored in ATP (adenosine triphosphate) and is utilized for the normal functions of the organisms (respiration) thus cause a decrease in the organic matter and O_2 content and an increase in the CO_2 content of the planet. Respiration by living organisms and combustion of carbonaceous fuels consume on average about 10 000 tones of O_2

every second on the surface of the earth. At this rate, all the O_2 of the atmosphere would have been used up in about 3000 years. Fortunately for us, the loss of organic matter and atmosphere oxygen during respiration is counterbalanced by the production of carbohydrates and oxygen during photosynthesis. Under ideal conditions, the rate of photosynthesis in green parts of plants is 30 times as much as the rate of respiration in the same tissue. Thus photosynthesis is very important in regulating the O_2 and CO_2 content of the earth's atmosphere (Hall & Rao, 1994).

The discussion in this chapter shows that all the living organisms can not survive without photosynthesis so it goes without saying that it should be included in the school syllabuses since it is one of the major activities of life. Even general and commercial students need that basic knowledge concerning the importance of photosynthesis.

2.5 WHY LEARNERS SEEM TO SHOW LESS INTEREST IN PHOTOSYNTHESIS?

Plants sciences are, in general, under represented in high school and undergraduate courses, Hershey (1992) and often receive a poor response, especially from students enrolled in biomedical type course who complain that plants are boring. Looking at the central role of this process in biology, teachers struggle, nevertheless, to promote the relevance and importance of photosynthesis to their students. Photosynthesis is also a conceptually difficult topic, which spans several disciplines *biophysics, biochemistry, ecophysiology* and organizational levels including molecules, cells, organisms and ecosystem. Because of these problems of relevance and difficulty, major misconceptions often persist in students' understanding of photosynthesis. Learners seem to be bored when learning about plants because they feel photosynthesis is *too abstract.* The researcher concurs with Sharon (1994) because learners have a tendency of wanting to learn about something that is interesting in a way that they apply in their daily lives. Even though photosynthesis is a daily thing but according to learners it is a natural and automatic process (Sharon, 2004) that has not much to do with them. Students fail to understand that the cereal they consume for breakfast is a product of photosynthesis. An end to photosynthesis would probably mean death to all living organisms.

2.6 CHALLENGES IN TEACHIGN PHOTOSYNTHESIS

One of the fundamental challenges of teaching in areas such as biochemistry and biophysics is that learning in these areas involves the comprehension of objects and processes that can not be seen or experienced. In science, topics that are taught includes structure and functions of proteins, membrane, electron transport and light harvesting from indirect observations using measuring systems and analytical methodologies. From experience as a biology teacher, a lot of my colleagues who teach biology without a solid chemistry background skip the biochemistry topics that would lay a foundation to understand photosynthesis.

Knowledge about the nature of these invisible entities evolves, punctuated by controversy and consensus about the actual structure and the characteristics that define them. Regardless of the sophistication of our understanding as teachers, and its fit with empirical data, we visualize these objects and processes using imagination, models and metaphors. Our challenges in teaching are how to communicate our vision of objects and processes in such a way that we generate understanding and excitement while avoiding misconceptions (Robinson and Russell 2001). Pedagogical content knowledge (PCK) is important in teaching difficult topics like photosynthesis. It is a concept introduced by Shulman (1986) who started that different topics require very different ways of being taught if they are to be understood.

There is a need for new teaching materials and approaches that present photosynthesis in all its complexity, but in a way that stimulates the interest and excitement of students and promotes deep and accurate understanding. According to Moore and Miller (1996) multimedia has the potential, in combining written and spoken word with dynamic pictures and models, *to bring abstract concepts and invisible objects and processes to lif*e, and to do so in a flexible and reliable way which increases retention and learning. The interactive, user friendly format and excellent graphics should improve students' satisfaction and attention, and their learning outcomes. The problem of learners in rural and other poverty stricken areas is lack of proper resources to enhance learning as well as poorly trained educators who reinforce misconceptions because of their poor understanding of the subject's content.

Combination of written and spoken word with dynamic pictures models and animations should suit a range of students and learning styles, including the visually oriented, Beakes (2003). In spite of less interest in learners, educators need to be very innovative so as to arouse learner's interest. Educators need to develop their strengths in teaching photosynthesis through changing learner attitudes. Educators need to try learner centeredness where possible in teaching photosynthesis so that learners will own the self discovered knowledge and also have interest in developing it while educators present it. We can use innovative teaching methods having learners to write poems about leaves or plants.

2.7 STUDENTS MISCONCEPTIONS IN PHOTOSYNTHESIS

Photosynthesis is often de-emphasised in Biology curricular, because of the tendency to focus on animals, rather than plant processes. Conceptual challenges of understanding this multi – faceted process including electron transport, factors affecting photosynthesis and carbon dioxide fixation is also a problem in understanding this whole process. Netherwood and Robinson and a number of authors are supporting the statement that in this topic in Biology, major misconceptions often persist in students' understanding of photosynthesis (Haslams & Treagust, 1987).

According to Heshey (1992) in his article, “entitled Avoid misconceptions when teaching about plants”. Other misconceptions mentioned are:

- The ‘dark reactions’ of photosynthesis are a misnomer that often leads students to believe that carbon fixation occurs at night. It is better to use the Calvin Cycle.
- Plants get most of their food from the soil (which is why they need fertilizer), not from the sun.
- Photosynthesis is the simple conversion of CO_2 and water to carbohydrates and O_2 regardless of stages involved.
- Plant photosynthesises during the day and respires at night.
- Chlorophyll molecules in the light harvesting complexes transfer excited electrons to the reaction centre.
- Plants are green because they absorb green light.

Robinson (2004) states that these major misconceptions, students may become familiar with words and descriptions of processes such as electron transport, light harvesting, oxygen evolution and carbon fixation, but may have only very shallow, and in some case flawed, understanding of what these processes really mean. Although they may be able to develop these concepts sufficiently to pass exams in early years of school, but their literacy in this area is likely to remain at a low level, Uno and Bybee (1994), and they may have to unlearn and relearn this material at higher levels as flaws in their understanding begin to compromise their progress in this area (Robinson, 2004). This is usually seen in students who learn in a foreign language and not their mother tongue. Memorization of the terms does not mean conceptual understanding. The researcher feels that photosynthesis need to be taken step by step by introducing it at an early stage of education so that learners get deeper with it as they progress to higher levels of education. It is hoped that at their learning levels they will have clear understanding of concepts and terminologies. By so doing we will be promoting students with deeper insight in Biology, particularly in complex topics like photosynthesis.

2.8 WHAT MUST BE DONE TO OVERCOME LEARNERS' MISCONCEPTIONS?

In recent years many scientific researchers have focused on the student's comprehension of scientific concepts. It was determined in these studies that, students constructions of a concept on a subject are different from the experts of that subject. The students' different perceptions of the concepts have to be dealt with in a manner known as '**Conceptual Change Approach'** to remove the misconceptions. According to the Conceptual Change Approach, which was developed by Sahin (2000), the concepts should be comprehensible and logical to remove the students' misconceptions. However, taking into account the fact that the scientific concepts are mostly *abstract* and this field has microscopic facts, the perception of these concepts by the sense organs are limited. For this reason, the students' realization of the scientific concepts and events in their mind is important to make the scientific concepts comprehensible and logical. In science education, meaningful learning can be obtained by using analogies to teach the concepts and events that are difficult to understand. However, sometimes analogies are also limited and may introduce other misconceptions. Meaningful learning depends on the success of creating and finding relationships between pre – knowledge and newly learned content and one of the ways of finding such relationships is to create and use the analogies (Sahin 2000).

Science concepts can be taught better by using similar events that people meet in daily life e.g. watching a video player. When the active participation of the students is secured and the connection between the analogy and the behavior is set, students' misconceptions are reduced Brown (1992); Silverstein (2000).The analogies are generally classified into two groups as *individual* and *visual analogies*. In individual analogies the student has an active role and realizes these events in his/her mind. In *visual analogies*, the concepts which are difficult to understand are tried to be comprehended by students through using some diagrams and pictures, which are mostly accompanied by oral explanations. This type of analogy helps students making resemblances between pictures and the concepts. Analogies are the most important tools, which accelerate conceptual change in scientific judgment in learning and teaching (Duit 1991). Instead of giving them handy analogies, the students' creation of their own analogies makes the conceptual changing process of the students most useful (Wong 1993). Sahin (2000) emphasized that for developing analogies the students should also have adequate knowledge about the analogies and individual talents which are effective to develop analogies. In addition, developing analogy *requires both the desire and capability* to do so.

2.9 PHOTOSYNTHESIS EXPERIMENTS VERSUS STUDENTS' PERCEPTIONS

These are significant problems with teaching the practical aspects of photosynthesis. Laboratory exercises are available, but revolve around equipment and procedures that are either cheap and unreliable or prohibitively expensive, particularly for the kind of schools from which the participants came. Improvisation with poor quality apparatus for grade twelve students usually does not give accurate and credible results. Sometimes the educator does not have adequate command of the subject matter to explain why the experiment failed.

These are some very elegant experiments demonstrating the principles of, for example, gas exchange e.g. the classic Elodea experiment (Buttner 2000), Fox (1999), but they are often quite slow and require precision to gain meaningful results. Significantly, if learners are unclear about the principles before the practical, and take insufficient case in collecting the data, they *may gather data that is inconsistent with theoretical expectations*. Rather than clarifying concepts, this will merely reinforce misconceptions or generate confusion (or both). In large practical classes in particular, learning outcomes are affected by the quality of demonstration and the success of a particular experiment. This can result in variability within and between practical classes in any cohort, which has implication for equity, and as well as for learning outcomes generally. An ideal approach would be to use such experiment as demonstration, either in the practical class or theory class, so that students can see with their own eyes that the process is real, macroscopic and visual, but to also provide a more reliable practical experiment for the students to participate (Russel, 2004).

Russel (2004) further suggests that there is another problem with many of the available practical demonstrations and experiments for teaching photosynthesis. Such experiments often have long history, and many classic early experiments are recovered from antiquity to demonstrate principle to learners studying science, unless these are presented in their historical context (Hershey, 1991). The use of antiquated equipment and techniques in university courses while they may be educationally sound and consistent with resource constraints, create a false picture of modern science. As well as creating a picture of plant research as out of date and old fashioned, they create romantic impression of experimental science in terms of simple measurements, direct observations, simple, home – made equipment, ingenuity and trouble – shooting e.g. gaseous exchange experiment, transpiration rate by plants. While the skills and knowledge students pick up from these may be valuable in themselves, and such activities ought not to be dispensed with completely, they are out of step with modern, high technology, big science with its sophisticated and expensive instrumentation and automation. Practical work that is based entirely on antiquated experiments does not prepare students for work in modern science, or even for an appreciation of modern science and its methods. Some African students from previously disadvantaged historically black universities know what it means to be used to obsolete, out dated equipment and go for post graduate studies overseas and meet new and state of the art equipment. The student is both overwhelmed and excited by using the high precision instruments and getting credible results. They may also act to further devalue plants sciences as old science in the student’s point of view.

Since practical work follow theory, learners with misconceptions also are unable to link theory and practical work. Practical work also has major limiting factors like over crowding and lack of modern instruments as it has been mentioned. However, practicals are on the other hand very important for hands-on experience of some processes and concepts e.g. photosynthesis.

2.10 WHO SHOULD BE TAUGHT AND WHAT ASPECT OF PHOTOSYNTHESIS?

Science national curriculum for England states that all pupils aged 11 – 14 should be taught that plants need carbon dioxide, water and light for photosynthesis, and produce biomass and oxygen (Haslam & Freagust, 1987).

The syllabus also states that the students should also know that:-

- Photosynthesis can be summarized as a word equation
- Nitrogen and other elements, in addition to carbon, oxygen and hydrogen, are required for plant growth.

Pupils at this age are also taught that plants carry out aerobic respiration. These ideas are revisited between the age of 14 and 16 in slightly more details. At this stage the curriculum states that pupils should be taught: The reactants in and products of photosynthesis for instance:

- How the product of photosynthesis are utilized by the plant.
- The importance to healthy plant growth of the uptake of mineral salts.
- In addition they are taught that the rate of photosynthesis may be limited by light intensity, carbon dioxide concentration and temperature. Because of the overlapping of the curriculum between ages 11 to 14 and 14 to 16, it was possible to design a teaching sequence which could be used across

both age ranges, Haslam and Freagust (1987).This is the reason for choosing grade 12 since their syllabus include the topic photosynthesis.

In South African syllabus the department of Education requires the learners to study:

- The process of photosynthesis, a simple outline
- Practical investigation of the – starch test.
- Factors that influence photosynthesis – practical investigation of light, chlorophyll, carbon dioxide, oxygen, temperature and water.
- The two phases of the process of photosynthesis i.e. the light phase and dark phase.
- The products of photosynthesis.

Doctors Whitmarsh and Govindjee on their website on high school biology lesson plans(http://www.courseworld.com) give a very simple outline of what high school students should be taught on photosynthesis. The outline covers all that grade 10-12 learners in South Africa should know. The work covered is as follows :

The authors first state that at the end of the study the learners should be able to:

- Describe the energy transformations that occur in a chloroplast as light energy is converted to the chemical bond of energy of carbohydrate.
- Draw a sketch of a chloroplast and indicate where these energy transformations take place.
- List the inputs (raw materials) and outputs (products) of the light reactions and the Calvin Cycle.
- Describe the role enzymes in the process of photosynthesis.
- Explain what the plant does with the carbohydrate that is produced by photosynthesis.

Secondly the authors put a brief outline of the areas one needs to deal with in teaching about photosynthesis. These will be listed below according to the various topics:

1. Chloroplast Structure

- Outer membrane
- Inner membrane systems
- Thylakoid membranes
- Thylakoid space (within the thylakoids)
- Granum a stack of thylakoid membranes
- Stroma (the liquid area outside the thylakoid membranes)

2. The Photochemical Light Reactions

- Capture of light energy
- Thylakoid membranes
- Photosystems II and I
- Chlorophyll and accessory pigments.

3. Light absorbance and Photosynthesis

- Energy transformations
- Flow of Electrons
- Splitting of water molecules
- Release of oxygen
- Accumulation of H+ in thylakoid spaces
- Reduction of NADP to NADPH
- Production of ATP
- ATP synthase
- ADP + Phospate = ATP

4. The Biochemical Reactions : The Calvin Cycle

- “Fixing” CO2
- Cyclic series of enzyme reactions

- Rubisco (the enzyme that fixes CO_2)
- Stomates and CO_2 availability
- Addition of CO_2 to a 5 carbon compound
- Production of Carbohydrates
- Energy input from ATP
- Addition of H^+ and energy
- Production of carbohydrates for storage, transportation, and biosynthesis
- Recycling of 5 carbon compound to fix more CO_2.

The outline looks long and one may think it is an unnecessary list. However, many teachers in the rural areas are poorly qualified and have problems understanding at what depth they should be teaching. The outline presents a very good example of what concepts teachers at high school level should be unpacking with the learners. Looking for such material also helped the research to reflect at how she has taught the topic and how she could enrich future teaching by giving learners a holistic picture of this great process which feeds the whole world.

2.11 STUDENTS PERCEPTIONS ON PHOTOSYTHESIS

A review of the literature on teaching and learning about plant nutrition was conducted by (Driver 1993 and Barker 1993). The following characteristic patterns in students reasoning were identified:

- A view of nutrition, based on animal nutrition, as the ingestion of ‘food’ and the idea that ‘food’ is absorbed from the soil through the roots of a plant.
- A lack of differentiation between photosynthesis and respiration (the idea that photosynthesis is the plant equivalent of respiration, that sugar provides energy not biomass).
- The idea that sunlight is a reagent, not a source of energy.

- A lack of recognition of the chemical basis of biological processes, and those simple ingredients such as water and carbon dioxide can be combined (through chemical reactions) to produce more complex materials.
- A difficulty in accepting that gases can be a source of biomass.
- A lack of recognition that mass/matter is conserved in biological processes.
- A lack of recognition of the site of biological processes within an organism.

Based on the conceptual analysis of the curriculum, and these characteristic students reasoning, learning demands were identified and teaching goals developed. The teaching goals for the teaching sequences were outlined as follows by (Driver, 1993)

a) ***To open up*** the students own ideas about food (what it is, where it comes from, what it is needed for) to encourage students to discuss and question these to develop an explicit understanding of the distinction between source of food and functions of food.

b) ***To make the implausibility of the scientific explanation***. Explicitly: to problematise the simple scientific explanation that carbon dioxide combines with water to produce sugar in photosynthesis.

c) ***To demonstrates that apparently implausible physical processes do indeed happen***:
   - That carbon dioxide gas does have mass
   - That a gas and a liquid can combine to produce a solid.
   - That simple molecules (water and carbon dioxide) can combine to produce a complex molecule (sugar)
   - That matter is conserved in chemical change processed.

d) ***To develop a simple model of photosynthesis***
   - based upon the above physical principles, and to make this model plausible, demonstrating how sugar is produced in the leaf.

e) ***To show how this sugar can be converted into different food*** types and assimilated into the biomass of plants, making explicit the role of minerals in the soil:

- Glucose molecules can combine to produce different types of carbohydrate
- Glucose molecules can combine in different ways to produce fats
- Glucose molecules can combine with magnesium to produce chlorophyll.
- Glucose molecule can combine with nitrogen to produce proteins.

f) ***To assesses and consolidate the learning*** by revisiting the source and function of food in plants and animals.

2.12 THE ROLE OF PRACTICAL WORK IN TEACHING SCIENCE SUBJECTS

Bently and Watts (1989) states that for teachers in the Beatty Woolnough survey, practical work had many aims, the five most important of which were to:

- Rouse and maintain interest;
- Encourage accurate observation and description;
- Promote a logical reasoning method of thought;
- Make phenomena more real through experience;
- Be able to comprehend and carry out instructions;

The purpose of practical experience in the junior secondary school, then, is to encourage enthusiasm and excitement about science.

Pupils should be given the opportunity to engage in experimental work in which a variety of practical and investigative skills are developed. Practical work, then, is being seen as a way to encourage skills development and enable youngsters to test out their ideas about science. In Further Education and Training (FET) school teachers use projects very infrequently; middle–school teachers make plentiful use of them. Perhaps this indicates the influence of primary schools, where project work is a highly developed way of working. Projects allow pupils to shape the direction of their learning for themselves, be in greater control of the time they want to spend on different aspects and follow interesting ideas and avenues as they arise.

2.13 PRACTICAL WORK IN TEACHING AND LEARNING

Millar (2004) states that the term ‘science’ can be used to refer to a product (a body of knowledge), a process (a way of conducting enquiry) and an enterprise (the institutionalised pursuit of knowledge of the material world) .The distinctive characteristic of scientific knowledge is that it provides material explanations for the behaviour of the material world, that is, explanations in terms of the entities that make up that world and their properties .The aims of science education might then be summarised as:

- To help students to gain an understanding of the established body of scientific knowledge as is appropriate to their needs, interest and capacities,
- To develop students understanding of the methods by which this knowledge has been gained, and our ground for confidence in it.
- To claim to know something, it is not enough simply to believe it to be the case, but also necessary to have adequate evidence to support the claim. One has to be able to explain not only what causes change but, also why things happen in different ways. That is where hands on activities come into display.

In an example of a practical work relevant to photosynthesis cited at the site (http://teachingtoday.glencoe.com) the author illustrates an activity on the role of plant pigments in photosynthesis. The outcomes of this activity are that students should be able to:

- Relate the basic principles of photosynthesis
- Use paper chromatography to evaluate a hypothesis regarding plant pigments.
- Understand the role of chlorophyll and other pigments in photosynthesis.

The learners go through the process of separating colours of chlorophyll using chromatography. What was interesting about the lesson is that the following strategies are used to meet the needs of different learners :

- **Varying academic levels** : uses mixed-ability groups to allow learners to learn from one another, small and whole group participation.
- **Visual learners** : incorporates images related to photosynthesis, written guidelines, and journal writing
- **Auditory learners** ; uses discussion and direct inquiry to review concepts related to photosynthesis and discuss results of the experiment.
- **Kinesthetic learners** : engages students in an experiment to prove or disprove their hypothesis.

Before the practical begins learners are asked to think about why the leaves of some trees change colour in the fall. They are asked whether they believe that the red, yellow, and orange colours are present in the leaf when the leaf is green, or whether these colours are formed in the leaf only during the fall. The questions set the learners thinking and coming up with their hypotheses. In this experiment learners have to be shown how to do chromatography because this is a new technique, but learners interpret their own results and reject or accept their hypotheses. This gives the learners a chance to work like scientists. In real open ended inquiry learning the Manufacturing Chemists Association as cited by Sund and Trowbridge (1973) stated some of the features of the open ended experiments as follows :

1. The experiment asks a broad question and the design of the method is frequently left to the learner. The guidance from the teacher is of course crucial so that learners do not waste time fumbling about.

2. The learner generally does not know the answer to the question before the experiment.

3. The learner must thoroughly understand the problem, the reason for the problem, and the possible methods to be used to solve the problem.

4. The open ended experiment requires more thinking on the part of the learner to interpret what he/she observes.

In the context teaching of scientific knowledge, practical work is best seen as an act of communication. In practice, the representations constructed are tested out not only through action, but also through interpersonal interaction. The role of practical work, then, in the teaching and learning of science content is to help students make links between two ’domains’ of knowledge: the domain of objects and observable properties and events on the one hand, and the domain of ideas on the others. In the first category are practical work tasks main aim is to enable students to observe an object or material or event or phenomenon, to note some aspects of it, and perhaps be able to recall these. Students need to observe objects and phenomena in order to have basis of experience on which to reflect. Without first-hand practical experience of the world it is hard to see how a student could ever come to an understanding of it. It is hard to imagine, for example, a student who had never seen a chemical reaction coming to an understanding of what the term means from a verbal account, or appreciating what the spectrum of white light looks like without ever having seen what happens when ray passes through a prism. Practical work is necessary as a component of school science because we can not assume that students will have observed all the things we want them to have observed in their everyday lives.

Millar (2004) states that Practical work can be recognised in the teaching laboratory through simulations, that is, they model some aspects of professional scientific practice and not others. Practical work is an essential component of science teaching and learning, both for the aim of developing students’ scientific knowledge and that of developing students’ knowledge about science.

In the first ordinary meeting of the steering committee of the conference of ministers of Education of the African union (COMEDAF) (2007) it was stated that with greater use of experimentation in schools, a culture of scientific investigation and literacy will be developed, leading ultimately to increased production of new scientific knowledge in Africa. Science education has two broad components, first to promote scientific literacy and secondly to build up technological capabilities.

2.14 AVOIDING MISCONCEPTIONS WHEN TEACHING ABOUT PLANTS

The teaching literature contains hundreds of errors or misconceptions about plants, but this problem has not received enough attention to prevent its negative impacts. A plant misconception in a single textbook, educational web site, science project book, teaching journal article, or curriculum guide can potentially mislead thousands of teachers and students. Teachers often cannot detect even glaring errors because “new teachers coming out of our universities and colleges are very poorly trained in basic botany.

Many research studies have examined student misconceptions about plants. Not surprisingly, some misconceptions about plants also appear in the teaching literature, misleading students and teachers. Student misconceptions are difficult to correct even when teachers specifically attempt to correct them.

Many misconceptions involve oversimplification of concepts, particularly at the pre-college level. Such an “extreme of simplification” in plant teaching is not new.[6] The following summary equation for plant photosynthesis is an oversimplification that contains several misconceptions:

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Sunlight, chlorophyll}} 6\ O_2 + C_6H_{12}O_6\ \text{(glucose)}$$

The explanation of photosynthesis is a particularly good example. Chlorophyll alone is insufficient for plant photosynthesis. Many other enzymes and organic compounds are required. "Chloroplasts" essential requirement. Glucose is not the major photosynthetic product. There is virtually no free glucose produced in photosynthesis. The most common product is starch or sucrose, and students often test leaves for starch. Starch is approximated as $(C_6H_{10}O_5)_n$, where n is in the thousands. The six water molecules consumed per glucose molecule generated underestimates the water required. Much larger amounts are transpired to keep the stomata open. Without open stomata, photosynthesis is limited by lack of carbon dioxide. Submerged aquatic plants require large amounts of water for their aquatic environment. Drawing a single arrow wrongly implies that photosynthesis occurs in one step. Many small arrows should be used. Some of the energy captured in the light reactions of photosynthesis is used in the chloroplast to synthesize fatty acids and proteins. Thus, there are other types of "photosynthesis." The biology teaching literature contains much information on photosynthesis, yet it often has minimal discussion of mineral nutrient uptake by plants. To counter this problem, "mineral nutrients" should be added to the equation. Most essential mineral nutrients play a role in photosynthesis. Taking these misconceptions into account give the following summary equation for photosynthetic carbon fixation in plants:

$$H_2O + CO_2 \xrightarrow{\text{Chloroplasts, light, mineral nutrients}} O_2 + (C_6H_{10}O_5)_n\text{[starch]}$$

The scope of plant biodiversity is sometimes minimized. A major theme of biology is the great biodiversity of life. Overgeneralizations inaccurately minimize biodiversity. Teaching publications sometimes state that all plants are photosynthetic. Although they constitute less than 1% of plant species, a few hundred parasitic species lack chlorophyll, including the world's largest flower, *Rafflesia arnoldii*. Biology textbooks often portray plants as land organisms. They rarely mention seagrasses, flowering plants that live submerged in shallow ocean waters. Books sometimes state that all seeds have one or two cotyledons. This is one of several examples of focusing on angiosperms or flowering plants and ignoring gymnosperms, the nonflowering seed plants. Gymnosperm seeds often have more than two cotyledons.

Some terms are now obsolete because the Plant Kingdom has been restructured. A *saprophyte* is defined as a plant that obtains its energy from dead organic matter. Plants once thought to be saprophytes, such as Indian pipe (*Monotropa uniflora*), are now known to be indirectly parasitic on trees. They are *myco-heterophytes* because a mycorrhizal fungus connects the nonphotosynthetic parasitic plant to the photosynthetic host plant. The mycorrhizal fungus transfers nutrients from the host to the parasite. “Saprophyte” is an obsolete term because organisms that get energy from dead organic matter, such as some fungi, are no longer in the Plant Kingdom. Such fungi can correctly be termed “saprobes” or “saprotrophs.” Knops solution was developed in the 1860s to grow terrestrial plants without soil. Its use in teaching today is misleading because it contains just 6 mineral nutrients. Today there are 14 mineral nutrients considered essential for plants. “Geotropism” is misleading because the stimulus is gravity, not the Earth. The correct term is “gravitropism.”Carter (2004).

2.15 TYPES OF MISCONCEPTIONS

A familiar example from elementary school in learners’ understanding of relationship between the earth and the sun. While growing up, children are told by adults that the "sun is rising and setting," giving them an image of a sun that moves about the earth. In school, students are told by teachers (years after they have already formed their own mental model of how things work) that the earth rotates. Students are then faced with the difficult task of deleting a mental image that makes sense to them, based on their own observations, and replacing it with a model that is not as intuitively acceptable. This task is not trivial, for students must undo a whole mental framework of knowledge that they have used to understand the world.

The example of the earth rotating rather than the sun orbiting the earth is one of many that teachers refer to collectively as misconceptions. Misconceptions can be categorized as shown by Amir, (1994) as follows:

- *Preconceived notions* are popular conceptions rooted in everyday experiences. For example, many people believe that water flowing underground must flow in streams because the water they see at the earth's surface flows in streams. Preconceived notions plague students' views of heat, energy, and gravity among others.
- *Nonscientific beliefs* include views learned by students from sources other than scientific education, such as religious or mythical teachings. For example, some students have learned through religious instruction about an abbreviated history of the earth and its life forms. The disparity between this widely held belief and the scientific evidence for a far more extended pre-history has led to considerable controversy in the teaching of science.
- *Conceptual misunderstandings* arise when students are taught scientific information in a way that does not provoke them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs. To deal with their confusion, students construct faulty models that usually are so weak that the students themselves are insecure about the concepts.
- *Vernacular misconceptions* arise from the use of words that mean one thing in everyday life and another in a scientific context (e.g., "work"). A geology professor noted that students have difficulty with the idea that glaciers retreat, because they picture the glacier stopping, turning around, and moving in the opposite direction. Substitution of the word "melt" for "retreat" helps reinforce the correct interpretation that the front end of the glacier simply melts faster than the ice advances.
- *Factual misconceptions* are falsities often learned at an early age and retained unchallenged into adulthood. If you think about it, the idea that "lightning never strikes twice in the same place" is clearly mythical, but that notion may be buried somewhere in your belief system.

2.16 HOW TO BREAK DOWN MISCONCEPTIONS

Although vernacular and factual misconceptions can often be easily corrected, even by the students themselves, it is not effective for a teacher simply to insist that the learner dismiss preconceived notions and ingrained nonscientific beliefs. Recent research on students' conceptual misunderstandings of natural phenomena indicates that new concepts cannot be learned if alternative models that explain a phenomenon already exist in the learner's mind (McDermott, 1991). Although scientists commonly view such erroneous models with disdain, they are often preferred by the learner because they seem more reasonable and perhaps are more useful for the learner's purpose. These beliefs can persist as lingering suspicions in a student's mind and can hinder further learning (McDermott, 1991).

Before embracing the concepts held to be correct by the scientific community, students must confront their own beliefs along with their associated paradoxes and limitations and then attempt to reconstruct the knowledge necessary to understand the scientific model being presented. This process requires that the teacher:

- Identify students' misconceptions prior to teaching.
- Provide a forum for students to confront their misconceptions.

Help students reconstruct and internalize their knowledge, based on scientific models.

2.17 IDENTIFYING MISCONCEPTIONS

Before misconceptions can be corrected, they need to be identified. Many researchers and teachers have compiled lists of commonly encountered misconceptions. A number of professional societies have developed conceptual tests which allow teachers to identify learners' misconceptions.

(Hake 1992) used introductory laboratory exercises to help students test their conceptual bases for understanding motion. Essay assignments that ask students to explain their reasoning are useful for detecting students' misconceptions. These essays and discussions need not be used for grading, but rather can be used as part of the learning process to find out what and how students are thinking.

Misconceptions can occur in students' understanding of scientific methods as well as in their organization of scientific knowledge. For example, students in a science class will often express disappointment that an experiment did not work. They do not fully understand that experiments are a means of testing ideas and hypotheses, not of arriving at an expected result. To the scientist, an experiment yields a result which needs to be interpreted. In that sense, each experiment "works," but it may not work as expected.

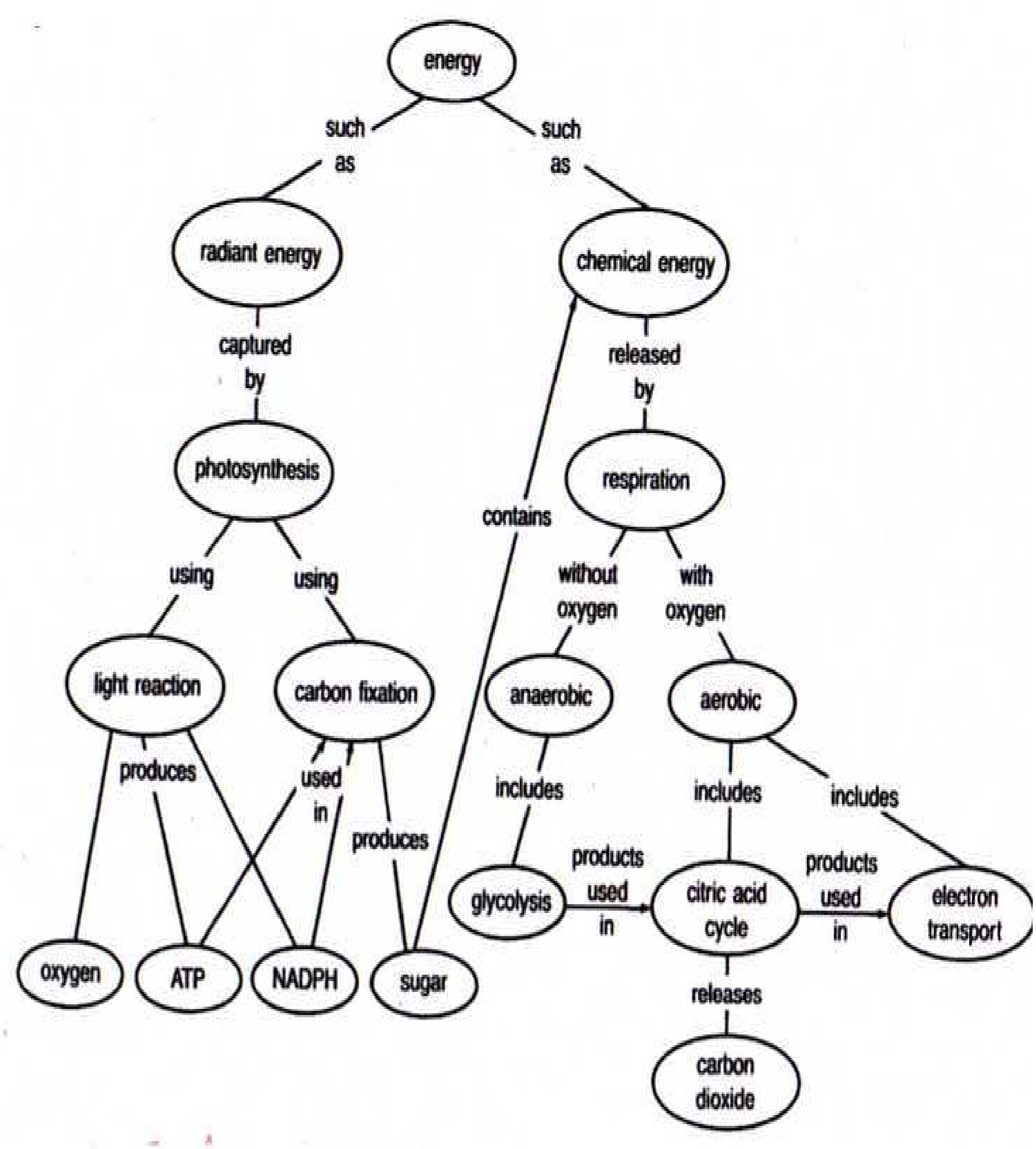
2.18 HELPING LEARNERS CONFRONT THEIR MISCONCEPTIONS

It is useful to review and think about possible misconceptions before teaching a class or laboratory in which new material is introduced. It is better to use questions and discussion to probe for additional misconceptions. Students will often come with the variety of their preconceptions. Teachers have to listen closely to their answers and explanations. You can help students by asking them to give evidence to support their explanations and by revisiting difficult or misunderstood concepts there after. Misconceptions are often deeply held, largely unexplained, and sometimes strongly defended. To be effective, a science teacher should not underestimate the importance and the persistence of these barriers to true understanding of content. Confronting them is difficult for the learners and the teacher.

Some misconceptions can be uncovered by asking learners to sketch or describe some object or phenomenon. For example, one might ask learners to sketch a structure of an atom before doing so on the board. By asking them to firstly draw their own model and then asking some students to share their answers with the class, a teacher can identify pre-existing models and use them to show the need for new models.

2.19 HELPING LEARNERS TO OVERCOME MISCONCEPTIONS

Strategies for helping students to overcome their misconceptions are based on research about how we learn (Arons, 1990). The key to success is ensuring that learners are constructing or reconstructing a correct framework for their new knowledge. One way of establishing this framework is to have learners create "concept maps". With this technique, learners learn to visualize a group of concepts and their interrelationships. Boxes containing nouns (and sometimes adjectives) are connected to related terms with a series of lines; prepositions or verbs are superimposed on the connecting lines to help clarify the relationship. Esiobu and Soyibo (1995) reported that learners constructing concept maps in cooperative groups show a greater increase in conceptual learning than students working individually, thus the utility of concept mapping may depend on the instructional setting. However Basili and Sanford (1991), found that cooperative group work on concept-focused tasks had a significant effect in helping college learners overcome certain misconceptions in chemistry, even though it did not involve concept maps. The following mindmaping shows a concept map linking ideas in photosynthesis and respiration (Mcharen & Rotundo, 1989).



A concept map linking ideas in photosynthesis and respiration

Helping students to reconstruct their conceptual framework is a difficult task, and it necessarily takes time away from other activities in a science course. However, if you decide to make the effort to help students overcome their misconceptions you might try the following methods:

- Anticipate the most common misconceptions about the material and be alert for others.
- Encourage students to test their conceptual frameworks in discussion with other students and by thinking about the evidence and possible tests.
- Think about how to address common misconceptions with demonstrations and lab work.
- Revisit common misconceptions as often as you can.
- Assess and reassess the validity of student concept

2.20 THEORIES OF TEACHING AND LEARNING

The way Biology and other learning areas are taught and learned are in line with the work of protagonists who have researched under different perspectives. Different theories will be discussed in relation to the teaching of photosynthesis as a topic.

a) Constructivism and learning

Constructivists see knowledge as actively constructed by individuals, groups and societies not simply transferred, Donald (2002) states that another related and dominant strand to constructivism is the idea that knowledge is not passively received but it is actively constructed. Through engaging in experiences, activities, discussions which challenge them to make meaning of their social and physical environment, learners are actively engaged in building progressively more complex understandings of their world.

b) Chacteristics of constructivist theory

Bertram (2001) states that in constructivist theories learners actively construct understanding, new learning depends on present understanding, learning is facilitated by social interaction and meaningful learning occurs within authentic learning tasks.

The topic photosynthesis is presented in the way which is in line with constructivism because learners are given assignments to do some research. They are actively involved since this is a practical topic where there is experimental work, even though schools without laboratories are affected.

c) Educational implications of Piaget's theory

Donald (2002) states that according to Piaget, the process of cognitive development has three very important characteristics. Each has profound implications for education: Firstly, although we need to take accounts of the effects of inheritance and maturation ('Nature') and chances of experience, these factors can not explain cognitive development. Development does not just happen to us. It is based on our active engagement with and exploration of our physical and social world. The implication of this insight is that teaching/ learning also need to be an active, exploration process if we are to optimize the process of cognitive development itself. This means giving students opportunities to 'try things out' to experiment and discover things for themselves, to question and discuss, and to reflect and solve problems for themselves.

Secondly, cognitive development is not a slow, even process of gathering more and more bits of information. It happens through an uneven process, but through a fixed sequence of stages, to higher level of organizing and of being able to manipulate information. Teachers have tended to interpret Piagetian stages in terms of limitation rather than in terms of progressive potential Donald (2002). Thirdly, the difference between an adult and a child's thinking lies not only in the amount of information that each has. It has to do with differences in the quality of thinking. These differences in the quality of thinking have important implications for understanding not only cognitive development, but also moral, social, and emotional development. These aspects relate to children's level of understanding of social relations, and therefore how they understand and deal with moral, social and emotional issues and feelings as they develop.

Looking at Piaget's theory, constructivism is rooted in his work because it states active engagement or involvement of the learner while learning. He also highlighted one of the things that educators are practising which does not help the learners. They focus on the learner's limitations rather than on their progress and potential. Piaget discourages the belief that learners do not want to learn about plant and the saying that plants are boring, educators must not take that as their point of departure. They must work on what the learners are able to do and follow, then work on it so as to help them to gain knowledge and develop interest.

This is confirmed by Brophy and Rohrkemper (1981) who stated that the teachers language and general socialization style can have strong effects on student behaviour. Rohrkemper (1981) found that students whose teachers use a behaviour modification style, develop sophistication about behavioural action-reaction linkages but not about the motives and intentions that underlie these behaviours. Teachers who just propound rules and consequences were apt to have less desirable effects on students than educators who also emphasize, model and explain the reasons for rules.

Piaget also emphasises that educators need to have a full understanding of children morals, social and emotional development because that helps educators to understand the learner's cognitive development.

d) Behavioural view of learning

This type of learning is based on a model of stimulus and response, as well as some form of reinforcement Mwamwenda (2004). Some behaviourist theories are discussed bellow.

i) Classical conditioning

Ivan Pavlov, a Russian physiologist, is credited with having developed a learning theory known as classical conditioning Mwamwenda (2004). The word 'classical' means 'of the first type', and seeing that Pavlov's theory is one of the first theories of learning, it is referred to as classical conditioning. Conditioning means learning, or modification of behaviour. Classical conditioning may also be referred to as stimulus substitution, because a new stimulus which was originally neutral can take place of a stimulus which elicits a response. Pavlov argued that through association, it is possible for an organism to develop a new set of behaviour. Pavlov did not stop with the positive results of his experiment but proceeded to test other aspects of the dog's behaviour. It was clear to Pavlov that the dog had not acquired a new behaviour, but was also capable of transferring the newly learned behaviour to a similar situation.

One of the factors that were not mentioned when the conditioning of the dog was discussed was that the dog had been deprived of food and therefore hunger was the motive for its subsequent behaviour. Motivation is a very important factor in learning. In Pavlov’s experiment, the dog was trained to generalise what it had learned in one situation to a related but different situation.

Looking at Pavlov's theory it is based on behaviour which he says educators can shape. I concur with him in that learners imitate the ways of the educator. I say that from my experience as an educator. If the educator is hard working and active his/her learners will take that behaviour. Learners know the educator who does not check whether the homework was done or not and they neglect it. Pavlov also mentioned motivation, learning centres upon intrinsic (internal) and extrinsic (external) motivation. Educators need to be creative so as to motivate learners with interesting ways of teaching. Learners need to be praised for their work so that they can have desire to succeed. Pavlov also mentioned transferring new knowledge to a similar situation. This is in line with Outcome Based Education which encourages learning to be applied in real life situations not to treat knowledge as isolated pieces. This is also in line with how biology is taught. Learners in some schools are not encouraged to be actively involved and to be able to apply their theory to practical situations which is experimental work.

ii) Operant (instrumental) conditioning

Mwamwenda (2004) states that operant conditioning is a relationship between a response (behaviour) and consequences. Operant condition is also called instrumental conditioning, because the organism is instrumental or solely responsible for generating reward for its activity or behaviour.

Skinner conducted an experiment which shows how the rat continuously pressed the bar in the box with the aim of getting the reward which is the food pellets Mwamwenda (2004). Skinner as one of the behaviourist proved that if there is a reward learners can be motivated and so co-operative in their learning. He concluded that part of the reasons for our behaviour is because of the consequences of our behaviour. It is in line with the way teaching and learning is conducted, the behaviour of the learners leads to their pass or failure to progress. If the learner wants to progress they make sure that they learn hard.

2.21 SCHEDULE OF REINFORCEMENT

Mwamwenda (2004) states that, a reinforcement may be defined as a stimulus which increases the probability of a response recurring. The process whereby behaviour is reinforced is referred to as a schedule of reinforcement. There are two major forms of reinforcement, namely continuous and intermittent or partial reinforcement. Continuous reinforcement involves rewarding an organism every time it makes a correct response. Continuous reinforcement facilitates the mastery of behaviour fairly quickly. Intermittent reinforcement involves rewarding the organism after it has made more than one correct response. The schedule of reinforcement is also in line with continuous assessment. The outcome based education system emphasises that the learners must always be assessed i.e. continuous reinforcement, it makes learners to be alert in what ever is done in class because they know that they will be a reinforcement. Looking at grade 12 Continuous Assessment (CASS) for Biology educators must submit not less than 17 pierces of CASS at the end of the year. These pierces must be chosen from the better performed work of the group. That means reinforcement in the form of marks must be there in everything that is done in class.

2.22 CONNECTIONISM

Thorndike was responsible for developing a learning theory known as connectionism Mwamwenda (2004). On the basis of his study of animal behaviour, he developed three laws of learning **- the law of effect, the law of practise and the law of readiness**. The law of effect states that a response which is followed by reinforcement is strengthened whereas a response which is followed by an aversive stimulus is weakened. The law of practice states that mastery over a given set of skills or body of information can be achieved through practice. The law of readiness emphasises the importance of an organism being prepared before it engages in a given set of behaviour: if it is prepared, the activity will be a pleasant and an enjoyable one, whereas if it is not, it will be annoying and frustrating. Such a law has important implications with regard to motivating students.

Thorndike later modified the laws of effect and practice. Regarding the law of effect, he argued that the component of punishment is less crucial to a change in behaviour than reinforcement to the maintenance of a desirable behaviour and regarding the law of practice, he postulated that practise has the intended effect if it is accompanied by knowledge of results, which help the organism to correct mistakes and capitalise on correct responses for mastery. Thorndike also addressed other laws of learning, motivation and identical elements. From this theory, we gather that reinforcement is important for learning. Equally important are motivation, readiness, practice and the transfer of learning.

Thorndike's theory of connectionism concur with Skinners (1953) and Brophy (1991) about reinforcement, and he also extends it to the fact that the behaviour which is being reinforced is likely to be repeated which is true. Learners like to be praised so they try to their level best to do their best all the time. This theory is one of the major theories in the teaching of photosynthesis. It is important because it requires the learners to connect theory and practical work (experiments). Some schools are disadvantaged by the lack of laboratory and laboratory apparatus to connect theory and practice. Connectionism serves as a way of consolidating what the learners have been theorising.

a) Social learning theory

According to social learning theory, a great deal of learning occurs as children interact with adults and other children. What children learn in this way facilitate their adjustment to their environment as they grow to be adults. Learning occurs through observation or modelling which is very effective given the time it would take and risk that would be involved if it were necessary for everyone to learn for himself all that is to be known. Whether the behaviour of a model will be imitated depends on factors such as reinforcement, memory, attention, etc. The most important of these is reinforcement, which serves as the motivation for people to imitate other's behaviour. If the model is reinforced, the behaviours will be imitated whereas if the model is punished the behaviour will be avoided. Should the observer not be impressed by the model's behaviour, or lack the skills necessary to perform the behaviour, or is simply not interested, no learning will occur. (Mwamwenda 2004)

Mwamwenda (2004) in his theory of social learning insist that through interaction the learner learn the good and the bad. The child is able to discriminate the bad or good through reinforcement and punishment. Social learning is related to outcome based education which is the system of education that talks about the children learning through interaction with others in groups, pairs, small groups etc. Science subjects are in line with social learning theory especially in practical work. Learners become actively involved in their learning and they all try their best to behave like the one who has been praised. They do not want to associate themselves with bad behaviour which does not lead to positive reinforcement.

b) Discovery learning

Mwamwenda (2004) state that by discovering learning, means that teachers should present their learners with the opportunity for analysing data for themselves and arriving at their own concepts. Information obtained in this way can easily be transferred and is more readily retained. Moreover, it teaches learners how to think, learn and solve problems independently. Some of the topics that can be used for discovering learning are science projects, research, independent reading, weighing objects, solving problems and writing interpretive reports on given topics. The teachers' role is primarily to provide learners with feedback on their performance. Bruner's theory of instruction stresses the importance of motivation, reinforcement, sequencing of information, and the learner's cognitive structure for effective learning and teaching.

Discovery learning is one of the powerful theories in learning because the information that the learners discover themselves is lasting as compared to the information which the learner received passively. Discovery learning is mostly useful when learners have to do experimental work and discover the results themselves. It also empowers learners with research skills when they have to solve problems independently. Sund and Trowbridge (1973) stated that it is desirable that students in the discovery laboratory are given much more responsibility in planning experiments and carrying them to completion.

c) Reception learning

Ausubels cognitive view of learning is based on meaningful learning, also known as subsumption theory, verbal learning or reception learning (Mwamwenda 2004). It is referred to as meaningful because it advocates learning or teaching based on what the learner already knows. It is believed that effective learning is not likely to take place if what is being taught has no bearing on what the learner already knows.

Learning can be made meaningful through the use of advance organisers –which include more general concepts- by giving a over view of the subject matter using lesson outlines, by drawing attention to similarities and differences and reviewing earlier related work. When an advance organiser is used, learners are presented with the main ideas before detailed information about the topic at hand is covered. An advance organiser serves as a pillar upon which subsequent new information can be built. It facilitates effective retention since new information is related to familiar information. An advance organizer must be well organised, clear and easily understood by learners if it is to be effective (Mwamwenda, 2004).

In reception learning theory the focus is mostly in driving the learner to have a clear understanding of the topic at hand. The educator tries to his/her level best to link the new knowledge with the existing knowledge. This learning theory is more of spoon feeding the learner because the learner is supplied with all ways and means of making sure he/she understands what is taking place. The teaching of Biology considers that the educator must link the new knowledge with the existing one. Reception learning is applicable in teaching of photosynthesis as a Biology topic.

2.23 SUMMARY AND CONCLUSSION

This chapter lays the background of photosynthesis. The importance of this process and the reasons why it must be taught at schools are also discussed at length. Challenges faced by educators and learners are also discussed. It looks at other countries aspects that are taught in photosynthesis together with South African syllabus specifically in this topic. The researcher also researched widely on strategies used by teachers internationally to enhance the learning/teaching of photosynthesis. The role of practical work in teaching this topic was also discussed and the emphasis was on that practical work should not be conducted like a cookbook recipe but must be inquiry orientated. Tips and ways of dealing with misconceptions are also discussed. Towards the end of this chapter there is a lengthy discussion of theories of teaching and learning because these help to understand the nature of the learners and how they should be treated to make schooling a useful and beneficial experience.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

Sound research methods must be employed in order to understand the nature of phenomena and problems in our surroundings. This study made use of a structured data collection method in the form of a special examination paper of 2005 on photosynthesis. Chapter three explains the rationale behind the methodology employed, how the research was conducted and the steps taken to ensure the validity and the reliability of the study.

3.2 STUDY AREA

The study was conducted in six secondary schools of the Mthunzini circuit in the Empangeni district of the Northern KwaZulu-Natal region. The schools were chosen because they had a low pass rate in 2008 compared to other regions. A “low pass rate” in this context refers to an average pass rate of below 50% in matriculation. Although the Zululand region has more qualified educators than other regions in KwaZulu-Natal, it was rated as number 10 (out of 12 regions) and thus among the poorly performing regions. This background aroused the curiosity of the researcher with regard to the challenges faced by the schools in this district in understanding scientific concepts such as the Life Science concept of photosynthesis.

3.3 RESEARCH APPROACH

Two research approaches were employed in the study, namely qualitative and quantitative research.

3.3.1 Qualitative approach

Furze, De Lacy and Birckhead (1997) explain the distinction between qualitative and quantitative forms of knowledge in terms of the conceptual aspect and the methods used. In the conceptual sphere, qualitative research is concerned with an understanding of human behaviour from the perspective of those people involved. Qualitative research assumes dynamic, social reality and cultural meaning out of data collected and is subjective in nature. According to (Kumar 2005) qualitative research focuses on interactive processes and events rather than variables. Qualitative research involves analysis, using themes that emerge from collected data. In qualitative research, data analysis involves cases that are compared (Kumar 2005). In this study, qualitative method approaches were used to analyse written responses in terms of understanding the questions, language difficulties and identification of learners' misconceptions with regard to the topic of photosynthesis. The qualitative approach was also used to investigate how learners' career interests affected their performance in photosynthesis.

Merriam (1998) states that the qualitative case study is suitable for dealing with critical problems of practice and extending the knowledge base of various aspects of education. The research deals with conceptual problems encountered by learners in mastering various concepts in photosynthesis. A qualitative method is therefore suitable.

3.3.2 Quantitative approach

The quantitative research method was also employed in the study due to objectives that dealt with aspects that are quantifiable. According to Kumar (2005), quantitative research differs from qualitative in that the research organisation is more analytical in nature, drawing inferences and conclusions which test the magnitude and strength of a relationship.

In this study the quantitative method was also used to analyse learners' geographic information, gender and the scores obtained in each question and to analyse the number of learners who passed and failed each question. One can use both quantitative and qualitative techniques in combination because this is in fact a form of triangulation that enhances the validity and reliability of the study.

3.3.3 Validity of research techniques

Kumar (2005) states that although both research approaches share basic principles, they differ significantly in certain ways as mentioned above. According to Neuman (1997), a quantitative approach reduces data in order to see a bigger picture in an objective manner. On the other hand, qualitative research techniques enable researchers to understand the key aspects of the study more clearly. Neuman (1997) furthermore states that since each approach has its own strengths and limitations, it is useful to combine the two research approaches. The study attempted to maximise the strength of validity by combining both qualitative and quantitative research approaches.

3.4 CASE STUDY METHODS

The study takes the form of a case study in six secondary schools. A case study is a specific instance that is frequently designed to illustrate a more general principle. Levinson (1994) states that a case study methodology is an in depth research of a particular phenomenon. This study replicates and extends that study and thereby adds to the body of knowledge in a particular field.(Kumar 2005) further states that case studies provide a unique example of real people, in real situations in a particular context, allowing a reader to understand more clearly how the abstract information has been put together.

A case study involves two main components: the case and phenomena. According to Kumar (2005), a case is the 'object' of study. In other words it is a unit of analysis. The unit of analysis may be a person on whom a theory is constructed, or it can be places such as residences in a community or organisations such as businesses and schools

.

The case may be a person, group, episodes, process, community, society or any other unit of social life. In this study the case is the topic.

Merriam (1988) confirms that most case studies in education approach a problem of practice from a holistic perspective. The investigation uses a case study design in order to gain an in-depth understanding of the situation and its meaning for those involved. New insight and understanding gained from the study can be used to improve classroom practice.

The study of conceptual understanding of photosynthesis was examined in six different schools located in three different areas. The different social locations were:

- **Rural schools**
- **Semi rural schools**
- **Urban schools**

The choice of different schools in the three locations served to lend representativeness of different populations of interest. Although it would have been ideal to deal with all schools in Northern KwaZulu-Natal, this would not have been possible because of financial constraints. Neale and Albert (1986) state that a major aim of analysis in science is to provide sound propositions about people in general or about specific groups of people. The authors, however, explain that it is rare for social scientists to actually study or observe all. The social scientist researches and tries to understand a segment of the society, a representative sample of people whom he or she is interested in, as the basis of his or her study. Each individual case study consists of a "whole" study, in which facts are gathered from various sources and the conclusions drawn from those facts.

3.4.1 Sampling methodology

The sampling was drawn from six high schools in the Mthunzini district of the KwaZulu-Natal province. The schools that participated in the study are identified by pseudo names as school 1, school 2, school 3, school 4, school 5 and school 6. This is in keeping with confidentiality. There should be no way of identifying the actual schools or the respondents. The targeted group was grade 12 learners, which fall under the Further Education and Training (FET) phase in the new education system.

The study population consisted of 143 grade 12 learners. Two schools, namely school 1 and school 2, were located in the rural areas; two other schools, namely school 3 and school 4, were in the semi-rural areas, and the last two schools, schools 5 and school 6, were located in the urban areas. Those three groups were chosen due to their localities.

The first group represented rural-located marginalised schools, from the site visit it was observed that some schools do not have potable water, no electricity and laboratories. Learners from the school informed the researcher that they walk long distances to school. This is the situation, which prevails in some schools, although the government is trying to improve the conditions of these schools. There is no transport and highly skilled educators do not want to work in such areas. Some learners explained that their parents do not have decent jobs so they cannot afford to buy their stationery and other needs.

The second group consisted of urban schools that enjoyed better teaching and learning conditions, including access to potable water, availability of electricity, library and laboratory facilities, and transport available for both learners and educators. Their condition attracts qualified educators and so the atmosphere is conducive to learning and teaching. Parents are working, so they are able to afford the amenities necessary to satisfy learners’ school needs. Due to the available facilities one can expect good results from these schools. However, it is necessary to note that availability of facilities does not always translate into the necessary equipment or to effective use of laboratories. In some laboratories one can find dusty boxes of new equipment that have never been opened.

The third group was semi-rural that occupy a space between the rural and urban schools. Some resources are available, such as electricity and water, but they lack other facilities such as libraries, although they do have laboratories. However, these facilities are underutilised since laboratories are used as classroom and storage rooms and the schools do not have adequate equipment to carry out practicals. Some parents are employed and can afford education for their children but others are not employed at all.

Table 3.1 List of schools that were sampled

Name of School	**Grade**	**Type of School**
1	12	Rural
2	12	Rural
3	12	Semi-rural
4	12	Semi-rural
5	12	Urban
6	12	Urban

3.4.2 Sampling tool

In this study the researcher employed a test consisting of structured questions as a tool for collecting data, because it allowed respondents the opportunity to answer questions in an appropriate manner. The research instrument was designed from different previous final examination papers on the section dealing with photosynthesis. Bertram (2003) states that it is important for questions to be designed properly, so as to ensure that respondents understand what is being investigated. The test technique was preferred because it can be administered to a large number of learners. The questions administered in this study can be understood without the presence of the researcher. A second benefit attached to usage of the question paper in this context was the learners had already been vetted for quality and appropriateness for the twelfth grade due to the fact that they had come through previous final examinations.

3.5 RESEARCH INSTRUMENT

The research instrument used in this study was in the form of standardised grade twelve test papers from the Department of Education (DoE). The paper was standardised because it was administered nationally after it had been screened by experts in the field. Thus the test could be considered a valid instrument for assessing the achievement of grade twelve learners. The instrument used was a test question paper. The researcher decided to use the test because it is the only accepted tool to measure learners' knowledge and reasoning skills from which to deduce the quality of teaching and learning. The question paper consisted of six questions with the total mark of 77. The questions covered different levels of Bloom's taxonomy (Table 3.2). The researcher was therefore satisfied about the reliability and validity of the instrument. Reliability is defined by Gipps (1995) as the extent to which an assessment would produce the same or similar score on two occasions or if given by two assessors. This is the accuracy with which an assessment measures the skills or attainment it is designed to measure. The same author states that validity refers to the extent to which an assessment measures what it supposed to measure.

The test was administered under national examination conditions, as stated in the government gazette, as follows: No explanation of examination questions may be asked or given, candidates must not assist other candidates or try to assist a candidate in getting help or communicating with anybody, candidates may not disregard the instructions of the invigilator, candidates may not have a book, memorandum, notes, maps, photographs or other material, which may be of help to them in the examination, other than that which was provided to them by the invigilator. Candidates may also not create a disturbance in the examination room or behave in an improper manner.

3.5.1 Cognitive level analysis of the diagnostic test questions

Cognitive function refers to mental processing of information by a learner. The levels in Blooms taxonomy refer to the complexity of the intellectual activity required from the learner. To be able to process information at a higher level, the learner needs to exercise thinking. The table below shows the levels of thinking in Blooms Taxonomy as captured by Kiviet and Du Toit (2006).

Table: 3.2 Cognitive levels of Blooms Taxonomy

Levels in Blooms taxonomy	**Description**	**Action verbs**
Knowledge	Recognition or recall of ideas and facts	name, select, state, define, list, tell, give
Comprehension	Requires an understanding of the facts	compare, discuss, match, illustrate, tabulate, justify
Application	Where the learner can use theory in a new situation	Solve, predict, draw, differentiate, determine
Analyse	The breakdown of content into parts, and discovering the relationship between parts	Analyse, identify, contrast, differentiate, verify
Synthesis	Recombination of parts into whole	Organise, design, synthesis
Evaluation	Judgements about the theory	Evaluate, assess, criticise, defend

The table shows a range of competencies that the learners are expected to master in learning any subject. A good test usually has a mixture of all the cognitive levels so as to ensure that the students are required to answer questions that require them to think and not only to regurgitate information. The analysis discussed below shows the cognitive demands of the test that was given to the grade twelve learners.

Question one – tested knowledge; learners were required to recall or recognise information, ideas and principles in the appropriate form that they had learned. It was a question that required learners to supply the correct Biological term. Learners were supplied with statements.

Question two – tested comprehension; learners were required to show understanding by translating and interpreting information based on prior learning. Learners were given a diagram of an experimental set-up to test for starch and were then required to answer questions that demonstrated their understanding.

Question three – tested the level of application of what they had learned; the learners were required to use given data and principles to complete the task. They were given a labelled drawing of an experiment testing for chlorophyll and carbon dioxide and were then required to answer given questions on the experiment.

Question four – tested learners' level of analysis; learners were required to distinguish, compare and examine the given possible answers. Learners were then given a drawing of the apparatus used to measure the rate of photosynthesis of a water plant and were required select and circle the correct four possible answers from the list of possibilities.

Question five – tested synthesis; learners were required to combine ideas by calculating the given data. Learners were subsequently given a drawing of a water plant and a lamp. They were required to answer questions based on the number of bubbles produced by the water plant at different lamp distances.

Question six was based on evaluation; learners were given data on light intensity and two different rates of photosynthesis in two different percentages of carbon dioxide. Learners were asked to plot a graph showing the given data. In addition to this, learners were required arrive at and make their own suggestions and conclusions about the graphs. The question also tested basic mathematical literacy, since some students found it difficult to produce simple graphs. There has been an outcry about the poor state of mathematical literacy among South African students, particularly in rural areas because of the lack of qualified educators.

3.5.2 Administration of the instrument

Appendix B, attached hereto, is a letter addressed to District Manager Empangeni district requesting permission to access the schools in order to conduct research. Appendix C is a letter directed to the principals of the six schools where the research was conducted. All the participating schools were visited by the researcher to make sure that they get the same information at earlier stages.

The researcher visited the schools to request permission from the principals and grade 12 educators to administer the test. Hitchcock and Hughes (1995) advise that it is best for a researcher to discuss her/his research with all the parties involved. After permission had been obtained from the principal, the following information was discussed with the grade 12 Biology educators:

i. Suitable time during the year to administer the instrument.
ii. Identification of the person who would invigilate the test the test.
iii. The importance of standardising the invigilation.
iv. Assurance of the educators that the results of his/her learners would be treated confidentially.
v. Informing the learners to prepare the test on the topic photosynthesis.

The researcher preferred the period just before the trial examination and this was discussed with the educators. The day and time was finalised and the researcher ensured that the instrument was administered to the learners on the day of delivery in order to avoid discrepancies, such as educators discussing the questions with the learners. The instrument was administered under formal examination conditions. Learners were told early to prepare for or to revise the topic photosynthesis.

3.6 HANDLING OF THE INSTRUMENT

The researcher made an appointment with the Life Science educators to discuss the date for the test as well as invigilation issues, including: all grade 12 sections were to write the test at the same time; how to control irregularities such as cheating (so that spoiled papers could be avoided and not be considered for sampling); and to request assistance from educators. The researcher requested the life science educators to help with the invigilation and explained that it was preferable to have educators who have experience in teaching grade 12 because they know more about controlling grade 12 tests and examinations. The researcher was present during the handling of the research instrument so as to monitor the situation and to collect the papers. Papers were collected immediately after writing; in cases where information such as gender, age etc was not filled in on the cover pages, these papers were considered as spoiled papers and were not taken into account in the study.

3.6.1 VALIDITY OF THE INSTRUMENT

3.6.1 Validity of the research instrument

Validity is defined as the degree to which the researcher has measured what he/she wanted to measure (Kumar, 2005). The instrument was considered to be valid for the purpose of the study because the instrument was a standardised paper taken from national previous grade 12 papers and the researcher was able to find out more about the reasons for conceptual misunderstanding of photosynthesis while analysing the data.

3.6.2 Validity of the sampling size

The sampling size was more than 50, which increased the variety of the responses. The researcher took the sampling from six different schools with three different levels, i.e. rural, urban and semi-rural areas, which broadened the scope of the population.

3.7 ETHICAL ISSUES

The matter of ethics is an important one in research (Regina, Scheyven & Storey 2003). In this study, confidentiality was taken care of by ensuring that the results obtained from the different schools were treated confidentially. The researcher making sure that she was the only one who would handle the scripts guaranteed this. The schools' results were used solely for analyses in the research, and the schools were not labelled or otherwise identified by name. Pseudonyms were used for all of the six schools in this study.

Ethical issues arise when we try to decide between one course of action and another not in terms of expediency or efficiency but by reference to standards of what is morally right or wrong. The researchers needed to consider aspects such as respect for the culture, traditions and knowledge of the community, and the return of knowledge and information to the schools.

All participants in human research have the right to remain anonymous, that is, the right to insist that their individual identities be a silent feature of the research (Tuckman, 1972). To ensure anonymity, two approaches are often used. First, researchers are usually interested in group data; thus scores obtained from individuals in a study are pooled or grouped together and reported as averages.

Since the individual scores cannot be identified, such a reporting process guarantees the anonymity of each participant. Secondly, wherever possible subjects are identified by number rather than by name. The researcher administered a group analysis and not individual analysis.

Participants have every right to insist that data collected from them be treated with confidentiality (Tuckman, 1972). To guarantee this, the researcher referred to all data by letters of the alphabet, rather than by name. All the scripts were destroyed as soon as the study was completed.

In this study the matter of investigating the grade twelve learners' knowledge of concepts related to photosynthesis was discussed with both the learners and the educators. The timing of the research was a few months before the final external examinations. The exercise was therefore seen as useful one for reviewing work on photosynthesis. The learners and educators were told that participation would be voluntary. They were also assured that there would be no consequences for participating students, as the result would not be passed on to the education authorities. The main purpose of the research was to find out what challenges faced grade twelve learners in trying to learn and understand concepts in photosynthesis. The results could in future help in structuring more effective and user-friendly strategies of learning about photosynthesis. The learners were told that there would be no reason for them to be confronted by the administration on their performance in the diagnostic test and that it would not affect them negatively. It would, however, make them aware of areas in photosynthesis which are a challenge to them and which they needed to concentrate on.

CHAPTER FOUR

4.0 DATA ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION

This chapter documents the results of the investigation to establish whether or not black learners have a conceptual understanding of the content of photosynthesis as covered by the Further Education and Training level, i.e. grades 10 to 12. The study was conducted in different high schools so as to determine the full range of challenges faced by learners who are learning about photosynthesis. The data collected is summarized and discussed in this chapter.

Research done in English-speaking countries, where English is also the language of mediation of learning, already point out that photosynthesis is an abstract subject that is difficult to comprehend due to the fact that it is integrated with other areas of learning. The present study, however, deals with learners with English as a second language – yet who receive their tuition in English. The results of the study are discussed below.

Data on learners' achievements is presented in histograms. The Statistical Package on Social Sciences (SPSS) was used to test whether there were any significant differences in performance in terms of gender and the various schools. Data on the different career choices made by learners appears in tabulated form. A bar graph illustrates the performance of the different schools, while the data on sociographic factors appears in tabulated form.

4.2 DEMOGRAPHIC DATA OF RESPONDENTS

Data related to learners' gender is analyzed in the following figure in order to facilitate exploration of some of the factors that strongly relate to poor results with regard to the subject of photosynthesis.

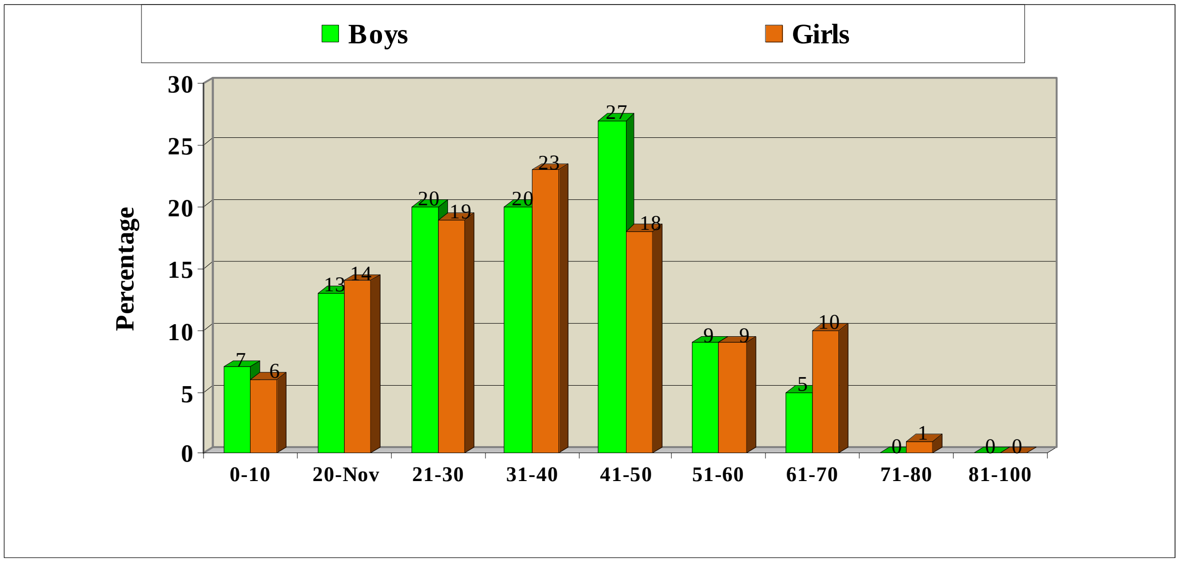


Figure 4.1: Achievement scores of boys and girls

Figure 4.1 indicates a slight difference (of 4 units) between the results of boys and girls, with the boys doing better than the girls (27 boys scored 41-50% versus 23 girls who scored 41-50%). When looking at the top scores (71-80 %) there is a reversal, with the girls obtaining all of these scores and the boys not featuring at all. Interestingly, basically the same numbers of boys and girls achieved scores of between 51 and 60%. However, at the interval of 61-70, the girls outperformed the boys. This study reveals that, in general, the girls obtain higher scores than boys in Life Sciences. In spite of the considerable duty load that girls traditionally carry with regard to assisting with domestic tasks at home, through sheer focus and dedication they managed to achieve higher marks even in the higher order questions, for example question six. This suggests that women are able to do well, regardless of the circumstances that they have to cope with.

4.3 DATA ON ACHIEVEMENT SCORES

Scores obtained from each question are presented in figure 2 (refer to the next page). The data clearly shows which questions (in practical work) gave learners the most difficulty.

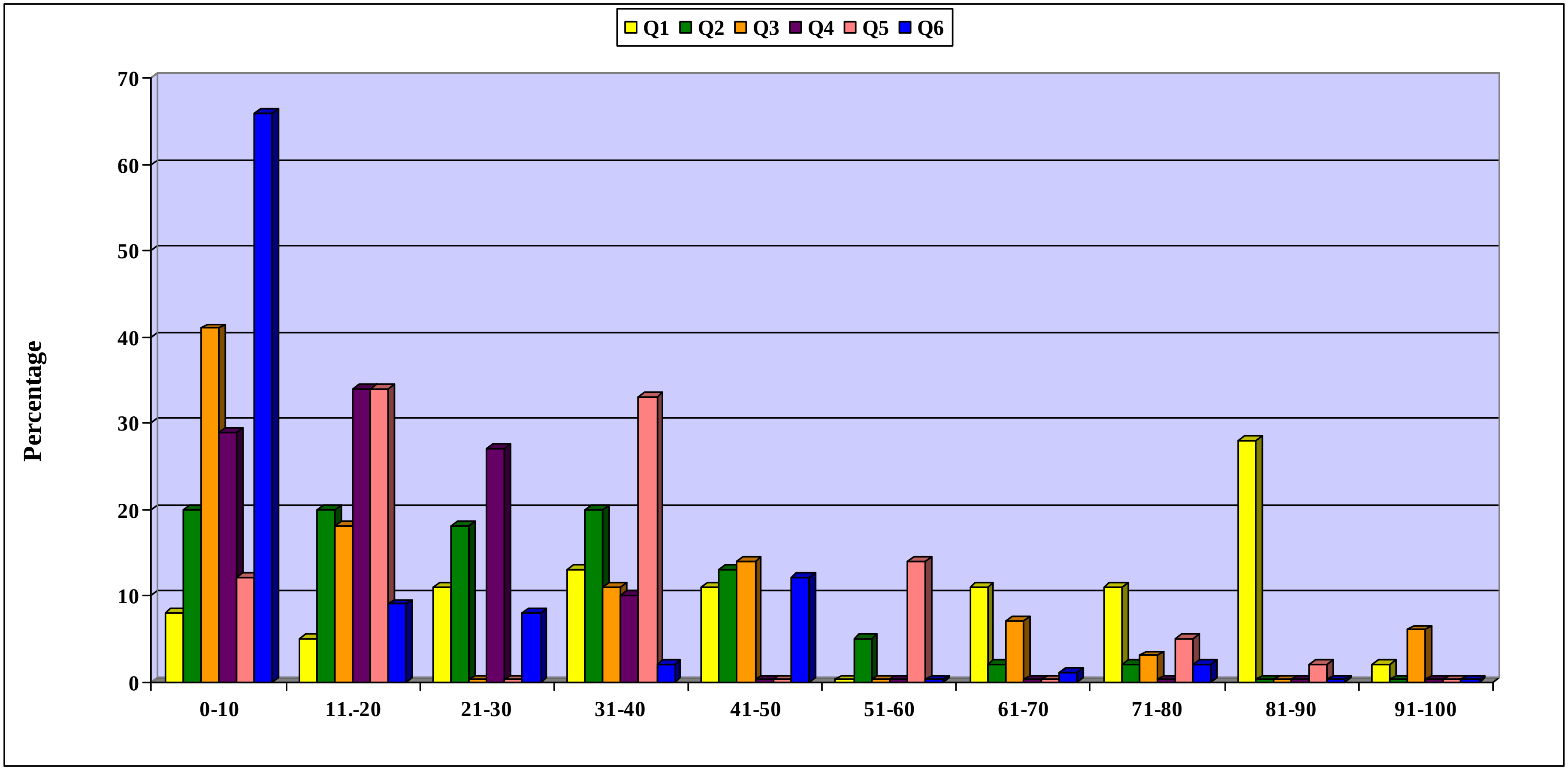


Figure 4. 2: Combined learners achievement scores per question

Figure 4.2 shows the overall achievement of all the learners in the six schools that participated in the research study. In the six schools, the maximum score was 70% at the range of 0-10. That is a poor performance. As the scores increase (up to 91-100), very few learners manage to obtain the higher scores. Maximum scores were 40% at 81-90 intervals.

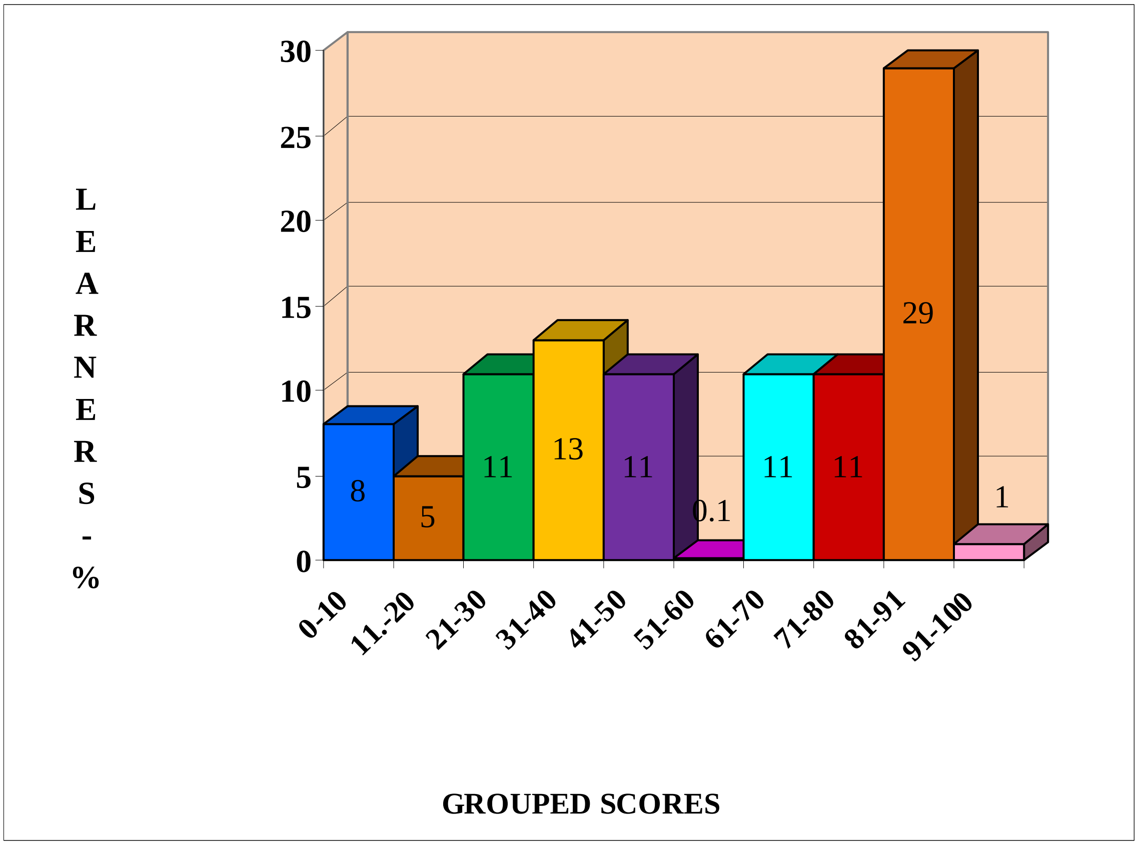


Figure 4.3: Achievement scores for question one

Figure three shows that 29% of the learners achieved scores of 81-90. This is a good score, but very few learners achieved it. The reason for high scores in this question is that it is at a low order question level by Bloom's taxonomy. Questions consisted of terminology and basic recall of information and required learners to choose the correct answer from a given list. This is a fundamental competence that all learners are expected to have. However, there were also low scores at the range of 91-100. Although this type of question does not demand written language usage, some of the learners could still not manage to make the grade. Their failure to supply the correct answers could be as a result of lack of knowledge, which may be caused by insufficient mastery of terminology. For instance, being asked what organic molecules controlled the dark phases of photosynthesis, some of the learners responded by stating these were “glucose, carbon dioxide, water and stomata.” It is apparent that the word “control” was not interpreted with understanding. This poses the question, do Black students fail to answer the question because they do not know the answer or because of language challenges (as they do not understand the question)? The overall result, however, also shows that it is easier to simply recall something that has been taught (by selecting from a list of multiple choice answers) than to supply an answer unaided and based on an understanding of the work.

There was also a lack of understanding of what an organic molecule is. Answers included inorganic molecules, such as water and carbon dioxide. The expected answer was enzymes. It was apparent that the word “control” was not interpreted with understanding. Another question asked for the exact location, within the chloroplast, of the occurrence of the light phase of photosynthesis. Responses included: “upper epidermis, chlorophyll and stomata,” while the expected answer was grana. The grana are structurally adapted for their functions. The learners’ responses show that they tend to memorise terms without trying to relate structure to function. This may also be due to an absence of practical work in schools without laboratories.

In another question, learners were asked to name the main photosynthetic tissue in an angiosperm leaf. This was a straightforward question, but some learners responded with “xylem tissue, respiration, cuticle and chloroplast,” while others did not answer the question. The expected answer was mesophyll tissue. This shows that some learners have a learning problem with regard to this topic, as there was evidence of a lot of guesswork. Robinson and Russel (2001) state that one of the fundamental challenges of teaching in areas such as biochemistry and biophysics is that learning in these areas involves the comprehension of objects and the processes that cannot be seen or experienced. Regardless of the sophistication of our understanding, and its fit with empirical data, we visualize these objects and processes using imagination, models and metaphor.

Achievement scores in question two are shown in figure four below.

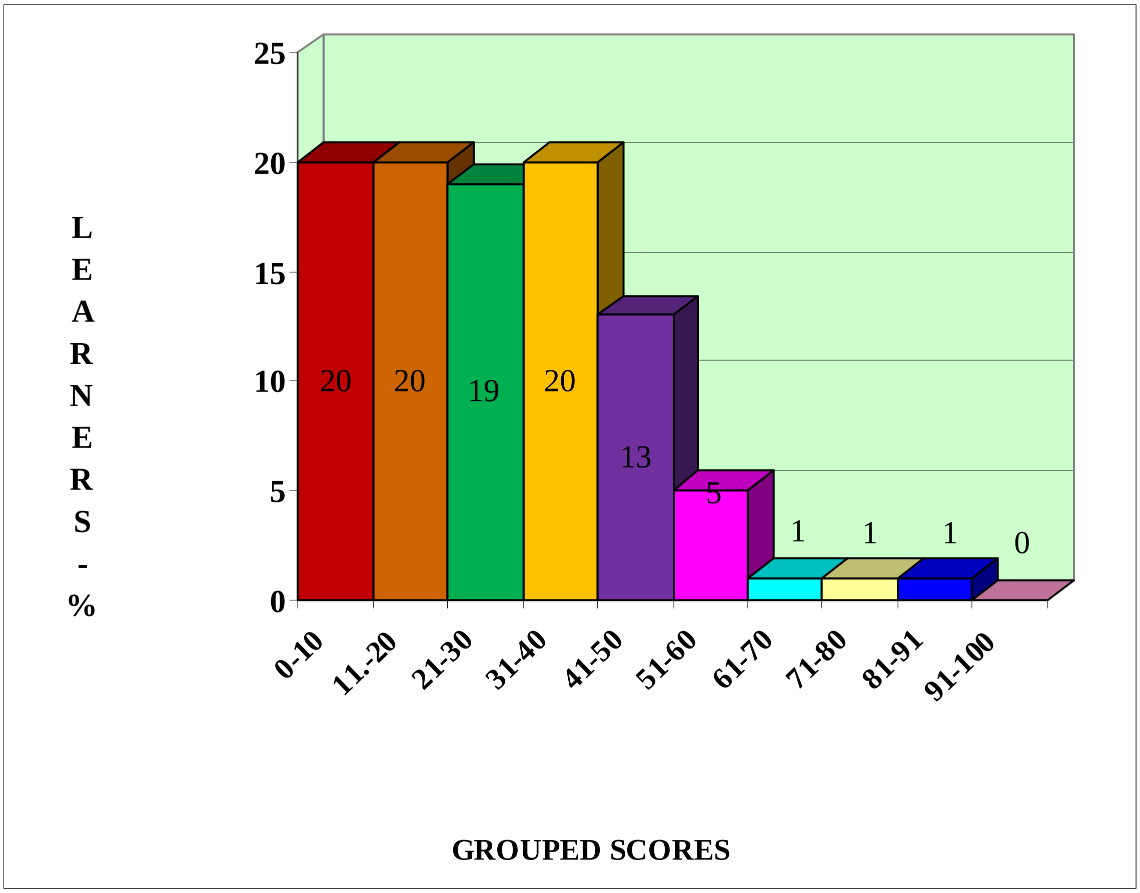


Figure 4.4   Achievement scores in question two

The pass rate in this question was very poor. For instance, 20% of the learners scored less than the range of 41-50 (figure 4). Only one percent of the learners passed this question at the score level of 71-80. The cognitive demands of the question show that the learners must be able to do the following:

- Study the diagram and make sense of how starch is tested for in a leaf. This includes procedural knowledge and knowledge of chemicals used.
- The function of alcohol (x) and the function of iodine (z).
- Being able to explain the change that occurs in a leaf after boiling in alcohol and how you soften the leaf.

- Knowing that in the scientific method there is an experiment and a control.
- Knowing what is the positive test of starch.

All these questions are easier for learners who have actually done the experiment than for those who must try to memorize the theory. Twenty percent of the learners scored 0-10 whereas only 13% of the learners fell in the range of 41-50. This is attributed to the language problem. For example, learners were asked to answer questions based on the diagram of the experiment to test for the presence of starch. This is an analytical question. If learners did the experiment practically the question requires comprehension and recall of information of this nature; it could be considered to be one of the simplest experiments in this topic.

There were cases in which it could be seen that the learners experienced language barriers; for example, they were asked to state safety measures when undertaking this experiment. Some of them responded as follows: "**make sure that the beaker is there, to keep the test tube away from the beaker, it can change into brown leaf, thermometer, lower than the optimum temperature**". This is a mixture of meaningless words. Learners need to have the experience of seeing that alcohol is a flammable liquid. Without practical work learners do not experience science like they are supposed to. The expected answer is: heat the alcohol in a water bath to prevent the vapor from catching fire. The learners' responses show that they are totally lost, which may, again, be due to a lack of practical work. Learners cannot comprehend science through imagination.

The other question which shows that the learners were confused due to a language problem or due to lack of laboratories is question two. Learners were asked to name the energy transformation which was about to take place. The responses included "light energy, chemical energy, radiant energy, light phase." They conflated all these, instead of just supplying the simple answer, namely that light/radiant energy changes/converts to chemical/potential energy. Language difficulties and insufficient teaching and learning facilities (i.e. a lack of laboratories) are huge problems that need to be addressed in the curriculum.

Buttner, (2000) and Fox (1999) states that if students are unclear about the principles before the practical, and take insufficient care in collecting data, they may gather data that is inconsistent with theoretical expectations. In large practical classes in particular, learning outcomes are affected by the quality of demonstration and the success of a particular experiment. The lowest percentages scored for performance in this question shows that there is a problem with regard to experimental work.

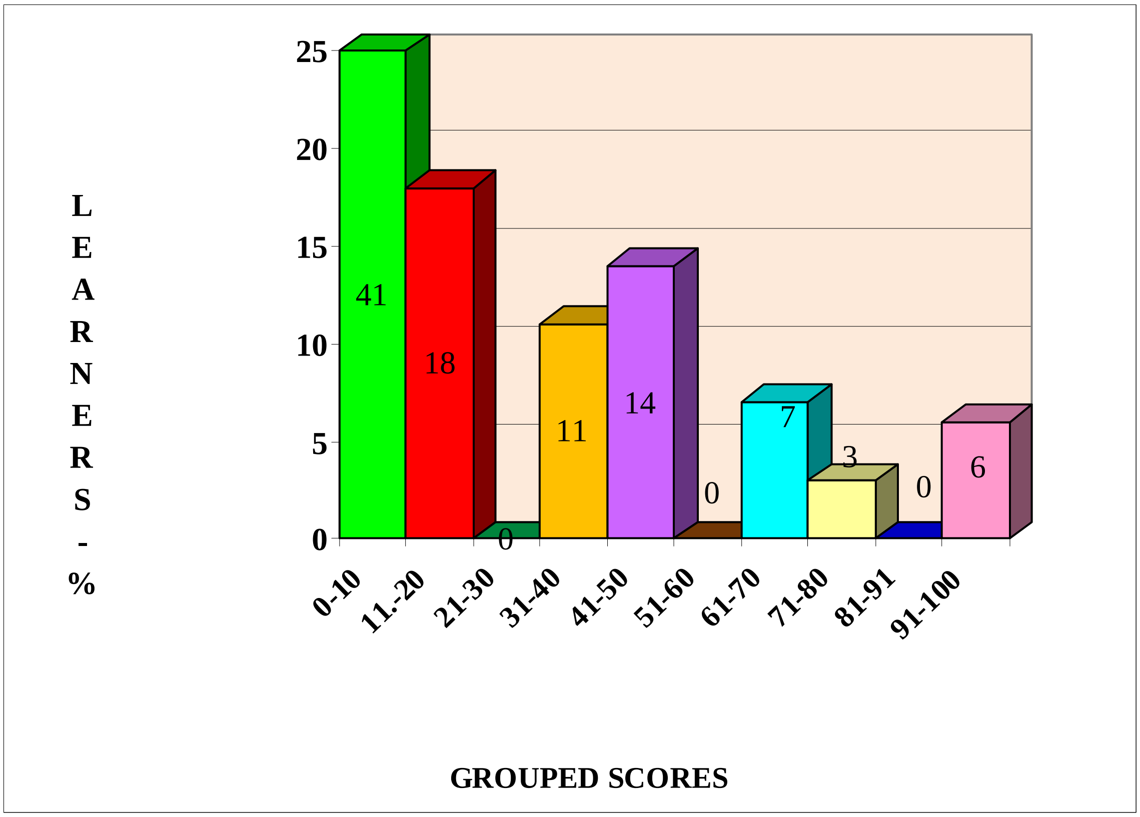


Figure 4.5: Achievement scores in question three

Question three was based on comprehension. Most of the learners (41%) scored between 0-10, which is the worst range of scores that could be expected from grade twelve. Indeed, it is the first time that the researcher has encountered such a high failure rate. Although many learners achieved a score interval of 20% in question two, the score level doubled in question three. This is indicative of a reading problem and poor thinking skills. Question three is based on laboratory work and, as the results showed, the appropriate experiment was obviously not done at all in certain schools. The question requires learners to write down the aim of the investigation. One of the responses reads as follows: “to whether chlorophyll, carbon dioxide is given during,” while other learners did not even attempt to write the aim of the investigation. When they were asked to write the meaning of the term “variegated leaf,” they wrote responses which show that they do not have any idea about the meaning of the phrase and that they experienced difficulty in expressing themselves. Some of their responses were as follows: “**it is a plant with two colors, leaf with two colors, is a different leaf, leaf with two regions, the pattern with white and green patches.**” The expected answer was “a green leaf with white margins.” The responses show that learners did have an idea of what was required, but that the language problem deprived them of the ability to express their thoughts coherently. The actual diagram shows a variegated leaf and explains it, but the learners exhibited poor observation skills and analysis of the given situation. Observation is a skill that has to be learnt during practical work. Achievement scores in question four are shown in figure 4.6.

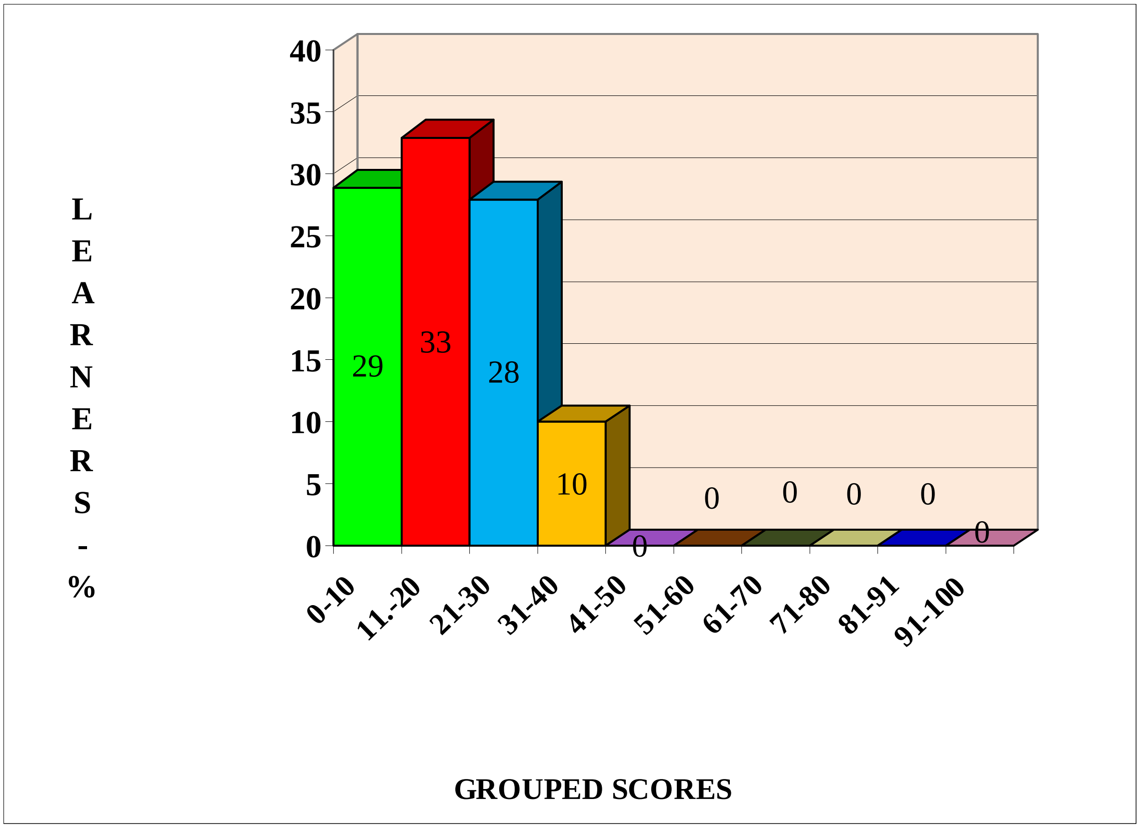


Figure 4.6: Achievement scores in question four

As indicated in the literature, photosynthesis is a difficult subject to understand. Question number four, which is represented in figure six, consisted of multiple choice type questions. The questions required the learners to understand different chemical processes that occur during photosynthesis, including the **inputs** (what is used in the process) and the **outputs** (what is produced). This question is based on the diagram of the apparatus used for measuring the rate of photosynthesis of a water plant. The diagram is likely to be completely confusing to learners who had never been in the laboratory. The learners' responses show that they failed to evaluate simply because they were not knowledgeable. It was easy to spot the schools that have not done this experiment. Most of their learners' answers were simply guesswork, while it was an easy question for those who had done the experiment. Most of the schools involved in the study are poverty stricken and have no laboratories, while those that had laboratories did not have the necessary apparatus. None of the learners achieved a score of above 50% (figure 6); most of the learners (33%) achieved a score of 21-30 intervals, which signifies failure.

The learners’ performance tells us that educators need to use analogies as suggested by Sahin (2000), who states that in individual analogies the student has an active role and realises these events in his/her mind. In visual analogies, the learners are aided in understanding the difficult concepts by means of diagrams and pictures, which are mostly also accompanied by oral explanations. Such analogies can help students to form resemblances between pictures and the abstract concepts by means of diagrams and pictures, which are mostly accompanied by oral explanations. Analogies are the most important tools in helping to accelerate conceptual change in scientific judgment with regard to learning and teaching (Duet, 1991). If educators can acquaint learners with learning through analogies, misconceptions as depicted in answers to this question can be minimised. Figure seven below shows learners’ achievement scores with regard to question five.

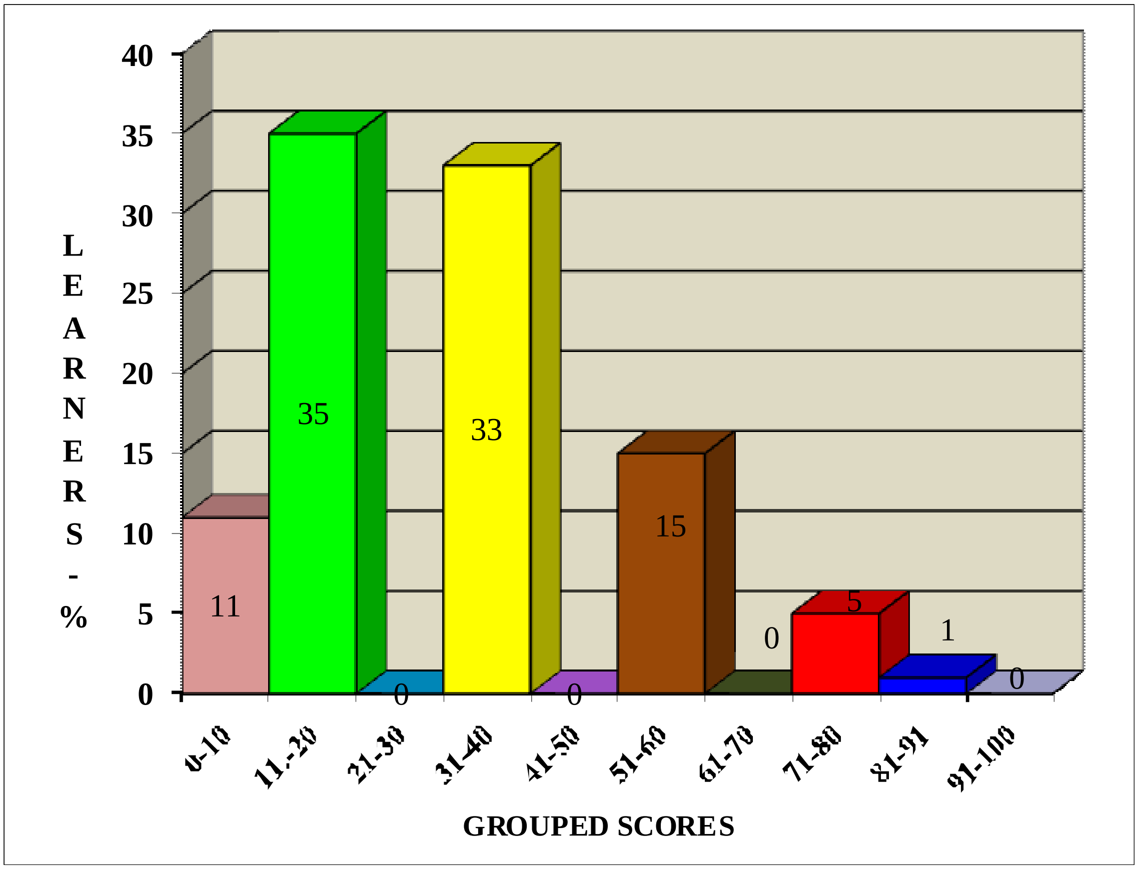


Figure 4.7: Achievement scores in question five

Question five involved activities that have to do with analysis and interpretation. The question is relatively easy for a learner who thinks carefully and evaluates his or her answer. Some 35% of the learners did not make an attempt to answer that question. This question involved a piece of a water plant placed in a solution near a bright light and which gave off bubbles of gas that is represented graphically. Some of the learners (5%) attempted that question and managed to get a high score of 71-80% even though they lacked knowledge of data interpretation. Learners failed to match the given distance and the time taken by the bubble to cover this distance. There was also a question on the rate of bubbling when the lamp was placed at 180mm distance from the plant. Learners' responses included: "5 per minute, the rate decreases, around 15, 13 minute, 12 bubblings per minute." The expected answer is 11-13 bubbles per minute.

The next question was intended to find out what happened to the rate of bubbling when the lamp was moved from 180mm to 200mm. Some of the learners could not see that the rate of bubbling would increase (as expected in the answer), while others claimed that they were mathematically illiterate, and therefore had little interest in calculations. This indicates that mathematics is needed in all science subjects. This is also evident to the government because it has introduced Mathematical literacy, which is a compulsory subject for all students in an attempt to improve mathematical literacy, thereby boosting learners' ability to do the necessary calculations. We hope that this measure will address the problem adequately as this question also revealed very poor graph interpretation skills among the learners, which is an example of poor mathematical literacy displayed by learners in schools.

Figure eight below shows achievement scores in question six.

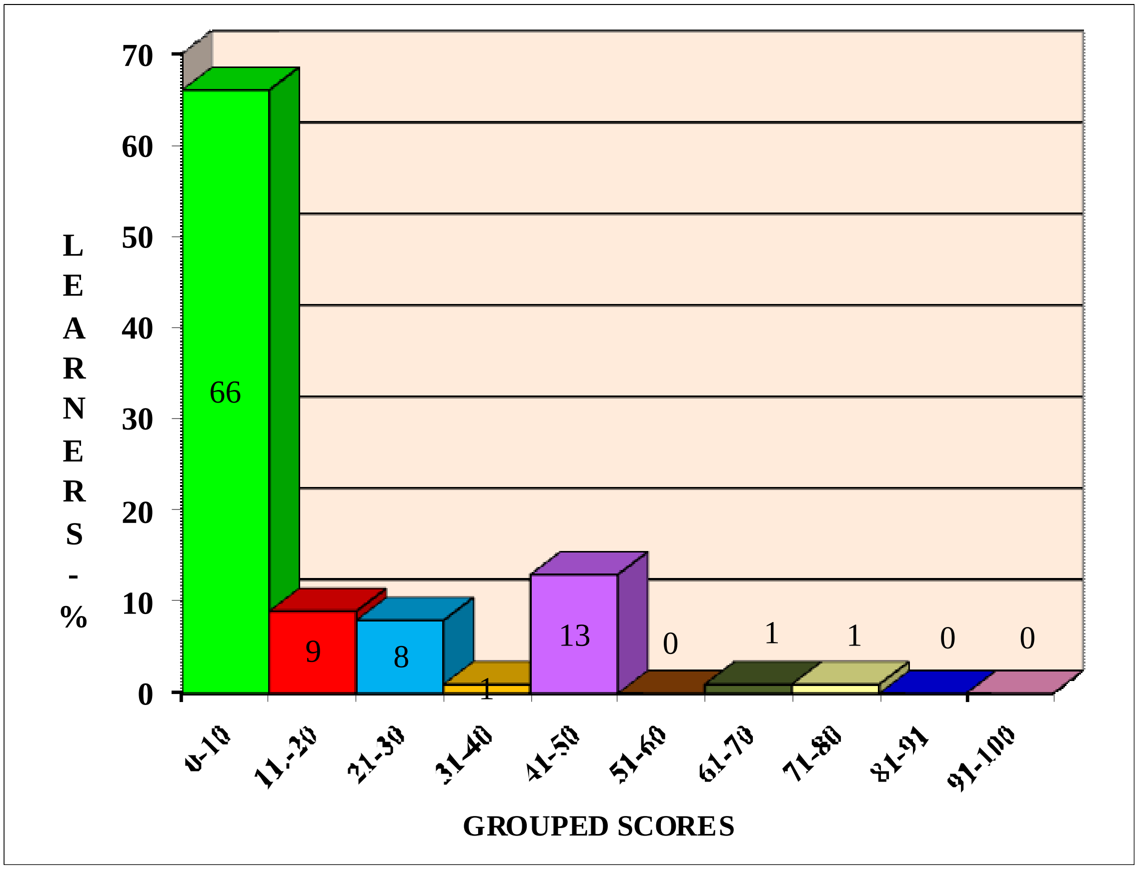


Figure 4.8: Achievement scores in question six

Question six required learners to evaluate and apply information. This was the question which most learners (66%) failed to answer correctly as witnessed by a majority of scores of between 0 and 10. This question required application of knowledge. Learners were given data of the results on the effects of light intensity on the rate of photosynthesis when the plant is placed in two concentrations of carbon dioxide. The learners were asked to plot a curve on the graph paper to show these results. Most of the learners did not plot the graph. Most of them did not attempt the question; those who did try to answer displayed a lack of knowledge of graph work. They were unable to identify the axes of the graph on which to plot relevant information. Learners were not sure of the type of labels to put on the y-axis or the x-axis. This indicates that learners in Biology need to do a lot of graph work in order to achieve desired standards. Learners were also asked to draw conclusions from the graph. This was not easy for them, as witnessed by the fact that most of them even failed to draw the graph.

The answers provided by some of those who tried to solve the problem indicate severe language problems. This is apparent in answers such as: "When there is more carbon dioxide and the light than the rate of photosynthesis is light, provides energy to all the tropic levels, it increases from 1 unit to 5 units." Some answers were totally incorrect and incoherent. Learners just wrote what came to their minds, including nonsensical phrases such as: "tissue denatured, it can be harmed the rate of photosynthesis when it optimal." The expected answer was that the rate of photosynthesis is higher at a carbon dioxide concentration of 0, 13% than at 0, 03%; for both concentrations the rate of photosynthesis increases up to a light intensity of 5. This question certainly shows that the learners have a very poor level of mathematical literacy. It was difficult to believe that such poor responses were produced by grade 12 learners.

Once learners saw the figures they became totally lost – and yet the question is very easy and straightforward. The question of mathematical phobia among African learners is one that needs to be addressed by the government; this must be done by training more educators to become mathematically literate. Fortunately, there is an Advanced Certificate Program that is sponsored by the government and is presently being harnessed to train educators in mathematically literacy. The question of the medium of instruction and effective learning is one which the government still has to confront and solve if Africans are to benefit more fully from education.

4.9 LEARNER ACHIEVEMENT IN RELATION TO THE LOCATION OF THE SCHOOLS

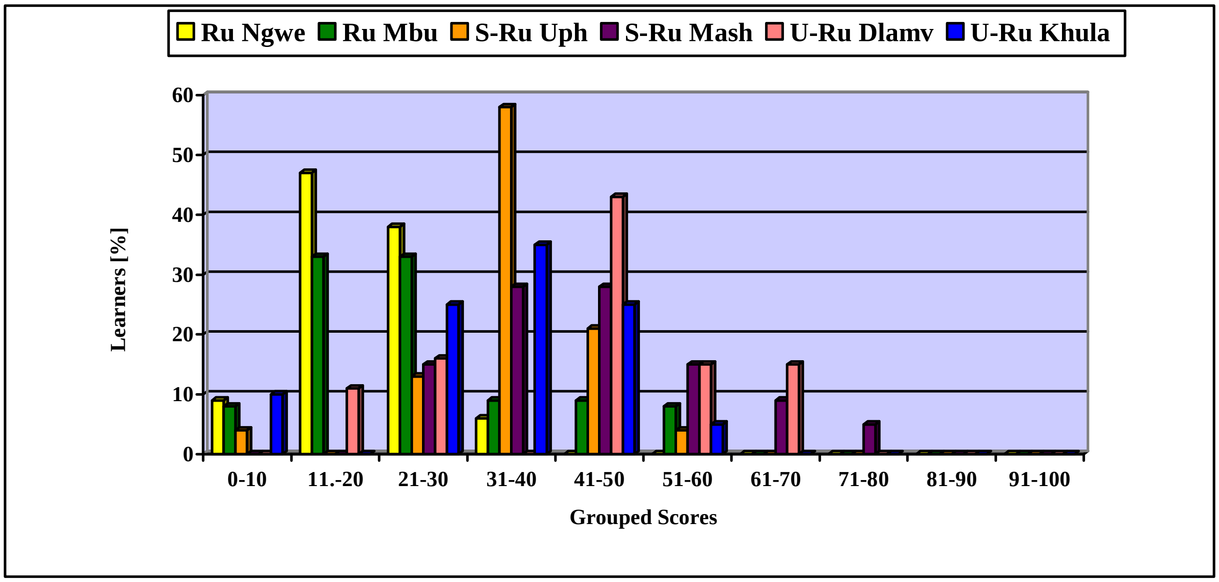


Figure 4.9: Comparison of achievement scores among schools

Figure 9 show that, generally, the urban schools achieved more than the rural (Ru) schools. For instance, at the range of 40-50 scores, the urban (Ur) schools obtained 42% as compared to 8% obtained by the rural schools. When looking at the lowest scores range, only rural (10%) and semi rural schools (SR) appeared. No urban schools registered that range of marks. On the other hand, only urban schools managed to obtain the higher range of scores, i.e. from 61%-70%. The reasons could be that in urban areas schools are well resourced; they have libraries, laboratories and electronic media, e.g. television. The learners receive support from parents who are educated and they do not come to school exhausted by having to walk long distances like the learners in the rural schools. The main reason for low scores in rural schools could be lack of parental care and guidance. Parents often work in towns and come home late and tired. Schools are not well resourced in rural areas and it is known that well qualified educators prefer to work at urban schools.

The researcher was amazed to find out just how much students can learn from access to the internet. Learners in rural areas would benefit immensely from lessons prepared by experts in the field of biology. Even if their teachers were unqualified to teach biology, they could get good material and well structured lessons free from the internet. Examples of some of these lessons have been included in this dissertation.

As stated in Chapter 2, Bently and Watts (1989) believe that practical work plays a major role in the teaching of science subjects. Rural schools maybe underperforming because they lack practical work experience; some have no laboratories, and if the do have laboratories these are often not functional. Practical work arouses interest and encourages accurate observation and description. It also promotes a logical, reasoned method of thinking. It makes phenomena more real through experience. Practical work also helps learners to comprehend and carry out instructions. It is also believed that self-discovered information or knowledge is lasting. Some of the questions in the test required both experience and knowledge of practical work. Those who were not exposed to practical work did very poorly in interpreting experiments. The government should seriously consider supplying poverty-stricken schools with the necessary resources if their right to access effective education is not to be violated.

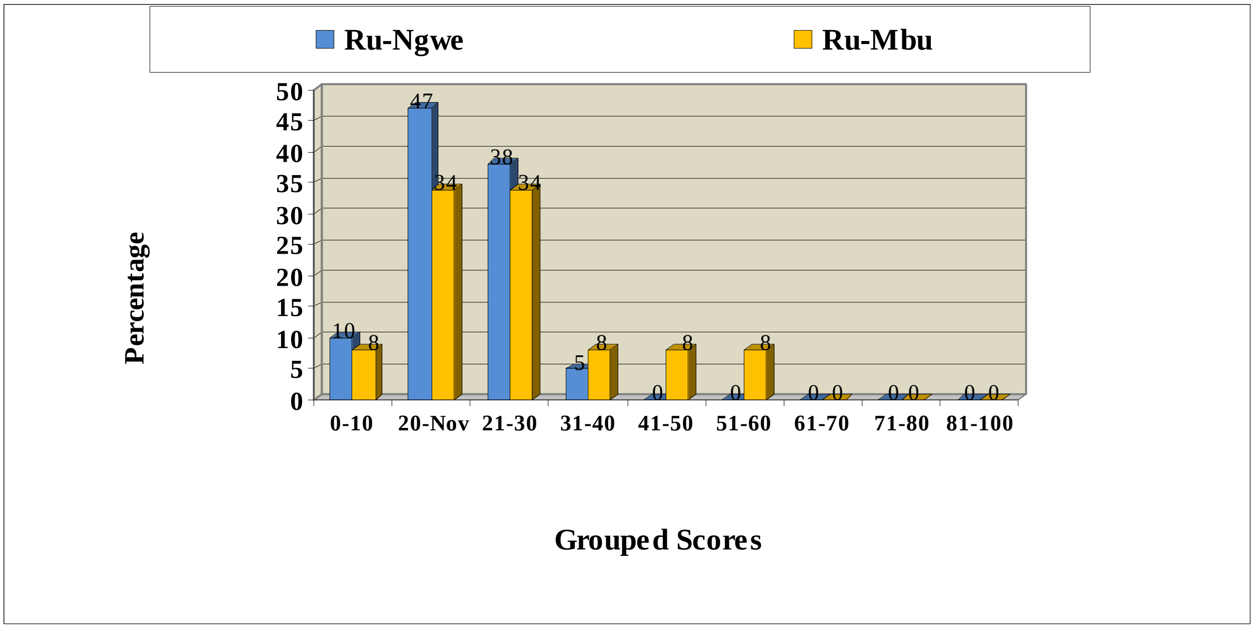


Figure 4.10: Achievement scores in rural schools

Scores obtained by rural schools are shown in Figure 10. These schools showed poor performance, such that the most learners (35% and 48% respectively) scored marks of between 11 and 20%, which is very poor. The results are a true reflection of low socio-economic status, which is one of the barriers of learning. In rural areas most of the learners are not motivated. They lack external motivation due to a number of reasons, including the fact that their environment does not have tertiary institutions that can serve as an external motivation for learning; their parents receive low incomes; there is a high level of illiteracy in the community, including their parents; their educators are less experienced since educators prefer to work in urban areas, and a lack of security is not conducive to the safe storage of laboratory equipment. The results from semi-rural schools, presented in figure 4.11 below, showed a different trend.

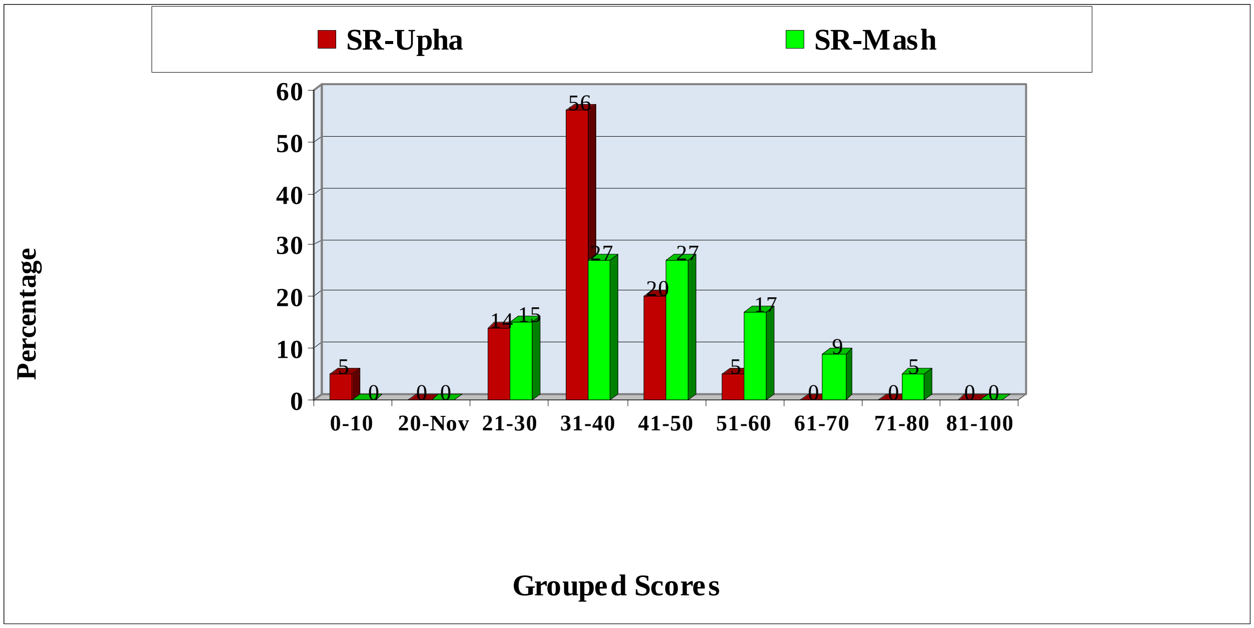


Figure 4.11: Achievement scores in-semi rural schools

This graph tells us that there are very few learners in semi-rural schools who achieved below 30%, which is the opposite of figure 4.10. Most learners scored between 31%-40%. Although the graph does not record a good performance in semi rural schools, it tells us that most learners are average achievers. Some learners in these schools are motivated but there is still a need for greater motivation. Semi-rural schools are better than the rural ones because they are positively influenced by the urban places in the vicinity that are endowed with educational amenities, such as science centres. For example, at Empangeni learners have the opportunity to visit a science centre in order to do practical work. They can also borrow some of the apparatus and conduct experiments in their schools, once these have affiliated with the Centre for Advancement of Mathematics and Science Education (CASME). They also have the opportunity to play video cassettes on a television set and observe demonstrations of experiments. There are also certain programmes on TV that enhance the teaching of science; disadvantaged learners in rural areas do not often get the chance to watch such programmes.

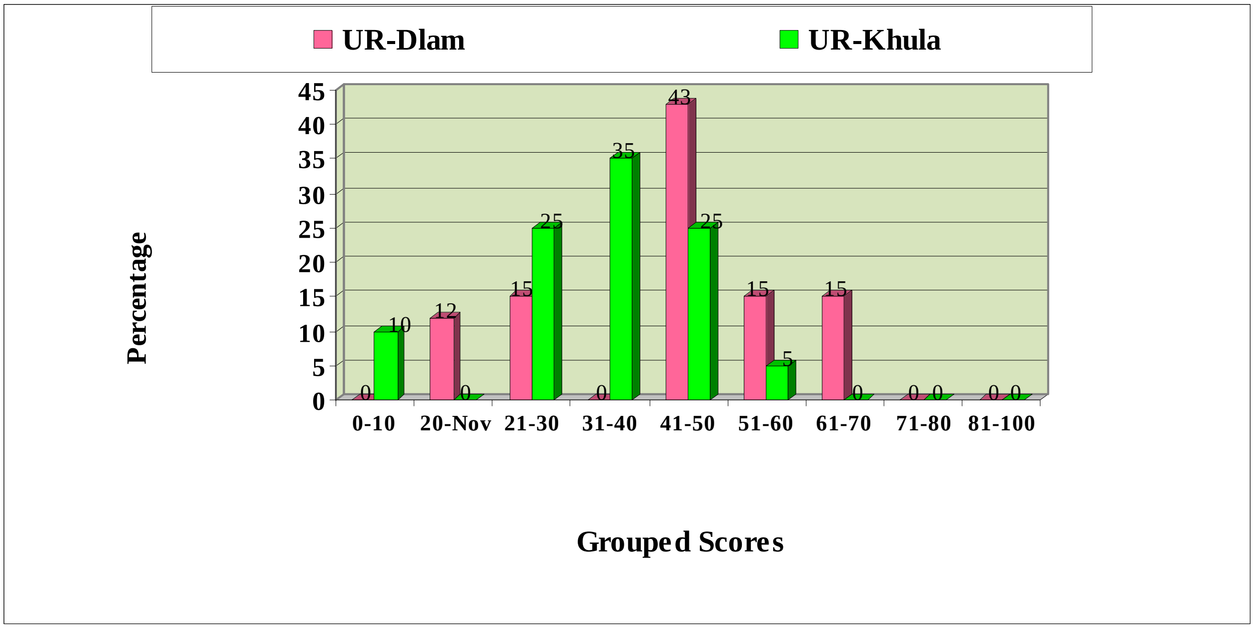


Figure 4.12: Achievement scores in urban schools

The graph above shows that the highest number of learners scored between 41-50, which is above average and significantly higher than the scores achieved by learners in the rural and semi-rural areas. Most learners scored above 40%, which means that the conditions of these schools are better than those at rural and semi rural schools. These schools have functioning laboratories and libraries. As most qualified educators prefer teaching in urban schools, these schools have the opportunity of choosing the best educators. The government has mooted incentives for teachers in rural areas, and one can only hope that this will happen in the near future to encourage qualified educators to teach in rural areas. These results are a true reflection of the statement made by Millar (2004), who states that, in the context of the teaching of scientific knowledge, practical work is best seen as an act of communication. In practice, the representations we construct are tested out not only through action, but also through interpersonal interaction. The role of practical work in the teaching and learning of science content is to help students make links between two domains of knowledge: the domain of objects and observable properties and events on the one hand, and the domain of ideas on the other. For example, in the first category the main aim of practical work is to enable students to observe an object (or material or event or phenomenon), to note some aspect of it, and perhaps be able to recall these. Without first-hand, practical experience of the world, it is hard to see how a student could ever come to an understanding of it.

4.4 STATISTICAL ANALYSIS

4.4.1 Statistical test of boys and girls

A t-test statistic was used to calculate if there were any significant statistical differences between boys and girls with regard to their achievement scores. The findings are presented in the table below:

Table 4.1: One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Boys	56	35	15	2
Girls	88	37	17	2
Average	72	36	16	2

Table one indicates that there were no significant differences in the achievement scores of girls and boys at the 95 confidence level (standard error > 0.005). The results show a narrowing of the gap between boys and girls with regard to achievement scores in the Life Sciences learning area. Historically, boys tended to achieve higher scores than girls in science subjects, but the government's efforts in levelling the playing field has resulted in an improvement for the girls, as witnessed by the closing of the gap in the achievement scores of boys and girls as reflected in table 4.1.

4.5 STUDENTS' CAREER INTERESTS, AGAINST THEIR PERFORMANCE

Scores were analyzed in 3 categories, i.e. students with career interests that required Biology (NB), students with career interests that did not require Biology (DNNB), and students that have not yet decided upon their future careers (ND).

Table: 4.2: Students' career interests, against their performance

Students	Total	Passed	%	Fail	%
NB	40	23	58	17	42
DNNB	50	22	44	28	56
ND	51	16	31	35	69

Learners' scores indicate that the pass rate in Life Science reflected their career interests. The data above tells us that an interest in Life Science also stimulated learners' desire to do well in preparation for a future career in this field. Some learners do not perform well in Life Science because they view it as just an additional subject, while their focus is on other subjects. Piaget states that educators need to have a full understanding of children's moral, social and emotional development because this is useful to educators in terms of understanding their learner's cognitive development. African learners in general tend to think about future careers too late, for instance, at the end of grade 12, and find that they have made wrong learning area combinations.

Learner performance, as reflected in table 4.2 above, shows that those who seem to be less in need of Life Science for future career also put less effort into passing that paper. Although this finding cannot be generalised, it is important to use this information to inform learners about the importance of career choices and the need to take Life Sciences seriously. Furthermore, the subject addresses issues that affect all living organisms irrespective of future life careers.

4.6 DISCUSSION

Although there were no significant differences in learners' achievement scores at 95% confidence interval, the graphs show that schools in urban areas performed better than those in rural areas. Most of the schools in rural areas have no electricity, laboratories and libraries. All of these missing needs contribute to the learners' performance. Schools without libraries deprive learners of the opportunity to improve their English, which is the medium of instruction. A general comment can be made that pupils fail not because they do not know the facts but because they fail to express themselves in English. A factor that tends to complicate learning in Life Science is the shortage of biological terms in the learners' mother tongue in contrast to the oversupply of demanding terminology that he/she encounters (and is expected to master!) in the medium of instruction, namely English. Photosynthesis is a practical topic; it is very hard to learn it without experimental work. Rural schools without laboratories really deprive learners of hands-on experience. Electricity also necessary in order to utilize the wide range of audiovisual aids that is available to demonstrate experiments that are supplementary to laboratory work.

4.7 CONCLUSION

The statistics show that learners from rural areas are poor performers due to a number of reasons. Some learners lack the necessary support from parents who work in urban areas due to economic factors. Some of the learners in deep rural areas take care of themselves with no figure of authority to establish disciplined homesteads. The homesteads may not have a radio or television to assist them to know what is happening in the world around them. Learners from semi-rural areas outperform those in rural areas; this may be due to the fact that their socio-economic status is somewhat better than that of their counterparts in the rural areas. Semi-rural areas do have electricity and some parents (especially those who are not migrant labourers) own their homes and are therefore able to provide the learners in their families with the necessary support. Schools in urban areas outperform those in other areas. This is so because learners from these schools mostly live with their parents and also get the necessary support from them.

Parents in urban areas are, in most cases, educated and able to assist the learners in some of the learning areas. The learners may also be motivated by the surroundings, including the universities and technical colleges that are nearby. Better performance at school also relies upon parent support and a home that is conducive to study – including factors such as adequate light to study. Parents from urban areas also tend to hold better paying jobs, which means that they have enough money to rescue their children. They are able to pay for their stationery and can afford to expose them to excursions, recreational facilities and other enriching experiences. They are also able to support their children academically by exposing them to public libraries and by buying them educational videos and paying for extra classes.

CHAPTER FIVE

5.0 SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

This chapter presents a brief summary of the results of the study and implications of the research. The chapter also highlights crucial findings from the study, which could assist education practitioners, particularly in rural areas, to improve their practice. Misconceptions about photosynthesis have been underscored and the study confirms that these exist across all communities of different races and cultures. The study also confirms that photosynthesis continues to be a challenge to students because it is such an abstract concept. The literature review suggests ways that can be used to try to demystify photosynthesis and help students to master applicable concepts, practical work and technical vocabulary.

5.2 RESEARCH FINDINGS

5.2.1 Availability of Teaching/Learning Facilities and Resources

With reference to the first aim of the study, namely to investigate to what extent the availability of facilities and resources affect learners' performance in photosynthesis, the following results emerged:

- The schools that did not have facilities such as laboratories, libraries and teaching aids such as television showed very poor performance, which implies that teaching and learning of photosynthesis is more effective if the school is resourced. The schools need to do all in their means to obtain such facilities because photosynthesis is a practical topic. It must have been very difficult for learners to respond to practical questions in photosynthesis when they had never done practical work in this field before. Hands-on learning has always been recommended as the kind of learning that can produce permanent results, because learners tend to learn better when they are involved. Other resources such as libraries help learners to find a variety of books, some of which explain things in a way that is more accessible than others.

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The government has been making promises to improve schools so that there is equal opportunity to learn effectively instead of this seemingly being a right that is restricted to learners in well-resourced urban schools. A UNESCO (2007) poses the question whether we will reach the goal of education for all by 2015. There is no doubt that everything possible must be done to realize this goal because the inadequacy of physical and material resources in schools has an adverse effect on learner achievement in especially the developing countries. This need can also be extended to instructional materials. The UNESCO publication (2007) furthermore states that international and regional assessments reveal a pervasive low achievement. The result is that key conclusions from international and regional student assessments point to low learning outcomes in much of the world. The present research, as crystallized in this dissertation, serves to highlight the current position of this country and some of the steps that should be taken to ensure that our learners learn effectively by addressing shortcomings in our education system.

5.2.2 Learners' Background and its Effect on Education

Regarding aim 2, namely to investigate to what extent learners' background affect their performance, the following seemed to confirm that disadvantaged communities are not only economically disadvantaged but that such disadvantage also impacts negatively on learning.

It was evident from the results that learners from underdeveloped backgrounds and who do not get support and encouragement from their parents are not likely to do well. Such learners are disadvantaged in so far as exposure to all the modern day facilities which enhance learning is concerned. The learners from rural areas did very badly compared to those from semi-rural and urban areas. They seemed less knowledgeable in a number of areas that their peers managed to master. Some children in urban areas have access to computers which expose them to the internet and a whole world of knowledge. They can access Wikipedia and enrich their minds with well researched definitions. Access to this kind of information helps the learner not only to improve his/her content knowledge but also to improve language skills. The more one reads the more one masters the language.

There is a need for government to deliver on better services for impoverished schools in rural areas. A comment by the well-known academic, Prof Jansen, as published in the *Sunday Tribune* of the 4th of January 2009 under the heading “Old school: new system produces same results” is interesting in this regard. Prof Jansen states that matriculation results mirrors the new economics of the country, showing that the middle-class White and Black learners, predictably, perform better than the rural and urban poor.

5.2.3 Gender Issues in Education

In this study the girls achieved much higher scores in some of the questions than the boys. The South African government has been concerned about the poor achievement of girls in science and a clear directive has been given to educators to ensure that girls are encouraged to do science. There has been emphasis on equality and equal opportunity to study and to pass science. This message seems to be working. In a paper presented at the International Organization of Science and Technology Education (IOSTE) entitled ”Learning Biology in Student-Relevant Contexts,” Elster and Bayouber contend that many students find school science boring and irrelevant to their lives. However, in this study it was also found that girls respond positively to biology. Boys in poverty-stricken rural areas find themselves more vulnerable than girls to engaging in strong drink, drugs and general lawlessness.

The results of the study were, however, consistent with what Imenda (1989) found in a research project that explored gender differences in science achievement amongst Swazi Primary Teacher Trainees. This study showed statistically significant differences in favour of females with regard to scores in Biology questions.

5.2.4 English as a Medium of Instruction to Second Language Speakers

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Looking at the learners’ responses, it was evident that language is a barrier to some students. This is borne out by many examples of irrelevant and incoherent answers, as well as a collection of English words that did not make sense in the context in which they were used. Poor ability in language usage also means that, even if the learner knows the answer, it will still be difficult for him/her to express it in a second language such as English. Answering questions on practical work requires learners to be able to express themselves in order to reflect accurate and precise observations and conclusions. Some learners are clearly disadvantaged in this regard because it demands following of discussion which is not in their mother tongue. There is an ongoing and long-standing debate about teaching learners in a foreign language.

Unfortunately there is no consensus about what should be done and the learners continue to be failed by the system. Problems in adopting ethnic languages as the medium of instruction include a lack of appropriate terminology for scientific words, a lack of textbooks in ethnic languages and a lack of motivation and will in the government to address the issue. Parents also want to see their children learning in the language of business, in spite of the language being a barrier to successful learning and mastery of concepts.

5.2.5 The extent to which the career interest of the learners affect their performance

- The learners' choice of careers in the context of their performance levels reveals that learners whose future careers do not required Biology performed below the level of those who stated that their career choices demanded Biology as a school subject. Learners who chose careers like nursing, medical doctor, dentist, dietitians, veterinary did well because 90% of them scored above 45% which is acceptable. One can conclude that the learners who scored better grades were motivated by their desire to enter careers focusing on biology, among other incentives. This tells us that a choice of career early in life may be a strong motivation to do well in relevant subjects.

5.2.6 Action plan for the identified problems

- *Recommendation for aim No 1:* Educators need to explore all avenues to find possible ways of obtaining the facilities that are necessary to make their teaching and learning effective. For example, if their departments cannot afford to provide the necessary buildings and facilities they must write letters of motivation to major sponsor companies in an effort to raise the necessary funds.

- *Recommendation for aim No 2*: Educators need to motivate parents because the fact that their children have managed to reach the grade 12 level implies that they are deserving of every effort to help them succeed in completing the final grade in school. This may mean that parents have to make even more sacrifices in order to assist their children. Learners must also seek donations, no matter how small. Learners furthermore need to be creative and find ways to improve their school. Biology students, for instance, could start vegetable gardens, not only in order to "green" their schools, but also to earn the necessary income to buy basic amenities for their schools. Middle class urban schools, where facilities are good, always seem to be raising funds in order to buy the extra equipment and paraphernalia that their budgets cannot accommodate. Schools in rural areas should try to do the same.

- *Recommendations for aim No 3*: Girls need to have a girls' corner at school for the purpose of arranging occasions where they can listen to motivational speakers, including educators and/or prominent figures from outside the school. They need to be taken care of because in their relationships they tend to end up being victims in circumstances that have a disturbing influence on their performance. Educators must not focus on academic matters only but also on social aspects that promote good performance so as to reap good results from both boys and girls.
- *Recommendation for aim No 4*: If learners can be forced to speak English all of the time at school, they can improve their proficiency in the English language considerably. This could possibly be achieved through positive motivation and reward, while a negative response could be discouraged by a form of punishment, such as detention. It is well known that learners from schools where the speaking of English during the school day is enforced become more proficient in the language.

- *Recommendation for aim No 5:* Learners need career advisors to tell them more about the importance of passing all the subjects so as to have a wide scope of choices and they also they need knowledge about how to achieve the higher marks demanded for entrance to universities. Educators need to arrange for appropriate counselors to assist learners, as motivated learners who succeed in passing their grades are also in the best interests of the educators. Dlamini (2002) states that many young people, unless guided very well, do not realize the need for a strong early education in mathematics, science and Life Sciences in order to prepare for a career in science. Given the freedom to choose their curriculum, most Black learners tend to avoid the "difficult" subjects and choose easy subjects that do not demand much abstract thinking – thereby denying them access to science and technology.

Many students at the University of Zululand opt to teach Life Orientation and Languages because of earlier poor choices of subjects. Such teachers often end up not being in demand for employment.

5.3 THE VALUE OF RESEARCH

It is hoped that this study will not only benefit the researcher in (terms of providing the necessary material for a Masters dissertation) but also the participating schools and biology teaching as a whole. The schools stand to benefit from the research in that it reveals some of the areas in which the learners are weak and such insight can assist them in deciding what kind of revision is desirable. The researcher endeavored to assist the learners by arranging a practical session at the university in order to expose the learners to practical work in photosynthesis. It is hoped that information gained from the students' performance will also be helpful in determining when or at what grade the topic photosynthesis should be introduced to the learners. It might help to start the topic at grade 11 in order to give the learners a more time to master the abstract concepts. The shortcomings of each school with regard to photosynthesis were discussed with the schools concerned. It is hoped that information gained in these discussions will help them to improve their results.

The researcher benefited from the study in the following ways:

- The practical process combined with in-depth reading and careful thought that culminated in the compilation of a Masters dissertation taught the researcher a great deal about the various stages of research and the joys of postgraduate study.

- The researcher attended a local conference arranged by the National Research Forum for Postgraduate Students in KwaZulu-Natal and presented a poster entitled: Conceptual understanding of photosynthesis. The conference was in held in the Pinedene Hotel in Pinetown from the 11^{th} to the 13^{th} July, 2008.

- The researcher plans to publish a paper in a SAPSE-recognized journal, and future benefits may emerge from this initiative. This may include efforts towards improvement of the way in which biology, and photosynthesis in particular, is taught.

5.4 CONCLUSION

It is generally recognized that an environment conducive to study is required for effective performance of academic work of any nature. This is also true for learners in the field of science and, in this case, photosynthesis. An appropriate leaning environment and adequate teaching resources is of crucial importance if success is to be achieved. According to the findings of this study, there are three factors that appear to have a negative impact on effective learning in impoverished rural areas. These are a lack of learning tools, poor mastery of language of instruction and parents who are not able to help their children to aspire to greater achievement.

Educators need to make sure that they do not focus on academic content only but also cater for the holistic development of their learners. They should teach them values by motivating them to work hard in order to achieve their goals and by helping them to get information on possible careers that are available to them. Educators must have full knowledge of their learners so that they can detect the kind of problems that are discussed in this study, because there are solutions. The conclusions of this study are supported by a UNESCO (2007) entitled “Education for all by 2015: Will we make it?” The paper states that the inadequacy of physical and material resources in schools adversely affects pupil achievement in many developing countries. Inadequacies include poor instructional materials and poor infrastructure. Any government seeking to improve results in teaching and learning needs to prioritize the provision of environments that are conducive to learning – for all the learners, including those in rural areas.

BIBLIOGRAPHY

Amir, R. & Tamir, P. (1994). In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: The case of photosynthesis. *American Biology Teacher* 56: 94-100.

Barker, M. & Carr, M. (1986). "Teaching and learning about photosynthesis". *International Journal of Science Education 11*.

Beadle, C.L.; Long, S.P.; Imbamba, S.K.; Hall, D.O. & Olembo, R.J. (1985). *Photosynthesis in Relation to Plant Production.* England: Tycooly Publishing Limited.

Beakes, G. (1993). A picture is worth a thousand words. A personal view of using images in the teaching of the biological sciences. *Bioscience Education E-journal, volume 1.*

Bentley, D.I. & Watts, M. (1989). *Learning and Teaching in School Science*. Oxford : Alden Press Limited.

Bertram, C.; Fotheringham, R. & Harley, K. (2001). *Curriculum Studies, School of Education, Training development*. South Africa. University of Natal.

Bertram, C.; Harley, K.; Grant, C. & Fotheringham, R. (2003). *Understanding Research.* South Africa: School of Education and Training, University of Natal.

Brophy, J. and Rohrkemper M. (1981). The influence of problem ownership of teachers perceptions and strategies for coping with problematic students. Journal of Education psychology,73'2955-311.

Brophy, J.; Alleman, J. 1991. Activities as instructional tools: a framework for analysis and evaluation. *Educational researcher.* Washington, DC (20) 4: 9-23.

Brown, D.E. (1992). Using examples and analogies to remediate misconceptions in physics: Factors influencing conceptual change. *Journal of Research in Science Teaching*, 29(1), 17-34.

Brown, J.; Cooper, A.; Horton, H.; Toates, F. & Zeldin, Z. (1986*). Science in schools.* Great Britain: British Library Cataloguing in Publication Data.

Butcher, H.J. (1968). *Educational Research in Britain*. London: University of London Press LTD.

Buttner, J.K. (2000). Photosynthesis and respiration in a jar. *Science activities*, 37 (2) 10-15.

Canal, P. (1999). Photosynthesis and "inverse respiration" in plants: An inevitable misconception? *International Journal of Science Education* 21: 363-371.

Carter, J. L. (2004). Developing a curriculum for the teaching of botany. _Plant Science Bulletin _ 50: 42- 47. http://www.botany.org/bsa/psb/2004/psb50-2.pdf

Campbel, N.A.and Reece , J.B. (1995) Biology Benjammings; New York.

Dekker, J.G. (1989) Advanced Biology. Cape Town: Juta and Co.

Dilemmas, needs and partnership (2006) *Science and Technology Education for a Diverse World.* Maria Curie-Sktodwska: University Press.

Dlamini E.T. (2002) Non-Traditional Career For Black Children In South Africa In N.Bizzo, C.S.Kawasaki, L Feracioli and da Rosa (eds). International Organisation For Science and Technology (IOSTE) Symposium Proceedings 28th July 2nd

August 2002 Foz do Iguacu, Brazil.

Donald, D.; Lazarus, S. & Lolwane, P. (2002). *Education Psychology in social context.* South Africa: Oxford University Press.

Duit, R (1991). On the role of analogies and metaphors in learning science. *Science Education,* 75(6) : 649-672.

Driver R. (1993) The name of the games, *School science review*, (197)

Esiobu, G. O., & Soyibo, K. (1995). Effects of Concept and Vee Mappings under Three Learning Modes on Students' Cognitive Achievement in Ecology and Genetics. *J. of Research in Science Teaching, 32*(9), 971-995.

Fenshan, P. (1988). *Development and Dilemmas in Science Education*. London: The Falmers Press.

First ordinary meeting of the steering committee of the ministers of education of The African Union (COMEDAF) (MAY 2007) Ababa, Ethiopia.

Fox, M., Gaynor, J.J., & Shillcock, J. (1999). Floating spinach disks –an uplifting demonstration of photosynthesis. *Journal of College Science Teaching*,28 (3), 210-212.

Furze, B. De Lacy, T. & Birckhead, J. (1997). *Culture, Conservation and abaiodiversity*. New York: John Wiley & Sons.

Gipps, C.V. (1995). *Beyond Testing: Towards a Theory of Educational Assessment*. London: The Falmer Press.

Hall, D.O. & Rao, K.K. (1994). *Photosynthesis*. Great Britain: Press of the University of Cambridge.

Hake, R. R. (1992). Socratic pedagogy in the introductory physics lab. *Physics Teacher, 30,* 546

Haslam, F., & Treagust, D.F. (1987). Diagnosing Secondary Students misconception of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biology Education.*

Hershey, D.R. (1991). Linking history and hands on biology . *Bioscience,* 42 (3), 188-191.

Hershey, D.R. (1992). Making Plant Biology Curricula Relevant. *Bioscience,* 42 (3), 188-191.

Hitchcock, G. & Hughes, D. (1995). *Research and the Teacher*. New York: Cataloguing in Publication Data.

Imenda, S. N (1989). In investigation into Gender Differences in Science Achievement Amongst Teacher Trainees in Swaziland UNISWA Research journal p 21.

Kiviet, A.K. & Du Toit, E. (2006). The ABC of learning science: A look at learning theories, planning and lesson presentation. In *Teaching Science in the OBE Classroom***.** Pp 39-59. Gauteng: MacMillan.

Kumar R. (2005) Research Methodology. A step guide for beginners, second edition SAGE publications, London 215pp.

Levinson, R. (1994). *Teaching Science.* Britain: British Library Cataloguing in publication data.

Lonergan, T.A.(2000) The photosynthetic dark reactions do not operate in the dark. The American Biology Teacher, 19

Mader S.S. (2004) Biology. Mcgran Hill : New York

Magi, N.V. (1993). *Biosocial issue as a component of Biology Education*, Unpublished D.Ed thesis. Durban: University of Durban-Westville.

Martin, R. & Sexton, E. (1994). *Teaching Science for all Children***.** Instructors Manual, Transparency Masters and Text Bank. London: Allyn and Bacon.

Martin, R. & Sexton, E. (1997). *Teaching Science for all Children***.** Allyn and Bacon. Singapore

McDermott, L. C. (1991). What we teach and what is learned – closing the gap. *American Journal of Physics*, *59*, 301-315

Mcharen, J.E. & Rotudo, L. (1989). *Biology*. Canada: Heath and Company.

Merriam, S.B. (1998). Case Study Research in Education: A Qualitative Approach. London: Jossey-Bass Publishers.

Miller, R. (2004). *The role of practical work in the teaching and learning of science.* Washington DC: National Academy of Science.

Moore, R. & Miller, I. (1996). How the use of multimedia affects students retention and learning . *Journal of College Science Teaching*, 25, 289-293

Muwanga-Zakes J.W.F. 2005 Is science in education in a crisis. Some of the problems in S.A. Science in Africa WWW.Africa .CO.ZA. Accessed 2006 June

Mwamvenda, T.S. (2004). *Education Psychology*. South Africa: Part Print Heinemann Publishers (PTY) Ltd.

Nelae, J.M. & Liebert, R.M. (1986). *Science and Behaviour: an Introduction to Methods of Research.* New Jersey: Prentice-Hall.

Neuman L.W. Social Research Methods: Qualitative and Quantitative approaches 3rd Addition London Allyn and Bacon.

Robin. M. (2004). The role of practical work in the teaching and learning of science. Washington DC: *National Academy of Science*.

Robinson, S.A.; Russell, W. & Andrew, A. (2004). *Photosynthesis education at all tertiary levels.* Australia: University of Wollongong.

Robst, M.; Devlin, A.; Baker, V. (1971). *Photosynthesis*. Van nostrand Reinhold company international offices: London: Melboarne/circi.

Rohrkemper,M.(1981) Classrom perspectives study : An investigation of different Perspections of classrooms.

Rohrkemper,M.(1985) The influence of teacher socialisation style on students social . cognitions and reported interpersonal classroom behaviour elementary schools Journal 85, 245-275.

Russell, A.W.; Netherwood, G.M.A. & Robinson, B. (2004). *Overcoming the challenges of photosynthesis Education using multimedia CD-ROM*. Wollongong: University of Wollongong, NSW 2522.

Oxford dictionary (1999) The dictionary unit of Southern African English Cape Town Oxford University Press.

Ozay, E. & Oztas, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education* 37: 68-70.

Sahin, F.; Guarda, A.; ave Berkem, M.L. (2000). *A research on meaningful learning of physiological concepts*. 4th Congress of Science Education, Hacettepe University, Faculty of Education, M.E.B. and Padogogische Hchschule, Heidelberg-Germany, 6-8 September 2000, Ankara, 17-23.

Sharan, A.; Robinson,W.R. & Andrew, A. (2004) **Photosynthesis Education at all Tertiary Levels**. Australia: University of Wollongong, Wollongong, N S W 2522.

Sharan, A. (1994) Deprtment of Biological Sciences . University of Wollongong, : Wollongong, N S W 2522. Australia.

Sharon, F Gurdal, A . Ave Berkem, M.L. (2000) A research on meaningful learning of Physiology concepts 4th congress of Science Education, Hacettepe University, Faculty M.E.B. and Pedagogische Hoschule, Heidelberg German, 6-8 September 2000, Ankora, 17-23.

Shulman, L.S. (1986) 'Those who understand : Knowledge growth in the teacher ' *Educational Researcher*, 15(2) :1-22.

Skiner, B. (1953) Science and Human Behavior New York : MacMillan

Silverstein, T.P. (2000). Weak vs strong acids and bases: The football Analogy. *Journal of chemical Education*, 77(7), 849-850.

Star. C.; Taggart, R. (2004). *Biology the unity and Divesity of life*. United States: Thomson books/cole.

Sund, R.B. and Trowbridge, L.W.(1973) Teaching Science by Inquiry in the Secondary School, Charles E. Meril Publishing Company: Columbus Oho

The AAUW Report. (1995). *How schools Shortchange Girls?* New York: Marley & Company.

Treagust, D.F. (1985). *Diagnostic Test to Evaluate Student's Misconception in Science.* A paper presented at the annual meeting of the National Association for Research and Technology Lick Springs, India.

Treagust, D.F. & Haslam, F. (1987). Diagnosing Secondary Students misconception of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biology Education.*

Tuckman, B.W. (1972). *Conducting Educational Research.* New York: Harcourt Brace Jovanovich Inc.

Uno, G.E. & Bybee, R.W. (1994). Understanding the dimension of biological literacy. *Bioscience*, 44, 553-557

Wenar, C. (200). *Development psychopathology*. Singapore: Library of Congress Cataloging in Publication Data.

Wong, E. D. (1993). Self-Generated Analogies as a tool for Constructing and Evaluating Explanations of Scientific Phenomena. *Journal of Research in Science Teaching*.30 (4), 367-380.

APPENDIX A

THE DIAGNOSTIC TEST ON PHOTOSYNTHESIS

INSTRUCTIONS: ANSWER ALL QUESTIONS

Please complete the following

GENDER

Female	
Male	

AGE

Under 16 years	
16 years	
17 years	
18 years	
19 years	
Above 19 years	

My Career interests are: ---
The name of my school is: ---
My first/ home language is: --

QUESTION 1

TERMINOLOGIES

Give the correct biological term for each of the following

1. The gas evolve and given off as a by-product during photosynthesis

2. A substance released during the light phase which combines with carbon dioxide during the dark phase of photosynthesis.

3. The exact location, within chloroplast, in which light phase of photosynthesis occurs

4. The exact location, within the chloroplast, in which the dark phase occurs.

5. Organic molecules, which control the dark phase of photosynthesis.

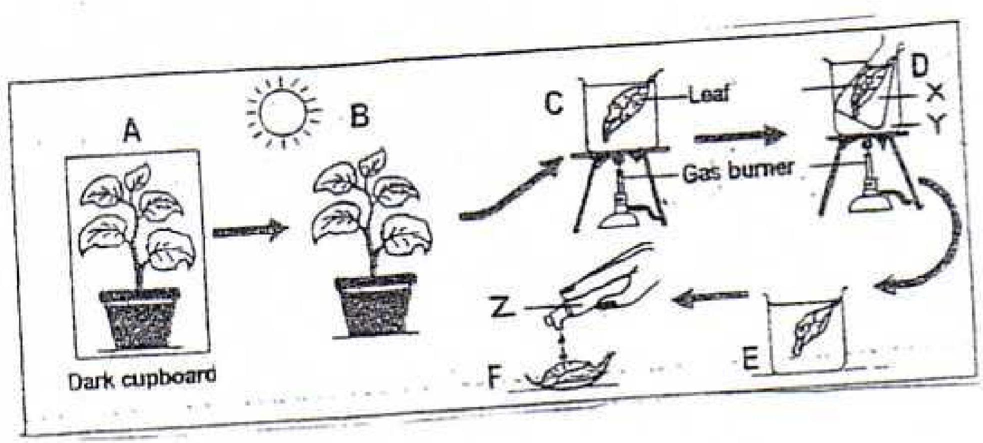
6. As energy-rich carbohydrate that is formed during photosynthesis.

7. Elongated chlorophyll-continuing cells arranged at right angles to the upper epidermis of some leaves.________________________________.

8. The main photosynthetic tissue in an angiosperm leaf
____

QUESTION 2

Question 1 to 7 refers to the procedure followed when testing for the presence of starch in a leaf. Study the diagrams and answer the questions.



1. During which process is starch formed in a leaf?

___

2. What is the main of doing stage A?

___

___

3. Which energy transformation is going to take place during stage B?
___(2)

4. Supply suitable labels for parts X, Y, and Z.
___
___ (3)

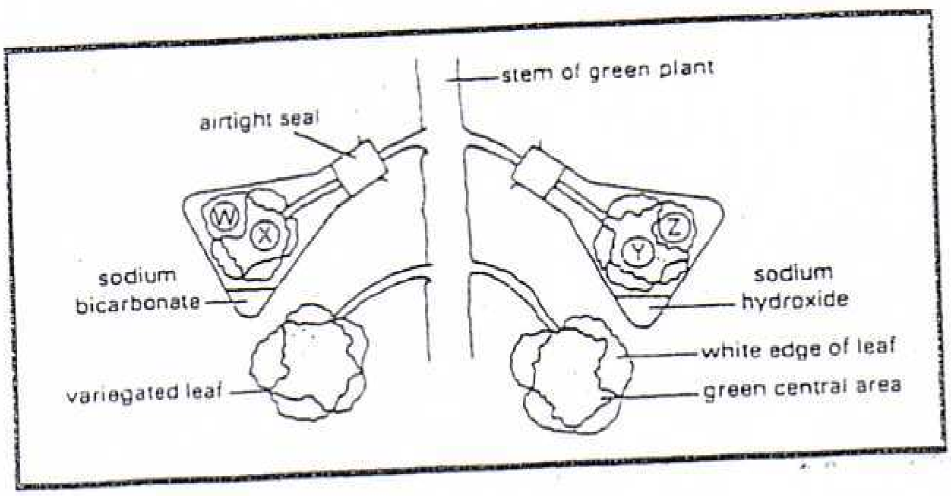
5. State **ONE** safety measures that should be taken during stage D.
___
___ (2)

6. What is being done at stage
D?___
Explainwhy?___
___(3)

7. What is the expected colour change at F? ___ (1)

QUESTION 3

The questions below are based on the following investigation that was left in sunlight for two days. Answer questions based on it.



1. What is the aim of the above investigation? ___________________________ (2)

2. The plant was destarched for 24 hours before being placed in sunlight. What does destarching mean?
____
____

3. What is meant by a "variegated" leaf?
____

4. What is the function of each of the solutions in above investigation?

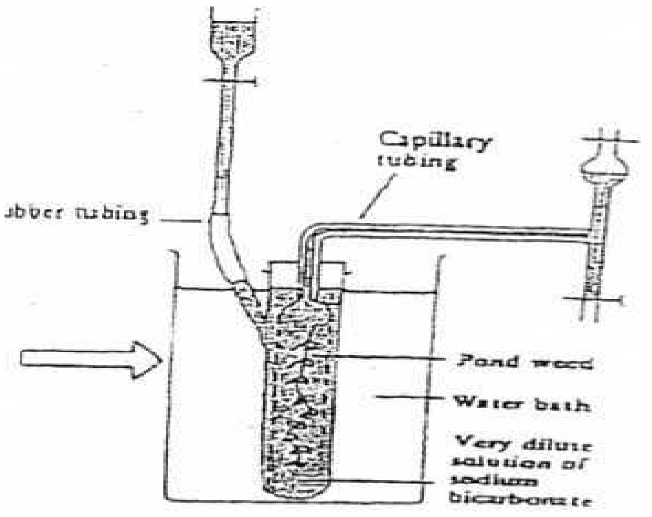
   (i) Sodium bicarbonate? _______________________________
   (ii) Sodium hydroxide? _______________________________

5. Leaf discs W, X, Y and Z from both flasks were tested for starch. What result is expected in each of the following leaf discs:
   (i) X?____
   (ii) Y?____(4)

(13)

[35]

QUESTION 4



The apparatus shown above is used for measuring the rate of photosynthesis of water plants. Gas produced during photosynthesis is collected and measured in the capillary tube the rate of gas production being proportional to the rate of photosynthesis.

Circle the correct alphabet

1. The function of the water bath is to:

(a) focus light on the plant
(b) prevent dehydration of the plant
(c) provide water for photosynthesis
(d) provide the plant with mineral salts
(e) minimize fluctuations in temperature

2. Why is diluted sodium bicarbonate solution used in this experiment rather than tap water?

(a) tap water is too alkaline
(b) tap water often contains bacteria
(c) tap water may contains pollutants
(d) the bicarbonate solution is clear than tap water
(e) the bicarbonate solution provides optional carbon dioxide

3. Compare with atmosphere air, the gas collected in the capillary tube would be richer in:
(a) oxygen
(b) nitrogen
(c) carbon dioxide
(d) ammonia

4. In which part of the photosynthesizing cells of the plant is the gas produced?
(a) nucleus
(b) vacuole
(c) chloroplast
(d) mitochondrion
(e) golgi apparatus

QUESTION 5

When a piece of water plant/ pond weed (Elodea) is placed in a solution near a bright light it gives off bubbles of gas shown below.

An investigation was carried out to measure the rate of bubbling with the lamp at different distances from the plant as seen in figure 1 below. The results obtained are shown in the graph in figure2 below.

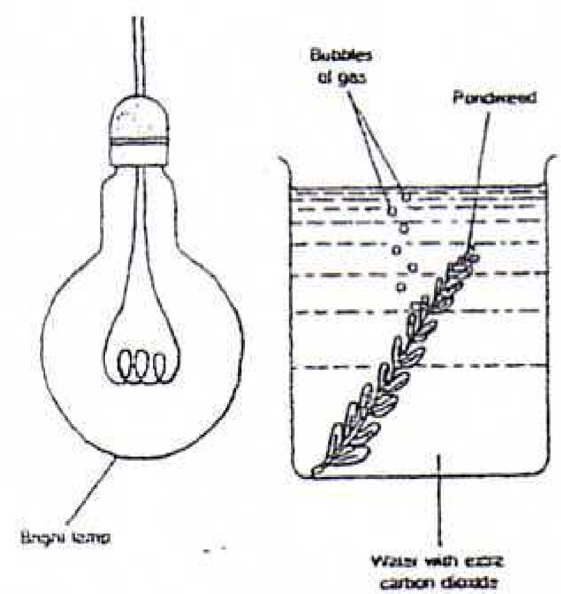


Figure 1

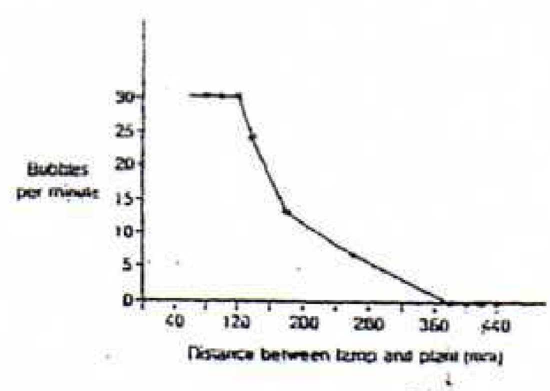


Figure 2

1. Which one of the following statements best describes the aim of this investigation? Write only the letter only the letter of your choices.

(a) To determine whether light is essential for photosynthesis.
(b) To determine whether water plants respire.
(c) To determine the effect of different light intensities on the rate of photosynthesis.
(d) To see the effect of different wavelengths of light on the rate of respiration
____ (2)

2. What was the rate of bubbling when the lamp was 180mm from the plant
____ (2)

3. How far was the lamp when the rate of bubbling was 5 bubbles per minutes?
____ (2)

4. What happened to the rate of bubbling when the lamp was moved from 280mm to 200m? ____ (2)

5. Name the gas that is in the bubbles.________________________ (1)

[9]

QUESTION 6

PLOTTING OF GRAPH

The results below show the effect of light intensity on the rate of photosynthesis in a plant when placed, in turn, in two concentrations of carbon dioxide.

Light intensity	**Rate of photosynthesis in 0.03% CO_2**	**Rate of photosynthesis in 0.13% CO_2**
1	0.9	1.5
2	1.5	2.3
3	2.0	3.1
4	2.3	3.9
5	2.4	4.3
6	2.4	4.3
7	2.4	4.3

1. Plot curve on graph paper to show these results. Label the axes. On the horizontal axis use a scale of 10 units= 1 arbitrary unit (light intensity). On the vertical axis use a scale of 10 units=1 arbitrary unit (rate of photosynthesis).

2. Describe two conclusions that can be made from the graph

   ____
   ____
   ____

3. Suggest reasons why the rate of photosynthesis would drop if the carbon dioxide level is raised to 4%

   ____
   ____
   ____

MEMORANDUM

QUESTION 1

1. Oxygen
2. Hydrogen atoms
3. Grana
4. Stroma
5. Glucose / starch
6. Palisade mesophyll
7. Mesophyl

QUESTION 2

1. Photosynthesis
2. To destarch the plant
3. Radient / light energy converted to chemical potential energy
4. X- ethanol /alcohol
   Y- hot water
   Z- iodine solution
5. Put out flame of burner/ heat alcohol indirectly
6. Raising leaf /to soften it
7. Blue-black / black / purple black

QUESTION 3

1. To investigate whether chlorophyll is required for photosynthesis and to investigate whether co_2 is required for photosynthesis.

2. To remove the starch that was previously stored in the leaf

3. A leaf having a green portion (which contain chlorophyll) and a white or other colour portion (does not contain chlorophyll)

4. i) releases co_2 into the flask
   ii) absorb the carbon dioxide in the flask

5. i) X- leaf disc turns blue-black indicating the presence of starch
   ii) Y-leaf disc remain brown indicating that no starch is present

QUESTION 4

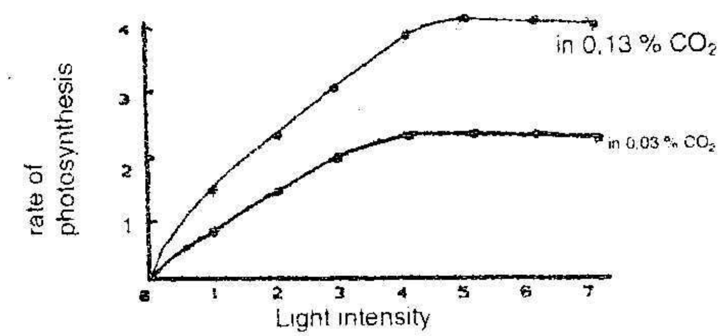
1. E
2. E
3. A
4. C

QUESTION 5

1. C
2. 11-13 bubbles per minute
3. 280-290 mm
4. The number of bubbles increased
5. Oxygen / O_2

QUESTION 6

1.



2. - The rate of photosynthesis is higher at CO_2 concentration of 0,13 % than 0,3%
- For both concentrations, the rate of photosynthesis increases up to a light intensity of 5 and thereafter levels off.

3. - High concentration of CO_2 in cells will increase acidity and lower the PH
-enzymes of the dark phase of photosynthesis denatured due to changes in PH
-Therefore rate of reaction decrease and the rate of photosynthesis will drop

APPENDIX B

P O Box 7064
Empangeni Rail
3910
12 June 2006

The District Managers
Mthunzini Circuit Office
ESIKHAWINI
3887

<u>Research Project School Based</u>

I hereby request your office to grant me permission to conduct research in six schools .of Mthunzini District. The topic is Conceptual understanding of photosynthesis. The instrument or questionnaire will be a formal test conducted under formal examination conditions.

Yours Faithfully

Mrs NV Mhlamvu

APPENDIX C

P O Box 7064
Empangeni Rail
3910

27 June 2006

The Principal

Sir/ Madam

Research Project -School Based

I hereby request your school to grant me permission to conduct research among the grade 12 learners. The topic is Conceptual understanding of photosynthesis. The instrument or questionnaire will be a formal test on photosynthesis. Any information given will be strictly confidential and no identification of a specific school or name of the teacher will be given when the report is completed.

Written permission to conduct this study has been obtained from the district office. Thank you.

Yours Faithfully

Mrs N.V.Mhlamvu