UNIVERSITY OF EDUCATION, WINNEBA

USING STUDENT-CENTRED AND RECIPROCAL INSTRUCTIONAL APPROACHES TO PROMOTE SHS STUDENTS' UNDERSTANDING OF PHOTOSYNTHESIS AND CELLULAR RESPIRATION: A COMPARATIVE STUDY

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A Thesis in the Department of Science Education, Faculty of Science Education, submitted to the School of Research and Graduate Studies, University of Education, Winneba in partial fulfillment of the requirements for award of the Master of Philosophy Degree in Science Education.

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DECLARATION

STUDENT'S DECLARATION

I, Fortune Morkporkpor Adalevo, declare that this dissertation with the exceptions of references contained in published works which have all been identified and duly acknowledged is entirely my own original work, and that it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE……………………………………DATE…………………………………

SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of dissertation as laid down by the University of Education, Winneba.

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DEDICATION

This work is first dedicated to the two most important men in my life, Rev. D.Y. Adalevo, my father and Jacob K. Amenano, my dearest husband. And also to my unborn children, I say I got busy whiles I waited for them.

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ABSTRACT

The purpose of this action research was to investigate possible ways of improving students' achievements in photosynthesis and cellular respiration using student-centred and reciprocal instructional approaches. The target population comprised all SHS biology students in the Ada East District of the Greater Accra Region. The accessible population was made up of SHS biology students in Ada Senior High School. A sample of 90 students in two intact classes was used for the study. Data collection lasted six weeks and comprised Pre-Intervention Activities, Intervention Activities and Post-Intervention Activities. The instruments used were test items and an observation checklist. Before the instruments were used for data collection, the main research instrument was subjected to content-validation analysis with the help of the researcher's supervisors. Additionally, the reliability index of the main instrument was determined to be 0.97. Part of the data was analyzed using frequency counts, simple percentages means and standard deviation scores. They were later tabulated and also presented as multiple bar charts in different figures. The data was subjected to narrative description by reference to the appropriate research questions. Among other findings, the study revealed that students instructed using reciprocal instructional approaches obtained relatively higher achievement scores on concepts in photosynthesis and cellular respiration than those taught with student-centred instructional approaches. Based on the findings of this study it was recommended that biology teachers in the selected school should organize more reciprocal instructional activities. It was also recommended that student-centred activities be adopted as alternative instructional approaches by biology teachers in the target school.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter includes the background of the study, problem statement, purpose of the study, objectives of the study, research questions, and significance of the study, delimitations, limitations and definition of terms.

1.2 Background to the study

Over the years, it appears there has been a public outcry in Ghana concerning the performance of students in science and biology for that matter. Developing a positive attitude towards science implies erasing one's mind of the perceptions such as: science is a difficult subject, science is for some people not everybody, science is not real, science is for men not women etc. Abusing student's mind of these misconceptions could be effective only when teachers make good instructional decisions, which could provide relevant experiences to support student's learning and align with his/her teacher's teaching style (Asare, 2010). Effective teaching and learning of science requires sound pedagogical skills, knowledge of the subject matter and the appropriate classroom practices to support the learning process among all categories of students. Some of the ways by which a teacher can induce quality learning in science classroom are as follows: making science learning active and student-centred, knowing the students' background experiences, being accountable for the learning of all students (Eminah, 2009). Others include adopting quality classroom management techniques that foster positive behaviors among learners, providing conducive and productive learning environment as well as providing equal opportunities to all students to learn. The researcher firmly believes that students do their best and show their best when they are the center of the classroom and when value is given to what they own, their culture and their knowledge. Students need to be empowered to take responsibility and ownership of their learning to be successful learners. To help students feel safe and have comfortable learning, the classroom needs to be student-centered. For students to show what they know and feel proud of what they know, reciprocal teaching can be a powerful tool to become their own teachers. Students need to be guided and supported to prepare and deliver lessons to their peers. While preparing and delivering lessons, the following are improvements anticipated in the researcher's students: ability to select useful and meaningful information from different sources, reading and analyzing information, organizing and highlighting relevant information to teach a topic, and oral and written communication of their learning.

The performance of high school students in biology in examinations in Ada Senior High School has appeared to be low and a matter of concern to the school authorities. The fact that the low performance of the students has been criticized by most departments of school raised my interest as a Biology educator to study the reasons behind the learners' poor performance in form three, as doing well in form three is usually one's ticket to a better education. The study explored the results of learners' performance with regard to photosynthesis and cellular respiration and suggests ways and procedures to help the learners to perform at their maximum level. This study specifically set out to study the performance of students in two important topics taught in biology, namely photosynthesis, a process by which food is made for all living organisms and cellular respiration, the sum total of the chemical processes that release energy from food substances within cells, with or without the use of oxygen. These topics were targeted because of their conceptual difficulty and their suitability in revealing whether students are able to understand topics that combine biochemistry with practical work and require them to think not only at a lower cognitive level, but also to analyze, synthesize and evaluate information given. In all the history of education, science has held its leading position among all school subjects because it is considered as an indispensable tool in the development of the educated person. Educators give special recognition to biology among the sciences because of its educational values, its close relation to man as a living organism, its peculiar field of experimentation and interrelationships with the other sciences (Akinmade, 1987). As a result of this, biology occupies a relatively pivotal position in the natural sciences and it is one of the requirements to professions such as medicine, pharmacy, agriculture, dentistry and many others. It is for this reason that Babbie (2001) advocated for adequate biology education for every child in the contemporary world dominated by science.

The importance accorded science, and for that matter biology, in the school curriculum from the basic level to the senior high level reflects accurately the vital role played by the subject in contemporary society. The importance of the subject is not restricted to the development of the individual alone but for the advancement of the social, economic and political goals of countries all over the world.

In Ghana, biology as a subject is known to have the highest number of student enrolments in recent years in senior high schools. Research findings of Abdullahi (1982) have indicated that student enrolments in biology from 1977 to 1989 have always surpassed the combined enrolments in other science subjects. These high enrolments in biology figures indicated that biology was popular among the sciences. However, this number do not match the students' achievement in the subject, since the inception of the senior secondary school (SSS) programme as one of Ghana's educational reforms in 1987. The Chief Examiners' Reports from the West African Examination Council (WAEC) have consistently indicated poor performance of SHS students in the sciences (WAEC, 1994; 1995; 1996; 2002; 2003; 2004; 2005). Most students fail or get low quality grades in biology more than in the other science subjects such as physics and chemistry.

The Chief Examiners' Reports show that more students fail in biology because they do not perform creditably in paper 1, which is a theory paper. The biology paper 1, tests skills in drawing, science process skills of students in abstract concepts, analysis of some processes and interpretation of biological data. Some weaknesses identified by the Chief Examiners over the years (1994-2005) for biology were as follows:

(i) Candidates' answers show that they had not understood some concepts well enough.

(ii) Students' answers indicate that they had not done any practical work along the lines of the tested questions.

(iii) Candidates wrote answers based on pure guessing.

(iv) The standard of students' explanations was poor.

With these weaknesses in mind, the way the biology practical works are organized is of great importance and is worth investigating. To investigate biological phenomenon effectively, it is required that students develop the requisite skills of observation, critical thinking and appreciation, perform experiments competently and record data accurately (Bremner, 1997). Akinmade (1987), reported that on the average, 78.8 % of the students that sat the West African Senior Schools Certificate Examinations (WASSCE) fail biology and the situation has not improved with time. For this reason, in recent times there has been public outcry on the declining standard of science education, especially in the area of biology.

In modern life, the rule is absolute, that any country that disregards the study of science is doomed to obsolescence (Ogunniyi, 1988). The rise of Japan into the status of an economic giant today (Evans , 1991) as well as the emergence of Singapore, Hong Kong, Korea, Taiwan and Malaysia recently into economic miracles have all been attributed to the heavy investments these countries made in science education (Ranis ,1990).

According to Anamuah-Mensah (1989), by having knowledge in science education, the economy and socio–cultural status of the nation will be transformed. This implies that science education and for that matter biology is important in producing the required human resources needed for harnessing the natural resources of the country.

The current approach to science teaching and learning in most SHSs is most often based on classroom work where the teacher is seen most of the time to be at the centre of everything, which is intended to meet examination requirements. Unfortunately, the examination-driven mode of biology teaching and learning has limited the biological (science) and technological scope and perspectives of the students. The approach also tends to make the study of biology and for that matter science uninteresting, boring and unenjoyable. Students find it difficult to relate the theoretical knowledge with the practical realities of life and the use of manipulative skills. There is also very little orientation for problem-solving, inculcation of investigative skills, communication of knowledge and ideas efficiently, seeking, analyzing, and using information on their own, helping others and working together. For this reasons, this research is to investigate the differential effect of learner centred and reciprocal approaches on SHS students' performance in photosynthesis and cellular respiration. Biology is an activity-based subject and as such students must be made to participate fully in the teaching and learning process of the subject, so that they can understand the concepts involved better, so this study would be making use of the student – centred approach, with the reciprocal approach involving students helping each other and working together on the topics chosen in the study.

1.3 Statement of the Problem

Over the years the performance and achievement of Form 3 students in Ada Senior High School has been steadily declining. This according to Eminah (2009) could have resulted from several factors. In the 2012 academic year, at the end of second term examination, 120(60%) elective biology students failed the subject while 80(40%) had D7 in the subject. Students' difficulties in learning biology concepts have been investigated by many researchers at the international level. Johnstone and Mahmoud (1980), reported that water transport in plants and genetics were among the most difficult biology topics to be learnt by secondary school and university students. Finley, Stewart and Yarroch (1982), showed that cellular respiration, protein synthesis, photosynthesis, Mendelian genetics, mitosis and meiosis, were difficult topics for students to learn. Respiration and photosynthesis were also reported as difficult by Anderson, Sheldon and Dubay (1990), while gaseous exchange and concept of energy were reported by Seymour and Longdon (1991) as well as Jennison and Reiss, (1991) respectively, as difficult concepts for students.

Biology is one of the important requirements for SHS progression into advanced learning in the natural and applied sciences. To therefore leaving students difficulties of biology unsolved of course will be detrimental to their development.

However, currently in Ghana no study had been conducted on intervention activities to improve SHS students' cognitive achievement with concepts in photosynthesis and cellular respiration. For this reason, the study was designed to use student-centred and reciprocal methodology as intervention instructional approaches to promote selected SHS students understanding in photosynthesis and cellular respiration.

It is therefore with this gap in knowledge in mind that the current study was designed.

1.4 Purpose of the Study

The purpose of this study is to compare students' achievements on selected concepts in cells and energy using student centered oriented approach and reciprocal approach. Also, expose Ada SHS students' pre-conceptions related to cells and energy using pre instructional worksheet in both the student centered approaches and reciprocal method. The concepts selected for this study are photosynthesis and cellular respiration

1.5 Objectives of the Study

- To determine whether students hold any pre-conceptions related photosynthesis and cellular respiration.

- To determine whether there was any difference in achievement between students instructed using student-centered instructional approaches and those instructed using reciprocal instruction.
- To determine whether there were benefits to student centered and reciprocal instructional approaches in teaching photosynthesis and cellular respiration

1.6 Research Questions

The following research questions guided the investigative activities

1. What photosynthesis and cellular respiration pre-conceptions do the students hold?
2. Are there differences in the mean scores between students instructed separately using student centered and reciprocal instructional approaches on concepts in photosynthesis and cellular respiration?
3. In the view of the students, how beneficial are the student-centered and reciprocal instructional approaches for lessons in photosynthesis and cellular respiration?

1.7 Significance of the Study

The importance of the research cannot be overlooked. The findings' recommendations and suggestions could be an important source of information to the teachers in the selected schools and other teachers who teach biology. The study could bring to bear the teaching and learning activities that could ensure maximum student participation in the teaching and learning of biology. The study could give useful information to the Ministry of Education and other educational authorities to undertake interventions to promote practical lessons in biology. This study could also serve as a source of information for further research work on the topic. Additionally, the findings could augment the pool of data required by other educational researchers in their bid to design interventions to solve educational problems in the sciences in general and biology in particular.

1.8 Delimitations of the Study

The study focus on the views of biology students with respect to photosynthesis and cellular respiration. Due to financial constraints, the study would cover 98 students. Additionally, data were collected from students in senior high school 3 only. Students in senior high school 1 and 2 were excluded due to the fact that at the time of the study they had not reached photosynthesis and cellular respiration in the syllabus.

1.9 Limitations of the Study

Like all researches, this study has its limitations which determine the extent of its applicability. The first limitation of this study is the generalization of results. Because attitudes are formed by the interaction among several factors operating within different environments, generalizing the results of this study for an entirely different set of students in an entirely different setting should be made with utmost care.

The next limitation concerns the sample size. Though increasing sample increases precision, there is always a trade-off between precision and cost. Due to time and cost considerations, the sample size in this study will not be the entire student population. This however, does not imply that precision was completely not considered. A sample that is representative of the population – having all the necessary characteristics – will be taken to permit all the required analysis to be carried out in a scientific manner.

1.10 Operational definitions of terms

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:

$6CO_2 + 12H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

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 theories about how things happen. It seeks consensus. 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.

Cellular Respiration

Cellular respiration is the process of oxidizing food molecules, like glucose, to carbon dioxide and water. $C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 12H_2O + 6\ CO_2$. The energy released is trapped in the form of ATP for use by all the energy-consuming activities of the cell.

The process occurs in two phases:

- glycolysis, the breakdown of glucose to pyruvic acid
- Krebs cycle the complete oxidation of pyruvic acid to carbon dioxide and water

In eukaryotes, glycolysis occurs in the cytosol. The remaining processes take place in mitochondria.

1.11 Abbreviations and Acronyms

- ATP-Adenosine triphosphate
- WAEC-West Africa Examination Council
- NRC -National Research Council
- GPA-Grade Point Average
- NCE- National Curve Equivalent
- MEAP-Michigan Educational Assessment Program MEAP.
- K–2-Kindergarten 2
- RT-reciprocal teaching
- ERIC-Education Resource Information Center

- MANCOVA-Multivariate analysis of covariance
- TCS-Text Content and Structure Program
- ANCOVA-Analysis of covariance
- TT- taught
- NTT-not taught to
- LD-Learning disability
- SCL -Student-centered Learning
- SCALE-UP-Student-Centered Activities for Large Enrollment Undergraduate Programs
- BESTEAMS-Building Engineering Student Team Effectiveness and Management Systems

1.12 Organization 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 and their importance, and the views of learners about the learning of these topics. It also outlines the role of student-centeredness in teaching science subjects. Furthermore, theories of teaching and learning are discussed in relation to the research topic, with particular reference to the teaching and learning of photosynthesis and cellular respiration. 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 achievements scores, well as the medium of instruction used. Chapter five outlines the entire study, summarizes the findings and makes recommendations about how the results of the study could contribute to improving the teaching/learning of photosynthesis and cellular respiration in senior high schools.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter contains the review of the literature related to the study and the theoretical framework related to the important aspect of the study. The literature review discusses student-centred and reciprocal approaches, as some of the methods used in teaching biology at the senior high schools. The availability of conducive environment in terms of facilities like laboratories for biology practical work is also discussed.

2.2 Theoretical framework

Over the past century, society has required schools to prepare students for an increasingly complex set of social and economic realities (Christensen, 2008; National Academies of Science 2007). In response to these changing educational conditions, educators and researchers have developed new approaches to the systematic provisioning of learning. Learning is a process of knowledge construction, based on the constructivist model (Taber, 2001). For meaningful learning to occur, connections need to be clear between what is being taught and what one already knows. Piaget suggests that learning occurs through a process of assimilating and accommodating new information into existing organized knowledge (Taber, 2001). Prior knowledge is the foundation and framework for successful learning and application of new material. Prior knowledge is the cognitive structure a learner possesses at any given time. Taber (2001) explains this cognitive structure as the set of facts, concepts, propositions, theories, and raw perceptual data that learners have available to them at any point in time and the manner in which it is arranged. According to the Schema Theory, prior knowledge is an organized and elaborate network of abstract mental structures that represent one's understanding of the world (Davis, 1991). So learning is successful if prior knowledge exists. To access prior knowledge, teachers need to know their students' culture, language, and previous academic and life experiences to bring them to be able to build onto what they already know. Learning is meaningful when students see connections between what they know and the applications they can make to new experiences. When students realize how much they know and how new information can be relevant to their lives, they can become motivated to set their own academic goals. Learning is successful in environments in which students are at the center and in which what students know is valued; it is for this reason that the major themes in this literature review are student/learner centred classroom environments and reciprocal teaching.

2.3 A Learner-Centered Classroom Environment

The theory and practice of student-centred learning has been built over the past century. Piaget, Dewey and Vygotsky, among many others have made influential contributions to the understanding of learning and how best to maximize human potential through education.

According to the National Research Council (2005) there are four lenses that can be used to evaluate the effectiveness of teaching and learning environments. These are learner-centred, knowledge-centred, assessment-centred, and community centred. The learner-centred lens focuses on the students' prior knowledge, skills, attitudes, and beliefs they bring with them to the classroom. The knowledge-centred lens focuses on what needs to be taught, why, how and to what mastery it needs to be taught. The assessment-centred lens concentrates on how to assess/monitor student learning. The community-centred lens encourages a culture where students feel safe and comfortable asking questions and taking risks. The NRC shows an overlap of all three lenses under the community centred lens. The research study combined the knowledge-centred and the assessment-centred lenses as they both deal with knowledge. If learning is assessed, then it was definitely taught. It also combined the community-centred and student-centred lenses because the researcher wanted to see the classroom as a community of learners. Because every term there are new groups of students, leading to revise and update classroom norms and procedures based on the students' behavior. Curriculum plan based on students' prior knowledge and pace of learning were also modified.

The student-centred lens was used as the umbrella for the other three lenses because students were at the center of the learning process and teachers determined what happened in that classroom based on what they brought to it and what they were capable of getting out of it in terms of academic and life experiences. An efficient teacher who provides a student-centred classroom values students and their cultures; finds out what students already know so that they can build on that knowledge, wants to know how students feel and think about certain topics, especially in science, and enriches the classroom environment with students' skills and talents. This brings the researcher to discuss a research she read about what a student wants, even those who do not care about school.

What do Students Really Want?

In the researcher's short experience in teaching and according to Daniels and Araposthathis, there are a number of students who have the skills and abilities to succeed academically, but choose not to succeed. These are the "disengaged and reluctant teenage learners" who usually show good test scores but have low GPA (Daniels & Araposthathis, 2005). In this research, these learners' voices were heard. Three factors that contribute to these students' failures or success were found, and as such consequence ways to create encouraging learning environments for these students were developed. The first factor is the relationships students build with their teachers.

If students feel a genuine interest teachers have for them, they see teachers as their allies and advocates. That influence teachers have on students can raise the level of intrinsic motivation and effort towards academics. A motivating teacher has the following qualities: flexibility, ability to understand situations from a student's point of view and encouragement. If students feel supported and cared for, they engage. The second factor is the interest students have in the assignment because of relevance and connection they see of their academic success with their future. If the assignments relate to them, these students engage in learning. For example a student read "the Outsiders" because it related to him. Another student read computer books because they helped him help his dad and another student read art books because they gave him ideas for his art work. And yet another student liked home economics because they made "muffins and pancakes in class." The last factor that contributes to students' success or failure is the feeling of competency they have to complete a task. Students are successful if their skills are matched to the challenge at hand while at the same time being pushed to a slightly higher level. In short, ways to motivate disengaged and reluctant learners include educators building trusting relationships with the students, alignment of the curriculum with student interests, and decreased use of extrinsic motivation. These three ways to motivate students ultimately come from placing the students at the centre of the learning process and identifying what knowledge and skills they have as well as which of them, they can build on.

2.4 A Student-Centered Approach; the Constructivist Model.

In a study conducted by Burrowes (2003), traditional science teaching through lectures for 100 students and the student-centered approach for 104 students was used in Biology classes at a large urban university. In the student-centered approach, she used active teaching and cooperative groups to help students achieve better grades on standard exams, develop higher level thinking skills, and spark more interest in biology. According to Burrowes' data, more students in the student-centered group earned As and Bs in the final exam, only 4 dropped the class compared to 12 in the traditional group, the discussions in the student-centered group were a lot more engaging and alive in the portion of the final exam. In addition, at the end of the year, more students in the student-centered group (70% vs. 50%) expressed that their interest in biology was high. Burrowes used the Constructivist Learning Model described as the "5 E" (Engage, Explore, Explain, Elaborate, Evaluate) and cooperative learning to accomplish her goals. She engaged her students through short lectures (10-15 minutes) to introduce new material. To allow students to explore, Burrowes placed students in groups to solve problems or work on exercises immediately after the lecture. To explain, students in the group wrote their consensus answers on a sheet that was turned in at the end of the period. Students usually explained their answers to the rest of the class as well. To elaborate, misconceptions were addressed based on student responses when new material was introduced.

Mutual feedback between Burrowes and her students was immediate, which allowed for opportunities to evaluate her teaching approach, her students' academic progress, and the students themselves. The groups in this research included four students who worked closely together, that eventually felt comfortable having one member of the group taking quizzes and earning points for the group. They became comfortable with each other to solve problems together, develop excellence by practicing, and develop high order thinking skills. Higher order thinking skills were developed through multi-answer questions, concept maps, discussion scenarios, graph interpretation and graphing data. Student attendance improved as well.

Burrowes experienced success in three areas, better test scores, more student interest in biology, and improvements in attendance. Similar results were projected by the researcher at the end of the action research. Many students claim to attend school because of their friends. Providing a classroom where students feel comfortable sharing who they are and working together will definitely encourage friendships, which should improve attendance. If students experience success in learning biology, most likely their interest in it will improve.

2.5 Small-group Peer Teaching

Small-group peer teaching was used in an introductory biology course with 70-75 students aspiring to be elementary school teachers (Tessier, 2007). The goal was to help those pre-service teachers learn basic biology concepts and help them become comfortable enough with biology to share it frequently with their future students. Tessier provided students with questions in advance. Students took the responsibility to find correct and appropriate answers. They also solidified their understanding of their material before teaching to avoid misinforming their peers. According to Tessier, small-group peer teaching improved student learning and promoted active engagement in learning biology. At the end of the semester, students earned B+/A- on tests taught by peers and only B/C on material taught through lectures by the professor. Students reported not having to study the peer-taught material as much as the lecture-

taught material when it came to study for tests. They showed better retention of material as well as ownership of the material they taught. They said they enjoyed teaching their peers.

2.6 Reciprocal Instruction

A metaphor may help us understand Reciprocal Teaching strategies. Imagine that inside your brain resides a person who goes into action every time you read (or attempt to learn something new). Imagine this person is a sentry who stands guard at the ready to inform you if what you are reading makes sense to you. She will let you know whether you have really understood the content during (and after) your reading. She says, for example, as you read, "I agree with that," or "I understand that," or "It is similar to (or different from) that I know about," or "I disagree with that, it is different from what my experience has taught me to be true."

The sentry informs you when meaning is cloudy or nonexistent, as if she was saying, "Wait a minute, I don't get it," or "What exactly is this thing?" In reality, this sentry is a process, thinking and monitoring process called metacognition which informs all readers when understanding takes place and when it does not.

The metacognition sentry is at work when you realize that you can speed ahead past a slow part of the text (you already understand it; or you don't see the relevance of reading this, given the purpose you have for reading). Metacognition informs you when you encounter something interesting or substantive and suggests that you slow down so as to savor what is being communicated, to glory in the splendor of the message as it unfolds.

The sentry is at work when you reread a passage with frustration because meaning did not flow to you at first. Without good metacognitive abilities, readers have little facility to understand what they read simply because, for them, the process of constructing meaning will not take place. Reciprocal Teaching helps students develop their metacognitive "sentries."

Reciprocal teaching is characterized as a dialogue that takes place between the teacher and students (or student leader and members of the group) that results in students' learning how to construct meaning when they are placed in must-read situations (tests or assignments). Reciprocal Teaching derives from the theory that reading for meaning and retention what is referred to as study reading requires effort, a full repertoire of comprehension strategies, and the flexibility to use these strategies as the situation requires. The dialogues incorporate four strategies, as mentioned earlier: generating questions, summarizing, clarifying, and predicting.

According to a literature review conducted by Slater and Horstman, reciprocal teaching is a successful cognitive strategy used to help struggling readers and writers (Slater & Horstman, 2002). Its main purpose is to convince all students to become actively involved in using strategies to be successful learners and take responsibility for their own learning. According to Bransford (as cited in Slater and Horstman, 2002), cognitive perspectives focus on making learners aware of their prior knowledge, monitor their learning as they accomplish tasks and solve problems, and acquire a number of strategies that they can apply to their learning. At the beginning reciprocal teaching is teacher directed as strategies are modeled for students. Students are quickly encouraged to take leadership in their reading groups. The teacher plays the role of facilitator as he monitors group activity in the classroom. The teacher provides assistance when necessary by prompting questions and even providing extra modeling to individual groups. Slater and Horstman claim that reciprocal teaching has four supporting strategies, questioning, clarifying, summarizing and predicting.

When using this strategy for reading, students are placed in groups in which every member gets to be the leader. The leader begins by reading aloud a paragraph or two then follows the four steps of reciprocal teaching. Questioning helps students to focus on the main ideas and understanding what they are reading. They accomplish this by the leader or other group members generating questions and answering them based on the paragraphs read. Clarifying actively engages students as they read and unpack ambiguous portions of text. This is accomplished by members clarifying any problems or misunderstandings brought about when reading or questioning. Summarizing is the real cognitive step of reciprocal teaching. It requires students to focus on the major content of the reading and determine what is important and what is not. In this step, the leader summarizes the text read. In the predicting step, students rehearse what they learned in the reading and express expectations of the next portion of the reading. In teaching writing, the same steps are followed with the addition of actually writing the questions, answers, and summaries. The authors claim that with daily practice of this cycle students improve their reading and writing skills.

As it was explained in the introduction, many of the researcher's students struggle to learn concepts in biology. Reciprocal teaching seems to be a powerful tool to improve their learning. In this research project the above version of reciprocal teaching with a few modifications and scaffolding strategies were used. The researcher also used the "5 E" of the constructivist model presented by Burrowes (2003); Engage, Explore, Explain, Elaborate, and Evaluate. To encourage maximum student competency to learn, a student-centred classroom was also created.

2.7 Empirical Review on Reciprocal Teaching

Teachers in Highland Park, Michigan, conducted research and began an effective reading instruction program for students who were not succeeding in school. Reciprocal Teaching raised hopes, expectations, and student achievement in less than one year.

- Poverty
- Rigid school structure
- Lack of training
- Few resources and supportive systems
- Deeply entrenched resistance to change
- Low teacher morale
- Low student achievement
- Abysmal test scores
- Low graduation rate

In 1992, these indicators above had combined to doom the Highland Park, Michigan, school district to the limbo of possible takeover or sanctions by the state. Even when honest attempts to develop responsive intervention programs were launched in Highland Park (a small district in Detroit, with almost 100 percent African-American enrollment), nothing seemed to work. The children were not learning, and the teachers were frustrated, unhappy, and exhausted.

In that school year, when the researcher assumed responsibility for student achievement (as curriculum director first and later as assistant superintendent), he faced the challenge of his professional career: giving the teachers hope and stimulating student achievement. His first goal was to bring elementary student achievement to at least the minimum standard required by the Chapter 1 program. Three out of four Highland Park elementary schools faced the sanction of Program Improvement status, the designation given to schools that are unable to reach National Curve Equivalent (NCE) targets and so are required to revise their responsive intervention plans under state oversight and approval. Making the challenge even more daunting were the new core curriculum requirements, accompanied by new teaching strategies, new testing systems, and new school improvement teams that consumed even more teacher time.

His second parallel goal concerned secondary-level student achievement, which was perhaps even more dismal. In 1993-94, Michigan adopted a two-tier high school diploma system: endorsed and standard. Examinations for these diplomas began in the 10th grade, through the Michigan Educational Assessment Program (MEAP).

- "Endorsed" diplomas were those in which students met only minimal standards (at about the 50 percent level) in reading, mathematics, and science.
- "Standard" diplomas represented satisfactory scores (at about the 75 percent level) on the exam.

Thus, endorsement standards are lower than the state standard for satisfactory performance. Accordingly, students can receive "endorsement" even when they fail to attain a satisfactory score on the MEAP. However, their school cannot receive accreditation unless 66 percent of the students have met or exceeded the state standard for reading, math, and science. And if schools fail to receive accreditation status, they faced state sanctions including closure, state takeover, or vouchers for parents to send their children elsewhere.

In 1993-94, fewer than 30 percent of Highland Park's graduating seniors had attained scores high enough to qualify even for endorsed diplomas. The 10th and 11th graders also posted dismal records. By anyone's estimate, achievement was not taking place in Highland Park despite some Herculean efforts to reverse this state of affairs.

That same year, the team decided to take advantage of the extra chances that high school seniors were given to be retested for the diplomas even though retest results were discouraging. Previous test preparation efforts had generated few students whose scores improved as a result of the intervention tried regardless of the nature of the intervention. The typical average percentage of students who improved on MEAP retests was less than 5 percent. Yet despite these discouraging figures, the Highland Park curriculum office developed what was called a "quick-fix test preparation intervention" to help high school students particularly the seniors score higher on the MEAP.

For both goals, the researcher and his team surveyed the research on urban students, cognitive science, and reading comprehension and decided that they would try Reciprocal Teaching.

2.8 The Effect of Reciprocal Teaching on Students Achievement in Highland Park, Michigan

With a clear focus and purpose in mind and mounds of encouraging research findings, the researcher and his team chose Reciprocal Teaching because of its emphasis on reading comprehension, particularly in the short term. This program involved training students to use four strategies that were associated with both improving reading comprehension and self-monitoring of comprehension while reading (Palinscar & Brown 1984). The four strategies were (1) generating questions, (2) summarizing, (3) clarifying, and (4) predicting.

They needed to provide immediate support to the seniors and other students, but they chose Reciprocal Teaching for its ease of use and flexibility with various teaching styles and formats. The following summarized their rationale for using Reciprocal Teaching.

- Reciprocal Teaching has been heralded as effective in helping students improve their reading ability in pre-post trials or research studies (Pearson and Doyle 1987, Pressley et al. 1987). According to Bruer (1993), Reciprocal Teaching helps novice readers learn and internalize the strategies excellent readers employ. When engaging in Reciprocal Teaching strategies, the novices are practicing and developing the skills required comprehending and learning. Further, trials employing Reciprocal Teaching have consistently indicated that the technique promotes reading comprehension as measured on standardized reading tests. Bruer reports that one researcher, Annemarie Palinscar, experimented with the technique in a variety of ways: (1) one-to-one tutorials, (2) small-group sessions facilitated by trained reading specialists, (3) small-group sessions taught by general classroom teachers with no specialized training, (4) whole-group instruction in the technique by teachers with no specialized training, and (5) small-group sessions led by students who were peers of the students in the groups. In all cases, student comprehension improved—even in the groups facilitated by students. These promising findings convinced them that this strategy could be just what Highland Park needed.

- They felt that the technique was ideal because it provided numerous options for teaching and reinforcing the strategies. They believed that getting the teachers to buy in would be considerably easier than if they asked teachers to learn a completely new model.
- Because the technique is easily understood and mastered by both teachers and students, regardless of the level of training in reading, research and applications (or even ability to read), they felt confident that this technique would provide them with a model they could use to teach parents (and volunteers) how to help promote comprehension among their children—and therefore reinforce reading skills that would help students develop further.
- Best of all, Reciprocal Teaching parallels the new definition of reading that describes the process of reading as an interactive one, in which readers interact

with the text as their prior experience is activated. Using prior experience as a channel, readers learn new information, main ideas, and arguments. Most important, readers construct meaning from the text by relying on prior experience to parallel, contrast, or affirm what the author suggests. All excellent readers do this construction. Otherwise, the content would be meaningless alphabetic squiggles on the page. Without meaning construction, learning does not take place. Reciprocal Teaching is a model of constructivist learning.

How Researchers in Highland Park, Michigan, developed a Reciprocal Teaching Programme

After researchers in Highland Park decided to use Reciprocal Teaching, their next task was to develop a system for teaching students the strategies. They turned to the Chapter 1 program and developed short-term interventions, intensive classroom support for teachers, and opportunities to provide services for many students.

Using Chapter 1 funds, it established (and later expanded) a team of 10 professional and paraprofessional educators at each school except the high school. At K–2 school, they deployed two teachers and two paraprofessionals. The researchers called these teams the Academic Response Teams. The teams worked with small groups of students (six to eight) who experienced difficulty in math and reading achievement. The aim was to teach each child how to boost his or her learning through instruction in metacognitive skills. They first focused on mathematics and social studies classes because they felt these two areas were key routes to higher achievement on the MEAP.

The mission of the teams was to pull students from mathematics and social studies classrooms and teach them the techniques of Reciprocal Teaching daily for 30 minutes, 20 days in a row. They began the experiment in the fall of 1993 with some specific objectives in mind:

- To ensure that students at highest risk received instruction in monitoring and regulating their reading comprehension.
- To help teachers realize firsthand the benefits of small-group dialogues as vehicles of comprehension because these matched the new definition of reading exactly.
- To encourage a new basic requirement among teachers: proficiency in using the Reciprocal Teaching technique.

They designed the program to focus on the actual problems that students were having. To do this, they carefully chose the teachers who would be working with the most challenging students. These teachers would sometimes work in their own classrooms and sometimes in other classrooms or resource rooms; it was both a "pull-out" and "push-in" program. Selected team members led staff development sessions related to curriculum and instruction issues, and challenged those teachers to incorporate Reciprocal Teaching techniques into their staff development sessions.

How Reciprocal Teaching Raised Student Achievement in Highland Park, Michigan

One convincing result of the program was that high school students seeking endorsement in reading and mathematics made significant gains in MEAP scores. This time, instead of the customary 2-3 percent retest gains, Highland Park students posted gains that exceeded 25 percent in some of the test areas. As a result, more students received endorsed diplomas than had been anticipated. For seniors, 29 percent received three endorsements on the first test; on the retest, 43 percent received three endorsements. This suggested that students were learning how to learn and understood more of what they read. Armed with this knowledge (and the feedback from teachers and students regarding the benefits of Reciprocal Teaching), the researchers provided more staff development in reversing low student achievement.

All of Highland Park's students were improving. The 1994 state assessment reports were a delightful surprise. Whereas many Michigan school districts experienced a decline in their 4th grade reading scores, Highland Park 4th graders doubled theirs, from 14.4 to 28.8 percent in one year. This is represented in Table 1. And they more than doubled their scores in math. (These were the former 3rd graders who had received the intensive Reciprocal Teaching tutoring.) The higher test scores were encouraging and certainly for educators who went in search of solutions in uncharted areas.

Table 1: Comparison of Highland Park MEAP Reading Scores (percent), 1991–1994

Grade	1994	1993	1992	1991
4th	28.8	14.4	9.8	8.6
7th	9.3	10.9	8.6	12.8
10th	23.2	13.3	22.4	10.6

Note: MEAP = Michigan Educational Assessment Program. Percentages represent the proportion of students meeting state standards in reading. The 4th graders tested in

1994 had received intensive instruction in Reciprocal Teaching reading comprehension strategies in the 1993–94 school year. Reading scores for the next two years' groups of 4th graders continue to improve: for 1995, 31.5 percent; for 1996, 39.6 percent.

Sandra Thompson, Title One Coordinator, reported ongoing progress for Highland Park

For 1995, 31.5 percent of 4th graders met or exceeded the state standard; for 1996, the percentage was 39.6. Even though these scores were nothing to crow about, the urban Highland Park students, most of who were from minority families with low socioeconomic status, have achieved higher scores than many urban, rural, and suburban school districts in Michigan. Much work remains to be done; teachers continued to collaborate and consult research for solutions to the problems of low student achievement.

The district's teachers now know that research-based applications such as Reciprocal Teaching can be used to help students learn. What a breakthrough! Now, Highland Park can also boast that a significant percentage of its staff understood the application of reading research. Accordingly, the once dim future offers brighter hopes for student achievement in Highland Park. This alone is worth celebrating because high hopes precede high expectations, which, the research tells us, precede high student achievement.

Annemarie Palinscar, co-creator of the Reciprocal Teaching technique, agreed to assist Highland Park in the initial training. Following a session with Palinscar, team members worked in two groups: mathematics and social studies. The researcher challenged them to construct their own meaning about Reciprocal Teaching and develop an approach they might use to teach students the four strategies.

For three weeks, team members discovered what Reciprocal Teaching meant in their own practice, found ways to use it to improve student learning, and created staff development activities that they could use to help ease the staff into the process. Through daily dialogues regarding Reciprocal Teaching and through practice with the strategies on live bodies (the high school students who had failed to achieve endorsed diplomas as a result of their MEAP scores), the teams began to cooperate.

The transition was not as smooth as the researcher envisioned. Although cooperation among all segments of staff was exceptional, some teachers expressed concern about the process and the time it took to follow it in their classrooms even though the process involved teaming with them and supporting their attempts to promote learning for a short time.

There was similar study done by Park (2008), Candidate, School of Communication Sciences and Disorders, on The use of reciprocal teaching to improve reading comprehension of both normal learning and learning disabled individuals in the reading to learn stage. The study examined whether implementing a reciprocal teaching program will improve the reading comprehension of participants in the reading to learn stage. Study designs included: a systematic review, experimental, and quasi-experimental designs. Overall, research supported that reciprocal teaching can improve the reading comprehension of participants in the reading to learn stage, including adults and learning disabled participants. According to Park, in the past 28 years there has been a surge in empirical evidence on the positive association between metacognitive knowledge and reading comprehension (Kelly, Moore, & Tuck, 1994).

Metacognition is "the ability to plan, organize, and reflect on our own cognitive strategies" (Paul, 2001, p. 536). Comparatively, comprehension monitoring strategies consist of "evaluating the issues or failure of the meaning making process (comprehension) and selecting strategies to remedy comprehension problems" (Irwin, 2007, p. 125). Palincsar and Brown (1984) discussed a teaching method which aimed to equip subjects with techniques to increase the use of metacognition and reading comprehension strategies. Their program is called reciprocal teaching (RT). RT is an "instructional technique in which reading comprehension is viewed as a problem-solving activity in which thinking is promoted while reading" (Glaser, 1990, p. 30). Palincsar and Brown (1984) explained that comprehension (assuming adequate decoding ability) is the product of "(1) considerate texts, (2) the compatibility of the reader's knowledge and text content, and (3) the active strategies the reader employs to enhance understanding and retention and to circumvent comprehension failures" (p. 118). This illustrates that metacognitive factors affect reading comprehension, because while one reads, s/he must attend to his/her comprehension of the material. Palincsar and Brown (1984) elected to study the reading strategy element of comprehension. Through a literature review of traditional reading education and theoretical treatments, the authors developed four "comprehension-fostering and comprehension monitoring strategies: summarizing, questioning, clarifying and predicting (p. 121). Summarizing helps one to monitor his/her progress by finding and retaining information. Questioning text meaning leads to active monitoring of one's own comprehension. Clarification and prediction improve comprehension and help one to monitor his/her own comprehension. Hart and Speece (1998) explain "the goal of RT is to improve students' skill in independently comprehending text" (p. 671). RT has two major features. (1) Instruction and practice of the four comprehension-fostering strategies. During this stage, the teacher models these strategies, and may use a 'think-aloud model', illustrating why they are used as well as the mental processes involved in their use (Alfassi, 2004, p. 172). (2) Dialogue between the teacher and student acts as a vehicle for learning and practicing these four strategies (Rosenshine & Meister, 1994). It also acts to focus on "planning, implementing and evaluating the strategies during the discussion of text" (Hart & Speece, 1998, p. 671). Dialogue allows novices to learn from the contributions of more capable peers and it exposes the learner to various points of view which may clarify his/her initial understanding (Alfassi, 2004). Heterogeneous grouping by age or reading ability may maximize the value of RT by providing effective peer models for poor comprehenders. Great emphasis is also placed on encouraging students to provide instructional support for each other. Traditionally the direct instruction can be done with the entire class, and the dialogue is carried out within smaller class groups (Alfassi, 2004).

RT is considered better than explicit teaching or instructional methods alone, in which transfer or generalization effects are rarely found (Palincsar & Brown, 1984). RT takes into consideration Vygotsky's developmental theory and the benefits of expert scaffolding and proleptic teaching. Firstly, Vygotsky describes a child's "zone of proximal development" as the difference between what a child can accomplish unaided and what s/he can accomplish with the help of a more knowledgeable person (Palincsar & Brown, 1984, p. 123). “Vygotsky believed that a great deal of development was mediated by expert scaffolding” (Palincsar & Brown, 1984, p. 123). Expert scaffolding plays a significant role in RT. In “the early stages of RT, the instructor assumes the major responsibility for instruction by explicitly modeling the four strategies. After the initial stage the students take turns leading the group dialogue and practicing the strategies on other sections of text. At that stage, the teacher becomes a mediator who provides guidance and feedback tailored to the needs of the current dialogue leader and his or her respondents” (Palincsar & Brown, 1989, as cited by Alfassi, 2004, p.172). As the students use the four strategies more competently, the teacher begins to diminish his/her scaffolded assistance. Lastly, “proleptic means “in anticipation of competence,” and in the context of instruction refers to situations where a novice is encouraged to participate in a group activity before she is able to perform unaided, the social context supporting the individual’s efforts” (Palincsar & Brown, 1984, p.123). This means the novice performs a simple task while s/he observes and learns from an expert model.

Many studies, including Palincsar and Brown’s (1984), have found that young readers and poor readers do not use effective strategies for monitoring and constructing meaning from text. Poor readers include individuals who have language disorders which is an “impaired comprehension and/or use of spoken, written and/or other symbol systems” (Larson, 2003, p.1). However, “experimental studies have also clearly shown that any student can be taught these higher order skills, and that significant gains in students’ reading comprehension may be brought about through such explicit metacognitive instruction” (Haller, Child, & Walberg, 1988, as cited by

Kelly et al., 1994, p.53). RT has been proven to successfully increase ones metacognition and reading comprehension (Palincsar & Brown, 1984).

The primary objective of this paper was to critically evaluate existing literature regarding the influence of RT on improving the reading comprehension of individuals in the reading to learn stage, including young children and adults as well as normal-learning and learning disabled individuals. The secondary objective was to propose evidence-based recommendations for future research and implications for the use of reciprocal teaching programs.

Research studies selected for inclusion in this critical review paper were required to examine the effects of reciprocal teaching on the comprehension of individuals in the reading to learn stage. Therefore, participants in RT programs were required to be older than eight years, or beyond grade three. Studies were to include expert scaffolding, as well as Palincsar and Brown's four strategies to improve comprehension.

Results of the literature search yielded the following six studies: one systematic review, five experimental/ quasi-experimental controlled.

Rosenshine and Meister (1994) conducted a systematic review of studies to determine the overall effects of RT interventions. The reviewed literature included articles obtained through ERIC and Dissertation, Abstracts International databases, as well as programs from the annual meetings of the American Educational Research Association. Articles were required to meet stringent inclusion criteria and had to consist of comparable experimental and control groups. Each study was rated in quality. The median effect size was .32 when standardized tests were used to measure comprehension and .88 when experimenter developed tests were used. Effect size by type of student and type of test was also measured. Students good in decoding but poor in comprehension obtained an effect size of .29 on standardized tests and .88 on experimenter developed tests. Below average students obtained an effect size of .08 on standardized tests and 1.15 on experimenter-developed tests. The authors noted effective results by means of experimenter-developed outcome measures, regardless of grade level, number of instructional sessions, class size, number of strategies taught, or whether a teacher or experimenter provided the instruction. However, they did find a significant result by type of student interaction, which may have been due to type of measure used. It was noted that experimenter developed tests were used more often with participants who were good at decoding but poor in reading comprehension. These tests revealed significant results. If experimenter generated tests were shown to produce more significant results in general, then the type of test chosen to assess comprehension could have skewed the test results. This suggests that different results may have been obtained if different tests were used on the aforementioned population. The type of test measure could have skewed the results because experimenter developed tests produced more significant results than standardized tests, as the former is easier in nature. Another weakness was the inclusion of unpublished data and non-peer reviewed data. These studies may not have been published for methodological reasons which may have skewed the review's results. Alfassi (2004) carried out two studies, study one was utilized in the present review. Alfassi (2004) hypothesized that students exposed to RT incorporated within a language arts class would show greater improvements in reading comprehension than would students exposed to only traditional methods of literacy instruction and immersion. A comparative study was carried out. Two equivalent mainstream freshman classes of good readers were randomly assigned to a condition, with an experimental group (RT) consisting of 29 subjects, and a control group (traditional literacy instruction) of 20 participants. Equivalent teachers taught the lessons and received six hours of training. Intervention lasted 20 days and was outlined well, however, fidelity of treatment was not measured. Both groups were assessed pre- ,throughout, and post- intervention and maintenance testing was completed. Experimenter developed comprehension questions were used and rated independently, generating a chronbach's alpha of .71 to .85. Participants were also assessed using a standardized test. No effect size was given. A MANCOVA was carried out with post testing, revealing a significant difference favoring the experimental group on reading assessments and standardized measures. The experimental group significantly improved, both experimenter developed and standardized testing showed significant changes between pre- and post testing. Therefore, the educational benefits of incorporating RT into the English Language arts curriculum were verified. Lovett, Borden, Warren-Chaplin, Lacerenza, DeLuca, & Giovinazzo (1996) conducted a controlled comparison of two different approaches, Text Content and Structure Program (TCS) and RT, to train text comprehension skills of a group of adolescents (grade 7/8) with multifaceted reading disabilities. Matched pairs participants were randomly assigned to a program, teacher, and instructional test. There were two experimental groups with 16 participants and a control group with 14 participants. All participants (33 boys and 13 girls) were poor readers (<25th percentile) and 37% were deficient in word identification. The 25 day intervention was led by special education teachers who taught pairs of children matched for reading level. The intervention was not well explained and fidelity of treatment was not reported. Pre- and post-testing occurred using both experimenters developed and standardized tests. However, no assessments occurred during the study to measure progress. Assessment of both taught to (TT) and not taught to (NTT) materials occurred. Three types of comprehension measures were considered separately using a MANCOVA, ANCOVA, and uni variate ANCOVA with post hoc Tukey tests. Results indicated that program effects were large for the RT group and attributable to post test superiority of RT trained group on both TT and NTT texts. Effect sizes of RT on both TT and NTT texts ranged from medium to large on the 4 strategies. Transfer effects for the 4 strategies were evident. Lederer (2000) conducted a study illustrating the effectiveness of RT on text comprehension in social studies classes. He found that the use of scaffolding approaches, such as RT, in general educational classrooms can educate both regular and LD students. This experimental study had control groups but lacked randomization which may bias effects and reduce reproducibility. Participants were students in inclusive classrooms, grades 4-6, with approximately 5/22 LD students per classroom. During the 17 day intervention, the researcher served as the principle teacher and class participants were split into several working groups. The intervention was not described well and fidelity of treatment is unknown. Further, the way in which the leader led the sessions was not analyzed; therefore, there could have been significant differences in instruction between groups, which may have skewed the results. Non-standardized experimenter-developed comprehension assessments were conducted pre-, throughout and post-intervention and 20% of the assessments were scored independently by two different raters. Inter rater agreement was 94.55%.

A MANOVA and Tukey's post hoc testing found a significant change in reading comprehension for treatment and as a function of grade. Also a significant improvement was seen in the experimental group's ability to answer questions, generate questions, and compose summaries. A specific comparison between LD's in experimental and control groups were carried out using an ANOVA. No significant difference was found in the ability to generate questions, but a significant difference was found in the ability to compose summaries. An independent-test indicated that the experimental classes at the 4th and 5th grade performed higher, but not significantly higher than the control groups. The 4th and 6th grade experimental classes demonstrated significant comprehension gains 30 days post intervention. Lederer explained possible teacher confounds for grade five. Medium to large effect sizes were found for answering questions, generating questions, and creating summaries. A problem with this study was that it only assessed the use of answering and generating questions and summarizing. Hart and Speece (1998) examined the effects of RT on reading comprehension in post secondary developmental reading programs. They conducted a quasi-experimental, non-equivocal control group design with pre- and post-testing. The intervention was led by the researchers, which may have biased the results.

The participants were below average readers in the community college. Pre- and post-test scores were obtained from standardized and non-standardized testing. Prior to test scoring, high inter rater reliability of .80 was established. After scoring was completed, 25% of the assessments were randomly selected to check reliability, revealing a coefficient of .80. Various statistical analyses were carried out consisting of a Wilcox-on-Mann-Whitney test, MANCOVA, ANOVA, and Tukey's honest difference procedure. The analyses revealed a significant difference favoring the experimental groups on post-test scores on all four strategies with an effect size of .30. Post test scores revealed a significant difference between scores on all four strategies for poor readers, and on questioning for better readers and a significant difference between pre- and post-testing on all strategies. This study had a high treatment fidelity index of 95% and 93%. A weakness was that this study had a few drop outs and the authors did not indicate what was done to account for the missing data. Kelly, Moore and Tuck (1994) assessed the effects of RT with the four strategies on poor reading comprehenders in a regular classroom setting. A multiple baseline across group design with between phase comparisons were utilized. Participants were purposively chosen by academic delays. Twelve participants in the experimental group (received RT) were in two parallel standard three and four classrooms. The attention only comparison group consisted of six students in one class who were performing at average or above average levels. Comprehension probes occurred daily; however, the three groups did not receive identical testing throughout the sessions. Therefore, between groups comparisons may have been limited. The authors did not address this issue. As well the sample size was small; therefore, the results may not be replicable. No effect size was reported. The strength of this study was that participants received frequent testing and interrater reliability of assessments revealed a mean of 98% agreement. Fidelity was addressed by examining audiotape recordings of six baselines and 18 intervention sessions with experimental group one for all instances where one of the strategies was used.

2.9 Empirical studies on student-centred learning

Froyd and Simpson (2006) carried out a study ‘Addressing Faculty Questions about Student-centered Learning’, Texas A&M University. Below are the questions and suitable answers given.

What is meant by Student-centered Learning (SCL)?

A variety of phrases have been coined to describe a critical shift in mission and purpose of higher education. Barr and Tagg (1995) expressed the change as a move from an Instruction Paradigm in which universities delivered instruction to transfer knowledge from faculty to students to a Learning Paradigm in which universities produce learning through student discovery and construction of knowledge. Huba and Freed (2000) used the phrase learning-centered assessment to emphasize transition in the focus of instruction and assessment from teaching to learning. The following description of student-centered instruction provides another starting point for conversations about student-centered learning: Student-centered instruction [SCI] is an instructional approach in which students influence the content, activities, materials, and pace of learning. This learning model places the student (learner) in the center of the learning process. The instructor provides students with opportunities to learn independently and from one another and coaches those in the skills they need to do so effectively.

The SCI approach includes such techniques as substituting active learning experiences for lectures, assigning open-ended problems and problems requiring critical or creative thinking that cannot be solved by following text examples, involving students in simulations and role plays, and using self-paced and/or cooperative (team-based) learning. Properly implemented SCI can lead to increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes towards the subject being taught (Collins & O'Brien, 2003).

Student-centered learning can also be viewed from the perspective of an influential report from the National Research Council (1999) that synthesized research on learning and recommended organizing learning environments around four foci:

knowledge-centered, learner-centered, assessment-centered, and community-centered. Knowledge-centered learning approaches grow out of the research on novices and experts that has revealed that experts have organized their knowledge very differently than novices. So knowledge-centered learning stresses learners developing their knowledge to facilitate transfer of their learning to new contexts and application of their learning to open-ended challenges such as problem-solving, critical thinking, and design. In a learner-centered learning environment, McCombs and Whistler (1997) state that learners are treated as co-creators in the learning process, as individuals with ideas and issues that deserve attention and consideration: Learner-centered learning environments recognize that the prior knowledge of learners powerfully influences future learning and thus attempt to build on prior knowledge. Assessment-centered learning environments provide opportunities for feedback and improvement throughout the learning process leading to evaluation and judgment at the end of the learning process. Assessment for feedback and improvement is referred to as formative assessment while assessment for conclusive evaluation and judgment is referred to as summative assessment. Nicol and Macfarlane-Dick (2006) indicate that formative assessment can promote the development of capacities and attitudes used in lifelong learning.

Assessment-centered learning environments also emphasize congruence between learning goals and what is assessed (National Research Council, 1999). Finally, community-centered environments recognize that individual learners take many cues and insights from learners around them, so that community-centered learning environments facilitate purposeful interactions among learners to promote and sustain learning. For the purposes of this study, learning environments are student-centered to the degree to which they are concurrently knowledge-centered, learner-centered, assessment-centered, and community-centered. Many different faculty members have developed and used approaches to teaching that fit the criteria for student-centered learning. Many of these developers have created original names for their approaches. As a result, there is a broad spectrum of named approaches, which include

- Active Learning (Bonwell & Eison, 1991)
- Collaborative Learning (Bruffee, 1984)
- Inquiry-based Learning
- Cooperative Learning (Johnson, Johnson, & Smith, 1991)
- Problem-based Learning
- Peer Led Team Learning (Tien, Roth, & Kampmeier, 2001)
- Team-based Learning (Michaelson, Knight, & Fink, 2004)
- Peer Instruction (Mazur, 1997)
- Inquiry Guided Learning
- Just-in-Time Teaching
- Small Group Learning
- Project-based Learning
- Question-directed Instruction

Faculty members often have many questions about student-centered learning approaches and implications for how they might teach. Several of these questions will be addressed in this document:

- Why would one adopt a student-centered learning approach in your course?
- Can the teacher cover the content in the syllabus using student-centered learning approaches?

- Can the student-centered learning approaches be used when teaching large classes?
- Is it possible to move from teacher-centered to student-centered in stages? How?
- How does one respond to student resistance when I start using student-centered learning approaches?
- How does one respond to students who really like being entrusted with their own learning when one begin using student-centered learning approaches?

Also, many student-centered learning approaches involve faculty forming students into small groups or teams for learning activities. Prospects of working with student teams raise another set of questions, which are addressed in the last portion of the document.

- How should one form the teams?
- How does one get teams off to a good start?
- How can one help students develop their teamwork capabilities?

Why might one adopt a student-centered learning approach in a course of study?

Although there are many different reasons why faculty members choose to adopt a student-centered learning approach, they might be placed into two broad categories. First, it is enjoyable. Faculty members who have adopted one or more of these approaches report that they are energized (Mhlamvu, 2006). Second, there is a growing set of results on how these approaches lead to improved student learning.

What does research say about student-centered learning?

Do student-centered learning approaches lead to improvements in student performance? Results from a growing number of studies indicate that the answer is yes. For more details on these studies the Center for Teaching Excellence at Texas A&M University is compiling a bibliography of papers that demonstrates student-centered learning approaches lead to measurable improvements. Some of the papers are meta-analyses that synthesize results from numerous individual studies. These results confirm positive influences of student-centered learning approaches to teaching on academic performance, attitudes toward learning, and persistence in programs. In light of the growing evidence of the effectiveness of student-centered learning approaches, Handelsman et al. (2004), in an article in *Science*, stated that there was ample evidence that supplementing or replacing lectures with active learning strategies and engaging students in discovery and scientific process improved learning and knowledge retention.

Can one cover the content in the syllabus using student-centered learning approaches? Although faculty members may find student-centered learning approaches to be more enjoyable and lead to improved student learning, they still have questions about the amount of content that can be covered using the approaches (Cooper, MacGregor, Smith, & Robinson, 2000; Cooper, 1995; Felder & Brent, 1999; Tien et al., 2001). Content coverage is still high priority for faculty members, especially for faculty members teaching prerequisite courses on which faculty members teaching downstream courses are depending for student preparation. Answers to whether faculty members can cover the same or more content with student-centered learning approaches as can be covered with traditional lecture-based approaches depend on individual teachers. Although some teachers indicate that they cover as much or most content with student- centered learning approaches, some adopters of student-centered learning approaches indicate that they now cover less content than when they exclusively lectured, but that students are learning more. For example, as indicated in the research summaries of The Active Learning Site, Ruhl, Hughes and Schloss (1987) showed that students in courses in which faculty members paused at intervals and talked six minutes less performed significantly better on the same exam than students in courses where faculty lectured the entire time. For faculty members who are interested in learning more about how to cover the same or more material with student-based learning approaches, the following resources offer well-tested ideas:

- Richard Felder and Rebecca Brent have addressed this question many times in workshops on effective teaching. In the first half of this column (Felder & Brent, 1999) they offer a summary of their response.
- In an article, Cooper, MacGregor, Smith, and Robinson (2000) address several questions or concerns that faculty members have raised about small-group learning. The first question that they address in their article is about content coverage. The faculty members who were interviewed expressed consistent satisfaction that students in their classes are demonstrating one or more of these indicators of increased learning: much greater conceptual understanding, more complex critical-thinking skills, better class attendance, more independence in lab settings, and greater confidence. About two-thirds of the faculty members we interviewed said that they covered fewer topics in class when they used group work, but that students learned and retained more of the big ideas that they chose to address relative to using lecture formats. Answers

to other questions provide approaches that faculty members have used to adapt student-centered learning approaches for their courses.

Can one use student-centered learning approaches when teaching large classes?

- Cooper and Robinson (2000) offered strategies for using informal (students working in small groups for short periods of time) small-groups in large classes. Strategies include: think-pair-share (Lynam, 1981), peer instruction (Mazur, 1997) and minute papers (Angelo & Cross, 1993; Stead, 2005).
- After faculty members are comfortable with informal strategies, they might consider moving to formal strategies described by Smith (2000). Implementation of these strategies requires more advanced preparation, but can move students toward accepting more of the responsibility for their learning and lead to the development of greater capabilities for lifelong learning.
- Participants in workshops by Felder and Brent have raised this question frequently. In the second half of their column (Felder & Brent, 1999) they offer a summary of their response. They indicate that it is important to limit each interactive activity to its predetermined time limit and select students to share some conclusion or result from their work.
- Allen and Tanner (2005) offer a set of seven strategies that have been applied in large enrollment biology courses.
- Michaelsen, Knight and Fink (2004) offer examples of team-based learning in large classes.

Can one move from teacher-centered to student-centered in stages? How?

First, using student-centered learning approaches to teaching never means that teachers do not lecture. Next, slow, thoughtful, reflective transitions to student-centered learning approaches are likely to lead to the most sustainable changes in teaching. Faculty members might begin with informal cooperative learning approaches: think-pair-share (Lynam, 1981) and minute papers (Angelo & Cross, 1993; Stead, 2005). Here are possible directions:

- They might consider using a small number of the approaches listed on the Engaging Students Tip Sheet [include sheet prepared by Jean Layne].
- They might consider using a few informal cooperative learning structures (Cooper & Robinson, 2000) for engaging their students for short period of time after lecturing for a portion of a class. Informal cooperative learning structures include:

Think-Pair-Share: Ask students to think individually about a question for about a minute, turn to a neighbor and exchange ideas, and then randomly select a small number of students to share both ideas (Lynam, 1981). Instead of pairs, you can use groups of 3 or 4.

Roundtable: Ask a group of students a question. First, student writes and shares her/his answer, passes to second student, and so on.

Minute Papers: Ask students to address two questions at the conclusion of a lecture segment or a class. The first question is about what they thought was clearest or most significant (Angelo & Cross, 1993; Stead, 2005).

- Allen and Tanner (2005) recognized that moving out from behind the relative safety of the lecture podium to adopt the types of active strategies that shift classroom emphasis away from teachers 'teaching toward students' participation and learning is often an unsettling prospect, even in the small-class setting: Therefore, they have assembled a set of seven strategies, ranging from simple, easily implemented approaches to complex restructurings of the entire course.

Bookend Lectures: Faculty members can insert short interactive sessions (think-pair-share, student writing) after every 10-20 minute lecture session (Bonwell & Eison, 1991; Ruhl et al., 1987). If they begin with an advance organizer and finish with a classroom assessment technique, such as a minute paper, they create a bookend lecture (Smith, Sheppard, Johnson, & Johnson, 2005).

Immediate Feedback via Classroom Technology: Various technologies from scratchable scantran sheets (Allen & Tanner, 2005) to personal response systems (clickers) (Fies & Marshall, 2006) can be used to provide students immediate feedback through questions on their preparation for class or concepts that arise during class.

Student Presentations and Projects: Faculty members can assign projects and reports to actively engage students in explorations of the course material.

Learning Cycle Instructional Models: Faculty members can use different learning cycles to construct classes that move students through a sequence of questions about the material in a class (Why, What, How, and What if) (Harb, Durrant, & Terry, 1991).

Peer-Led Team Learning (PLTL): Undergraduate students can facilitate one or more cooperative learning groups in course to guide exploration of problem solving, inquiry, or discovery (The Peer-Led Team Learning Workshop Project, nd).

Problem-Based Learning and Case Studies

As you develop comfort with a small set of approaches, expand your set. Consider a more involved activity, e.g., a jigsaw or extended project in which you prepare students to work more effectively as a team and manage the project over the time you have allocated.

How does one respond to student resistance when using student-centered learning approaches?

Since you will be asking learners in your class to behave differently, you should expect some resistance, since all humans tend to resist requests for changes. So anticipate some resistance and be prepared to address the resistance constructively. Explain to students why you have chosen to adopt these approaches and how you think it will benefit them. It may be helpful to indicate that you will be providing opportunities for their input and will respond to their ideas. Here are some suggestions:

- Felder and Brent acknowledge some of the bumps in an article, Navigating the Bumpy Road to Student-Centered Instruction (Felder & Brent, 1996) and offer ways they have found to address these.
- One of the questions that Cooper, MacGregor, Smith, and Robinson (2000) address is student resistance: The faculty members who were interviewed indicated that initial resistance among students generally focused on prior bad experiences with poorly planned and executed group work in high school and college. They offer some strategies based on their interviews with faculty members: clarify changing expectations before and during implementation of new strategies, create meaningful activities that encourage students to process

information in different ways and yet that are at an appropriate level of difficulty and complexity, and clarify expectations for each learning activity.

- Keeney-Kennicutt, Gunersel, and Simpson (2008) studied an implementation of Calibrated Peer Review, a web-based program that supports peer review of student papers following an exercise in which students calibrate their assessment of faculty-generated examples. They uncovered student reasons for liking and disliking the innovation and documented instructor modifications to address resistance.

How does one respond to students who really like being entrusted with their own learning when using student-centered learning approaches?

The need for learning how to learn is becoming more widely recognized from many different directions. It may be helpful to provide resources to these students that affirm and reinforce their inclination to initially accept responsibility for their own learning:

- Accreditation mandates have brought to the forefront the need to be life-long learners in the ever-changing and evolving engineering profession, coupled with the fast changing technologies and the need to accommodate a global society (Marra, Camplese, & Litzinger, 1999).
- A new class within the workforce has been identified as knowledge workers. The key knowledge workers are engineers. Engineers must continually learn in order to stay abreast of the technologies that impact their jobs (Wells & Langenfeld, 1999).
- The half-life of an engineer‘s technical skills is 2.5-7.5 years, depending on your discipline. This means that the vast majority of the technology that will

exist in the latter part of a 40-year career has not yet been developed: During an engineer‘s career, he/she will develop some of this new technology. New tools and techniques will be used in daily work. Employers expect engineers to either learn this new information on their own or to find someone who can teach it to them (Todd, 2001). Other information on the rate of growth of scientific and engineering knowledge can be found in Wright (1999).

- Finally it should be acknowledged that the greatest motivation for learning is learning itself. If a student can make the transition from extrinsic rewards (recognition, grades, etc.) to intrinsic rewards, then the basis for lifelong learning will have been established. In engineering, there is a joy of learning that is associated with knowing and predicting how the world works. Students need to have opportunities to experience this (Parkinson, 1999).

Given the importance of attitudes and capabilities for lifelong learning, students who have accepted greater responsibility for their own learning, which is inherent in any student-centered learning approach, have made an important step in their intellectual development. Faculty members can work with students to raise deeper questions about how they learn and how they can adjust to facilitate their own learning. Kornell and Bjork (2007) raise key decisions that learners must make about their own learning and how they need more accurate pictures of how they learn.

Facilitating Small Groups

Many of the student-centered learning approaches have students participating in small groups in class, and in some cases, out of class. Often, students do not have the knowledge and skills to work effectively in groups. However, if prompted, they are familiar with problems that can arise when working in groups and they have some ideas about how to address these situations. Here are some of the questions that faculty members often ask about using small groups or teams as part of an approach to teaching.

How should one form the teams?

The faculty member has the primary, but not the only, responsibility for creating a safe, productive learning environment. In general, the teams that are formed influence the learning environment that is created. As a result, the faculty member has the responsibility for forming teams.

- The Foundation Coalition in 2001 created a resource, Forming Student Teams that addresses questions about team size and offers strategies for forming teams that faculty members have used in their courses.
- In Effective Strategies for Cooperative Learning, Felder and Brent (1996) offer some strategies for forming teams
- The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project has written a peer-reviewed book chapter, called The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP), in which physics faculty members from several different institutions share their insights for forming teams
- Michaelsen, Knight and Fink, (2004) offers strategies for forming teams in a primer, Getting Started with Team Learning. The primer contains information on forming teams. More information about his approach to Team-Based Learning can be found in his book, *Team-Based Learning: A* Transformative Use of Small Groups in College Teaching, and a summary, Building Learning

Teams: The Key to Harnessing the Power of Small Groups in Higher Education, by Michaelsen and Block.

How does one get teams off to a good start?

Most college students do not have the knowledge and have not developed their capabilities to function effectively on a student team. Therefore, faculty members must work to establish a learning environment that supports effective student teams. Many of the challenges that occur when using student teams can most effectively be addressed at the beginning of the course. Here is when student teams can identify potential concerns, including possible leader and participant issues, and develop norms of behavior through which these concerns can be addressed. Here is when the teacher can set out policies for addressing problems which may occur downstream. Here is when the teacher can lay out evaluation policies that will address grading team assignments.

- The Foundation Coalition created a resource, Helping Teams Off to a Good Start.
- National Institute for Science Education - College Level One: Innovations in Science, Math, Engineering, and Technology Education offers an annotated bibliography, stories from teachers using collaborative learning, and a set of strategies that have been used for collaborative learning.
- Information Technology Services at Penn State University offers guidelines and activities to offer a solid foundation for future teamwork

How does one grade team assignments?

Giving every team member the same grade on a single assignment submitted as a team does not promote individual accountability which is one of the core elements of effective cooperative learning. For faculty members looking for alternatives, the following resources will be helpful.

- Smith, (1990) offers the following suggestions to promote individual accountability: (i) keep group size small, (ii) assign roles, (iii) randomly ask one member of the group to explain the learning, (iv) have students do work before group meets, (v) have students use their group learning to do an individual task afterward, (vi) everyone signs: ―I participated, I agree, and I can explain the information, and (vii) observe and record individual contributions.
- Peer assessment, in which team members offer data to help discern and evaluate individual contributions, is one approach to differentiating grades. The Foundation Coalition offers a resource on peer assessment and a resource on monitoring the progress of student teams on extended team assignments. The Office of Educational Development at the University of North Carolina offers a resource on developing effective student team exercises.
- Positive Interdependence, Individual Accountability, and Promotive Interaction offers guidelines to incorporate these three essential elements into developing team activities.

How can one help students develop their teamwork capabilities?

Faculty members have a tremendous opportunity to help their students develop an important set of skills that will be needed throughout their lives.

- Information Technology Services at Penn State University offers a suite of resources to help faculty members support the development of capabilities needed for effective teamwork.
- The Foundation Coalition, (2001) offers resources on conflict management and resolution, communication within a team, and decision making within a team framework.
- Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) offers a set of resources for working with student teams.

2.10 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 (Mhlamvu, 2006). 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 are somehow killed at school. 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 in 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, Prestley 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 dioxide 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+ light energy + green pigment-------- O_2 + organic matter + 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, Priestley. He found in 1864 that the photosynthetic ratio-the volume of O_2 evolved to the volume of CO_2 used up is almost infinity. 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 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 & Rao, 1994).

2.11 Why are photosynthesis and cellular respiration 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 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 respiration. According to Campbell and Reece (1995), oxygen released in photosynthesis also raises 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).

2.12 Why photosynthesis and cellular respiration should be taught

The majorities of the world's people live by growing plants 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 of every nation because it helps clear the air of carbon dioxide, which is poisonous to many organisms and contributes to global warming.

Trees after photosynthesizing will release O_2 which would be used by animals during respiration.

2.13 Why learners seem to show less interest in photosynthesis and cellular respiration?

Plant sciences are, in general, underrepresented in high school and undergraduate courses, in South Africa, (Hershey, 1992) and often receive a poor response, especially from students enrolled in biomedical type course who complain that plants are boring. The situation is not different in schools here in Ghana. Looking at the central role of photosynthesis and cellular respiration in biology, teachers struggle, nevertheless, to promote the relevance and importance of photosynthesis to their students. Photosynthesis and cellular respiration are also a conceptually difficult topics, which span 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 these two topics. Learners seem to be bored when learning about plants because they feel photosynthesis and cellular respiration are too abstract. The researcher concurs with (Sharan, 2004) 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, according to learners, it is a natural and automatic process (Sharan, 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.

2.14 Challenges in teaching photosynthesis and cellular respiration

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 cannot be seen or experienced. In science, topics that are taught include 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 and cellular respiration. 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 2004). Pedagogical content knowledge (PCK) is important in teaching difficult topics like photosynthesis and cellular respiration. It is a concept introduced by Shulman (1986) who stated 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 and cellular respiration 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 life, 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 (Beale, 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 and cellular respiration 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 reciprocal instructional approach where educators present the concept and learners analyze or having learners to write poems about leaves or plants.

2.15 Students' misconceptions in photosynthesis and cellular respiration

Photosynthesis is often de-emphasized 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, (2004) and a number of authors support the statement that in these topics in Biology, major misconceptions often persist in students' understanding of photosynthesis and cellular respiration (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 term 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 photosynthesizes 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 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, their literacy in this area is likely to remain at a low level, (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 and cellular respiration.

2.16 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 includes 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 give a very simple outline of what high school students should be taught on photosynthesis. The outline covers what the entire 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 play 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
   - Photosystem 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 + Phosphate = ATP

4. The Biochemical Reactions: The Calvin Cycle

- "Fixing" CO_2
- Cyclic series of enzyme reactions

2.17 Students' perceptions of photosynthesis

A review of the literature on teaching and learning about plant nutrition was conducted by (Driver, 1993 & 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 explicit: to problematise the simple scientific explanation that carbon dioxide combines with water to produce sugar in photosynthesis.

c) To demonstrate 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 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 assess and consolidate the learning by revisiting the source and function of food in plants and animals.

2.18 Summary and Conclusion

This chapter lays the background of learning and the various theories of learning. It also talks about creating environments and using instructional approaches that puts learners at the centre of the teaching and learning process rather than teacher. In addition, similar research studies on Reciprocal and learner centred instructional Approaches were mentioned. This chapter again lays the background of photosynthesis and cellular respiration. The importance of these processes and the reasons why they 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 and cellular respiration together with Ghana syllabus specifically in these topics. The researcher also researched widely on strategies used by teachers internationally to enhance the learning/teaching of photosynthesis. Towards the end of this chapter there is a lengthy discussion of tips and ways of dealing with misconceptions because these help to understand the nature of the learners and how they should be treated to make schooling a useful and beneficial experience.

Closer looks at all the works done by various researchers on Reciprocal Instructional Approach highlighted by the researcher in this chapter were to improve student performance in the English Language subject. In the case of the Learner-Centred Instructional Approach, various researchers used them in different subject areas that yielded a positive result in improving on the performance and achievement of students. It must however be stated that none of the research studies compared how effective any of the Instructional Approaches is over the other.

CHAPTER THREE

Methodology

3.1 Overview

This chapter focuses on how the study was designed and population and sample chosen. It also covers pre-intervention activities, intervention and implementation of intervention. Post intervention activities as well as data collection procedure and method of data analysis are also considered in this chapter

3.2 Research Design

The case study design, using action research approach, was adopted for this study. Because the researcher's initial intention was to determine how effective the student-centred and reciprocal instructional approaches were, two intact classes were used for the study. Consequently, the Collaborative Action Research approach was utilized in the intervention. The researcher sought the aid of one experienced female teacher as her research partner. 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 previous final examination papers on the section dealing with photosynthesis and cellular respiration. Betram (2003) stated that it was important for items to be properly designed so as to ensure that respondents understand what is being investigated. The test technique was preferred because it could be administered to a large number of learners at a time.

3.3 Population and Sampling procedure

The target population was all SHS biology students in the Ada East District in the Greater Accra Region. However the accessible population was SHS biology students in Ada Senior High School. A sample of 90 students in two equal intact classes was selected for the study. Thus each of the two intact classes (3vsc1 and 3vsc2) contained 45 students. Three V science 1 comprised 36 boys and 9 girls while 3vsc2 consisted of 38 boys and 7 girls.

3.4 Research Instruments

The research instruments used in this study were observation and standardized test papers designed by the researcher. The test was used to assess the achievement of the Form 3 biology students. The main instrument used was a test. The researcher decided to use tests because they are accepted instruments to measure learners' knowledge and reasoning skills from which to deduce the quality of teaching and learning after an ordinal encounter by a group of learners. The question paper consisted of fifty items in photosynthesis and cellular respiration with the total mark of 100. The items covered different levels of Bloom's taxonomy.

3.5 Reliability of the Main 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 reliability of the test items was determined using test-retest procedure. Students who had similar characteristics as the research subject were used for the exercise. The performance of the students in the first administration was recorded. The test was then administered to the same group of students after a week's interval. The data collected on the two days of test administration were analyzed using Pearson coefficient of correlation formula. This yielded a value of 0.97. Details can be found in Appendix E

3.6 Validity of the Main 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 standardized paper designed by the researcher and vetted by the researcher's supervisors. This resulted in the cancellation of some items in the instrument and the modification of some of the retained items. This was done to improve the readability of the items in the instrument.

3.8 Data Collection Procedure

This section documents the description of the Pre-Intervention Activities, Intervention Activities and the Post-Intervention Activities as used in the study.

Pre-Intervention Activities

In order to diagnose the specific cognitive challenges the students faced with respect to photosynthesis and cellular respiration, the following activities were undertaken. A pre intervention diagnostic test was formulated into five different items.

Item one consisted of terminologies 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 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" which obviously showed they have been holding on to this preconception for awhile. It is apparent that the word "control" was not interpreted with understanding. This poses the question, do students fail to answer the question because they do not know the answer or because of preconceptions they hold relating to the subject area (as they do not understand the question)? Or most importantly is it because of the mode of instruction used to teach them? 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. Students were again asked to give the difference between cellular respiration and gaseous exchange. Some candidates argued that cellular respiration is same as gaseous exchange. Another question which required candidates to identify various stages in glycolysis and Krebs cycle was poorly answered and students grossly displayed ignorance.

In the researcher's experience of teaching, students tended to use rote learning as a strategy in grasping related concepts in cells and energy. Beale (2003) reported that concepts in photosynthesis and cellular respiration are complex, difficult to grasp and abstract for students to understand because of the invisible nature of cells and how most of the processes occur. This assertion by Beale goes to confirm why students have difficulties understanding these concepts. After the diagnostic test, Students received an overview of future units and were warned that they were going to prepare lessons on given topics, become experts on those topics, and teach those topics to their peers. Students were told "one learns better when one teaches someone else." Other reasons included practice and mastery of speaking and presentation skills, use of academic and scientific vocabulary, and just the fun of being a teacher for a day. Details can be found in Appendix A.

Intervention Activities

The first month of the term was used to acquaint students with classroom norms, procedures, and routines, as well as with themselves (community building). Students were also presented with the curriculum plan for the term that included the units to be covered along with deadlines. The Unit "The process of photosynthesis" was taught through direct teaching with modeling of reciprocal teaching and learner-centred environment approach in 3vsc2 and 3vsc1 respectively. With 3vsc2 which was instructed using the reciprocal instructional approach, the researcher employed the four strategies as used by Palinscar and Brown (1984). The strategies involved training students to use four techniques that were associated with both improving reading comprehension and self-monitoring of comprehension while reading. The four strategies were (1) generating questions, (2) summarizing, (3) clarifying, and (4) predicting. With the class that was instructed with the student-centred instructional approach, the researcher used Peer-Led Team Learning (PLTL) which involved exploration of problem solving, inquiry, or discovery and Think-Pair-Share, where students were tasked to think individually about a question for about a minute, turned to a neighbor and exchanged ideas, and then randomly selected a small number of students to share both ideas. Instead of pairs, the researcher used groups of 6. Six lessons were designed in a period of six weeks for all classes.

In week one, the classes covered the following units: Photosynthesis; The process of photosynthesis, Adaptations of the leaf for photosynthesis. Week two, factors that affect the rate of photosynthesis and experiment to test for starch. Week three saw them do Biochemical nature of photosynthesis. In cellular respiration, the following were considered; week four the process of respiration and its chemical equation, week five, Glycolysis, with the final week on Krebs cycle.

For every unit, the following activities were completed: outlines, key terms with definitions and drawings that represent each key term, lesson preparations that involved reading, questioning, clarifying, and summarizing (reciprocal teaching steps) in forms that could be presented to the class, and finally presentations to the entire class. Students spent 1-2 class periods preparing their lessons which included visuals such as power points, graphic organizers, and posters. Students were also encouraged to practice their presentations and pronunciations. Lessons lasted 10-15 minutes followed by questions to the audience and from the audience. Emphases in presentations were placed on how efficient they taught the material to their peers.

One major weakness identified in both intact classes was that some students did not contribute to the group work.

Post-Intervention Activities

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 previous final examination papers on the section dealing with photosynthesis and cellular respiration. Bertram (2003) stated that it is important for items to be designed properly, so as to ensure that respondents understand what is being investigated. The test technique was preferred because it could be administered to a large number of learners. The items administered in this study could be understood with the absence 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 third year due to the fact that they had come through previous final examinations. Post-Intervention questions can be found in Appendix B.

3.9 Method of Data Analyses

Part of the data was analyzed using frequency counts, simple percentages means and standard deviation scores: The data were later tabulated and also presented as multiple bar charts in different figures. The use of the data was subjected to narrative description by reference to the appropriate research questions.

CHAPTER FOUR

RESULTS

4.1 Overview

This chapter documents the results of the investigation to establish whether or not there is a differential effect of learners taught using learner centered instructional approaches and those with reciprocal instruction in photosynthesis and cellular respiration.

The study was conducted in Ada Senior High School so as to determine the pre-conceptions relating to the concepts in photosynthesis and cellular respiration students hold. The data collected are 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 bar charts. Data on the different presentations made by learners appears in tabulated form.

Data on the different pre-conceptions relating to the concepts of photosynthesis and cellular respiration made by learners appears in this chapter. A bar chart illustrates the performance of the different groups.

4.2 Data Presentation by Research Question

The data collected are presented based on the research questions formulated for the study.

Research Question One:

What pre-conceptions relating to the concepts in photosynthesis and cellular respiration do students hold?

A pre intervention diagnostic test was conducted for both classes.

The study found that the pre-conceptions relating to photosynthesis included the following:

1. plants get most of their food from the soil not from the sun.
2. Plants photosynthesize during the day and respire at night.
3. sunlight is a reagent not a source of energy.
4. simple molecules like water and carbon dioxide cannot combine to produce a complex substance.

The rest of the students' pre-conceptions in photosynthesis are summarized in Table 2.

Table 2: Students summarized photosynthesis pre-conceptions

Statements of pre-conceptions
The light phase of photosynthesis occurs in upper epidermis, chlorophyll and stomata.
The main photosynthetic tissue in an angiosperm leaf is xylem tissue, cuticle and chloroplast.
Variegated leaf is a plant with two colors.
Food is absorbed from the soil through the roots of a plant.

Photosynthesis and cellular respiration does not work together to provide ATP for plants

On the other hand, the study also found that students' pre-conceptions relating to cellular respiration were:

1. Cellular respiration is same as breathing.
2. At the end of cellular respiration CO_2 is produced.
3. All the energy released from glucose is captured in ATP.
4. Input molecules for cellular respiration include only carbohydrate.

The rest are summarized in Table 3

Table 3: Students summarized pre-conceptions in cellular respiration

Statements of pre-conceptions
When O_2 is not available, cells use a different process to make ATP
Only animals carry out cellular respiration
Photosynthesis and cellular respiration do not work together to provide ATP for plants.

Below are the overall data illustrated graphically on preconceptions students hold relating to photosynthesis and cellular respiration. Performances of students during the pre-intervention and post-intervention have been illustrated in the charts shown in Figures one and two.

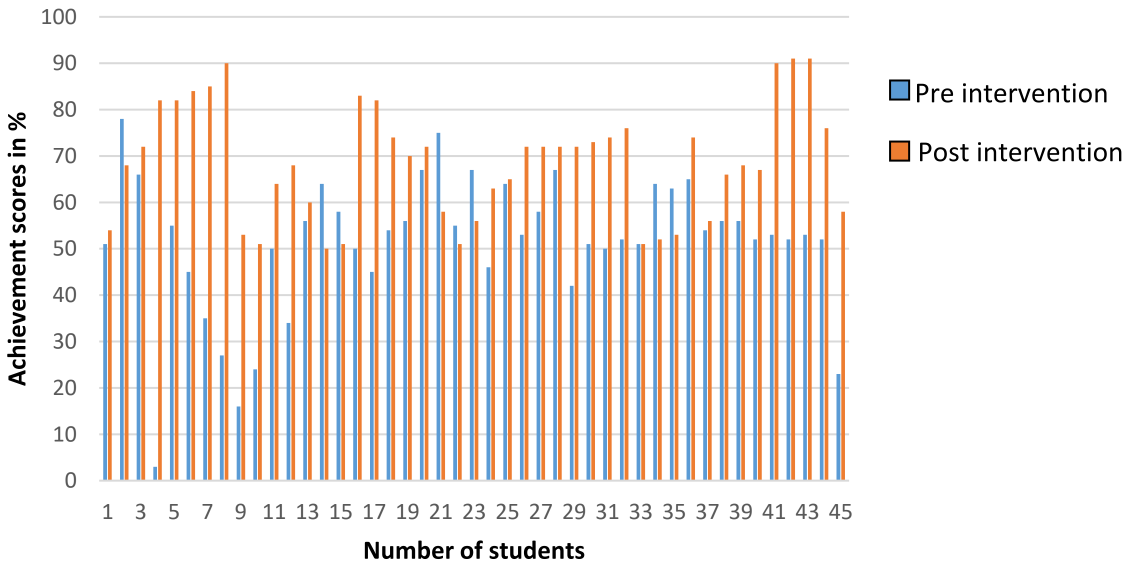

Figure 1. Achievement scores of students in 3vsc1, pre and post intervention data

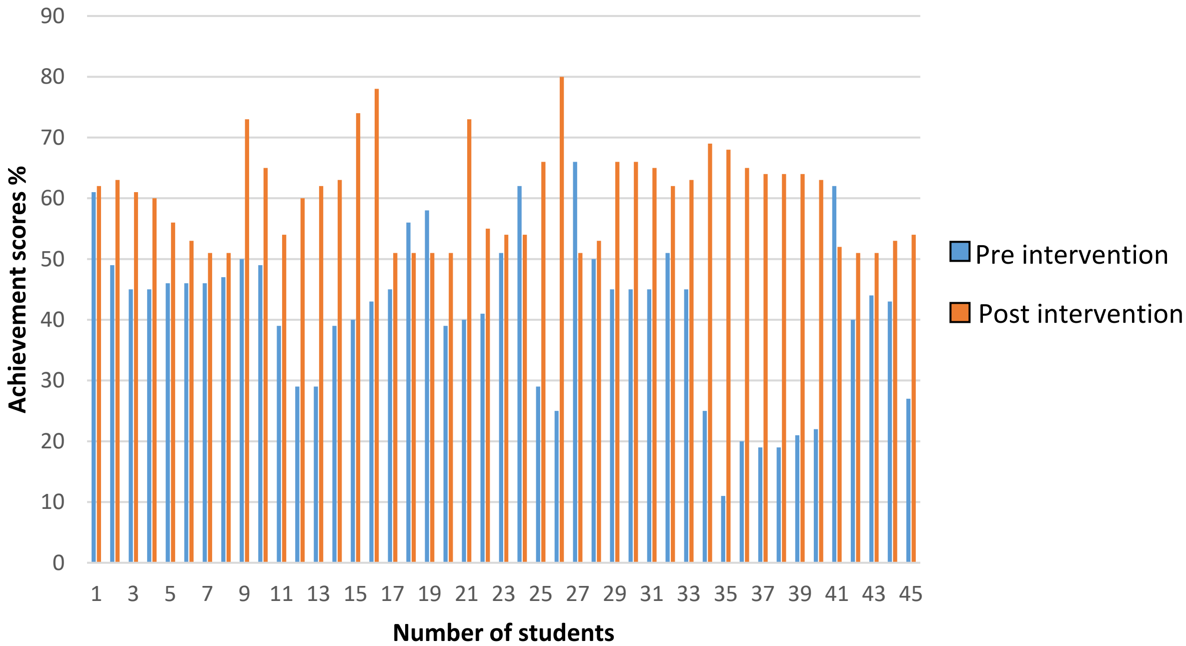

Figure 2: Achievement scores of students in 3vsc2. Pre and post intervention data

Research Question Two

Are there differences in the mean scores between students instructed using student centered and reciprocal instructional approaches on concepts in photosynthesis and cellular respiration?

The pre- and post-intervention scores of both classes were compared as shown in Table 4.

Table 4: Comparison of pre and post-intervention scores of 3vsc1 and 3vsc2 students

Group	Intervention Type	Pre-Intervention Score	SD	Post-Intervention Score	SD	Mean Gain or Loss
3VSC1	SC	51.28	14.8	68.71	12.3	17.42
3VSC2	RT	41.08	12.9	60.35	7.9	19.27

SC= Student-Centred, RT= Reciprocal Teaching

The results showed that the mean gains in the students' cognitive achievement were lower for the 3VSC1 students as compared to their 3VSC2 counterparts. While the mean gain for the 3VSC1 students (who were instructed using the student-centred approach) was only 17.42, that of the 3VSC2 (who were instructed using reciprocal instructional approach) was only 19.27.

This appears to suggest that the reciprocal teaching was relatively more effective as an intervention instrument as compared to the student-centred as an intervention instrument. Additionally, the data in Table 4 show that the standard deviation of the scores of 3VSC2 was lower after the intervention as compared to 3VSC1 students.

This is additional data proof that the use of reciprocal teaching appeared to be more effective as compared to the use of student-centred approaches.

Data on Respondents' presentations

Data related to learners' various presentations in the course of the research study is analyzed as shown in Figure 4

Table 5: Group presentation data

Rubrics for presentation	3vsc1	3vsc2
Source of information	8	6
	7	7
	9	9
Detailed of work	9	8
	10	9
	10	8
Understanding of concept	10	7
	10	7
	10	8

Learners instructed using learner-centred approach and those with reciprocal instruction after their group presentations, have their scores in Table 5. This was use to plot the graph below:

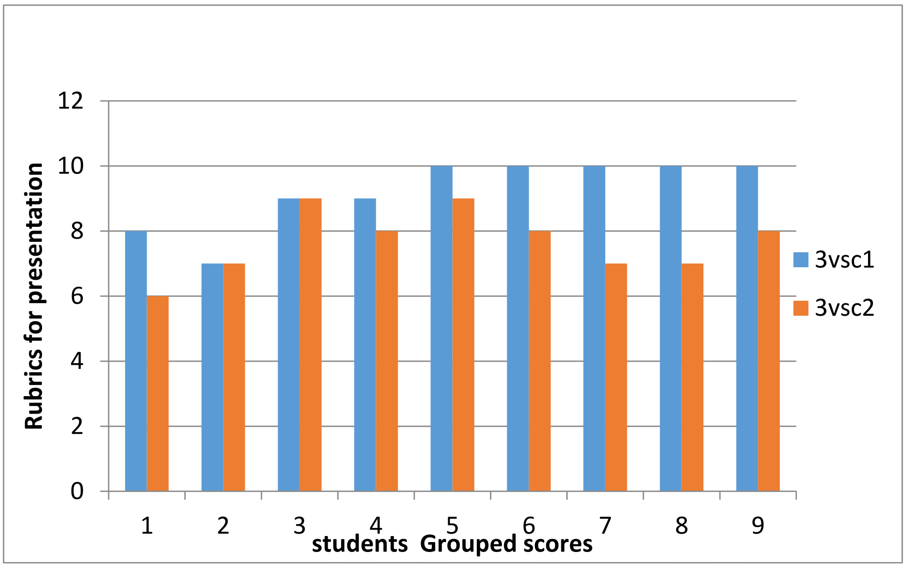

Figure 4: grouped achievement scores of respondents during a presentation

During the implementation of the intervention, respondents were tasked to explore and give presentations on specific areas of photosynthesis and cellular respiration.

Research Question Three

In the view of the students, how beneficial are the student-centered and reciprocal instructional approaches in photosynthesis and cellular respiration?

A questionnaire, aimed to collect the views of the students on how student-centered and reciprocal instructional approaches in photosynthesis and cellular respiration were beneficial to them was designed. The questionnaire was divided into different dimensions according to the specific issues of student-centered and reciprocal instructional approaches being investigated. The design of the questionnaire followed a Likert-scale format of two types (extent of agreement and extent of frequency). Extent of agreement format as reflected in the question "To what extent do your instructors use/not use the following?" was used for the first six dimensions (as arranged in the questionnaire) which are: teaching methods and strategies, Goals and objectives, students' involvement in educational process, assessment, teachers' roles, and students' roles. Extent of agreement format conveyed in the question "To what extent do you agree/disagree with the following statements?" was used for the last two dimensions which are: learning outcomes and learning environment which asked the participants for their own perceptions about SCL and reciprocal instructional approach.

In answering the third research question, the following items on the questionnaire helped the researcher.

Item 1: Which of these methods of teaching would you consider effective to the learning of biology?

In answering this question, items 1 and 4 of the students' questionnaire were used. The study revealed that most respondents (90%) consider practical work as effective method of teaching biology. A few (7%) indicated that the effective method of teaching biology was by demonstration and 3% also considered lecture method as effective method.

When researcher enquired from respondents which method their teachers use during biology lessons, it was revealed that most (80) representing 88.9% of the respondents indicated that their teacher used activity method during biology lesson. A few (2.2%) indicated that their teacher used enquiry while the rest (8.9%) indicated that their teacher used demonstration method as indicated in Table 6.

Table 6: Teaching and learning method used during biology practical lesson

(N= 90)

Teaching strategy	Frequency	Percentage (%)
Activity	80	88.9
Enquiry	2	2.2
Demonstration	8	8.9

This reveals that because the researcher used all the above methods in a point in time during instructions, students had enough opportunity to handle materials and equipments during biology lessons. This in a long run affected students' performance after the implementation of the intervention.

Item 2. How often do the biology teachers organize practical work during biology lessons?

In Table 7, the researcher sought to find out how frequent biology practical work was organized during biology lessons. Item 2 and 3 of the students' questionnaire were used to answer this question as elaborated in the Table 7.

Table 7 indicates that 78 (78.8%) of the respondents have practical very frequently, 9 (15.31%) indicated frequently. This situation allowed students to get the chance to manipulate objects to acquire more practical skills which made their performance better in the end.

Table 7: The number of times students have biology practical lessons

(N= 90)

Response	Frequency	Percentage
Very frequently	78	86.7
Frequently	9	10
Occasionally	2	2.2
Rarely	1	1.1

Item 5. How often did you do group work in biology lessons conducted this term?

When the students were asked of their views about how often they did group activities, 1(1.1%) indicated that they did group work occasionally. Majority 84(93.33.9%) were of the opinion that they were put into groups very often to perform activities both in class and the laboratory. None responded that they rarely did any group work. The results are summarized in Table 8

Table 8: How often students did group work in biology lessons

(N= 90)

Response	**Frequency**	**Percentage**
Very frequently	84	93.3
Frequently	5	5.6
Occasionally	1	1.1
Rarely	0	0

Item 6.To what extent has the use of student centered learning approach helped you to understand photosynthesis and cellular respiration?

Majority (93%) of students who were instructed with the student centered approach were of the view that because they were actively involved in the lessons, it has indeed helped them to understand the concepts. This situation would make students better teachers to their peers who had challenges in the course directives. The researcher enquired from the other students instructed with reciprocal instructional approach. Their response was not anything different from their counterparts. Ninety-one percent said the method used in teaching photosynthesis and cellular respiration has increased their memory span. Typical student responses are shown in shown in Tables 9 and 10

Table 9. Students instructed with student centered approach

(N=45)

Response	Frequency	Percentage
Very adequately	43	95.6
Adequately	2.0	4.4
Inadequate	0	0

Table 10: Students instructed with reciprocal instructional approach

(N=45)

Response	Frequency	Percentage
Very adequate	41	91.1
Adequate	4	8.9
Inadequate	0	0

In all, more students in the reciprocal instructed group earned As and Bs in the final exam, only few did not do well. The discussions in both student-centered group and reciprocal group were a lot more engaging and alive in the portion of the final exam. In addition, at the end of the study more students in the reciprocal instructed group expressed that their interest in biology was high.

CHAPTER FIVE

DISCUSSION, CONCLUSION, RECOMMENDATION AND SUGGESTIONS

5.1 Overview

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. Pre conceptions about photosynthesis have been underscored and the study confirms that these exist across students offering biology in Ada Senior High School. 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 Discussion

With reference to the first objective of the study, namely, to determine whether students hold any pre-conceptions related to photosynthesis and cellular respiration, the following results emerged: Since the school had facilities such as laboratories, library and teaching aids the teaching and learning of photosynthesis and cellular respiration was more effective after the implementation of the intervention thereby correcting the wrong preconceptions students had. It must be 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 which eventually made those who were instructed with reciprocal instructional approach doing well in the study. Young (1990), in his opinion emphasized that teachers in science education, should guide the students to fish out for information on their own through activities rather than by being fed with information. He explained that when students are involved in most of the activities during lessons not only do they learn to be inquisitive and creative but they also acquire knowledge more meaningfully.

The pre intervention diagnostic test was formulated into five different items.

Item one consisted of terminologies 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 few students who had 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" which obviously showed they have been holding on to this preconception for awhile. It is apparent that the word "control" was not interpreted with understanding. This poses the question, do students fail to answer the question because they do not know the answer or because of preconceptions they hold relating to the subject area (as they do not understand the question)? Or most importantly because of the mode of instruction used to teach them? The 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 memorize terms without trying to relate structure to function. This may also be due to preconceptions they hold. 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) stated 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.

Item Two:

The pass rate in this question was very poor. For instance, 20% of the learners scored less than the range of 41-60. 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 would be easier for learners who have actually done the experiment than for those who would have to 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 some preconceptions learners hold. 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, which is one of the approaches of student centred instructional approach; 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 a conducive instructional methodology. Learners cannot comprehend science through imagination. The other question which shows that the learners were confused due to some preconceptions already existing in their brains 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. Incorrect preconceptions, language difficulties and insufficient teaching and learning materials are huge problems that need to be addressed. Buttner (2000) and Fox, Gaynor and Shillcock (1999) stated 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.

Item three was based on comprehension. Some of the learners (41%) scored between 0-10, which is the worst range of scores that could be expected from form three. Although many learners achieved a score interval of 20% in question two, the score level doubled in question three, which 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 the school. 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 fact that they have not been actively involved in the teaching and learning of science 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. As indicated in the literature, photosynthesis is a difficult subject to understand.

Item number four, 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 and they were still holding on to some preconceptions. It was easy to spot the students that have not done this experiment. Most of these learners’ answers were simply guesswork, while it would have been an easy question for those who may have done the experiment. None of the learners achieved a score above 50% most of the learners (33%) achieved a score between 21-30 intervals, which signifies failure. The learners’ performance tells us that educators need to use analogies as suggested by Sahin, Guarda and Berkem (2000), who states that in individual analogies the student has an active role and realizes 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, incorrect preconceptions as depicted in answers to this question can be minimized.

Item 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 bubbling 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 said that, they were mathematically illiterate, and therefore had little interest in calculations. This indicates that mathematics is needed in all science subjects. In all, students in both classes showed after the pre intervention that there were some preconceptions they hold relating to photosynthesis and cellular respiration.

English as a Medium of Instruction to Second Language Speakers

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.

In regards to the second objective, to determine whether there was any difference in mean scores between students instructed using student-centered instructional approaches and those instructed using reciprocal instruction, it must be emphasized that after the implementation of the interventions on both classes, performance increased however, from Table 3 the intervention worked better on the reciprocal group. Therefore teachers can implore this method in their lessons more often.

Because there was mutual feedback between the researcher and her students, this allowed for opportunities to evaluate her teaching approach, her students' academic progress, and the students themselves, students in the two intact classes benefited from the interventions used. The groups in this research included four students who worked closely together, that eventually felt comfortable having one member of the group taking quizzes and earning points for the group. They became comfortable with each other to solve problems together, developed excellence by practicing, and developed high order thinking skills, thereby making objective number three of the study achieved.

5.3 Summary of the main findings in the study

From the analysis of the data in the study, the following were the major findings:

1. The findings indicated that majority of biology students in Ada Senior High hold some level of preconceptions relating photosynthesis and cellular respiration.
2. It was also found that any teaching method that actively involves learners increases their motivation to do well.
3. The study revealed that both learner-centred and reciprocal instructional approaches are effective methods of teaching and learning biology.
4. The study further revealed that the adequate utilization of the library in the school by students enhances their chances of understanding concepts better. The study revealed that the more students carry out experiments in the laboratories, the more they see themselves as part of the teaching and learning process.
5. One other observation made was poor ability in language usage on the part of the students. This was 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.

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 and cellular respiration. 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 two factors that appear to have a negative impact on effective learning. These are poor mastery of language of instruction and inappropriate teaching methods. 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. 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.

5.5 Recommendations

Based on the findings of the study the following recommendations are made:

1. Reciprocal teaching approaches should be used by biology teachers in Ada Senior High School for effective learner gains
2. Biology teachers in Ada Senior High School should make conscious efforts to organize more activity-based work notwithstanding the numerous topics in the syllabus.
3. A point worth considering is the time slot for biology lessons on the school time table. It is suggested that the curriculum developers, educational directors and headmasters in senior high schools should extend the time allocated for the sciences so that teachers will have enough time for exploration lessons with their students.
4. The Headmistress of Ada Senior High School should provide adequate and relevant teaching and learning materials for teachers to be used during practical lessons.
5. Schools with inadequate materials for teaching are advised to make good use of the various science resource centers nearer to them for practical activities.
6. Biology teachers in the school should introduce field trips and excursions as part of their biology teaching and learning programs. It makes students gain more interest in the subject area

5.6 Suggestions for Further Study

Since we are in an educational reform era, there is room for further research on any aspect of the senior high school level. It is therefore recommended that:

1. Studies could be undertaken to find the attitudes of students towards biology lessons.

2. Again, further studies could be undertaken to find out the influence of activity method in the teaching and learning of biology in senior high schools.
3. A research could also be carried out to find out whether the qualifications and areas of Specialization of the teacher have any influence on teaching of biology so that an appropriate decision could be taken.
4. More work need to be done to find out whether student and teacher motivation could have influence on the teaching and learning of biology at the senior high school level.
5. A study could be carried out to find out whether gender has any influence on the teaching and learning of biology at the senior high level.

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APPENDIX A

THE PRE-INTERVENTION TEST ON PHOTOSYNTHESIS AND CELLULAR RESPIRATION

INSTRUCTIONS: ANSWER ALL QUESTIONS

Please complete the following

QUESTION 1
TERMINOLOGIES

Give the correct biological term for each of the following

1. The gas evolved 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 the 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. An energy-rich carbohydrate that is formed during photosynthesis.

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

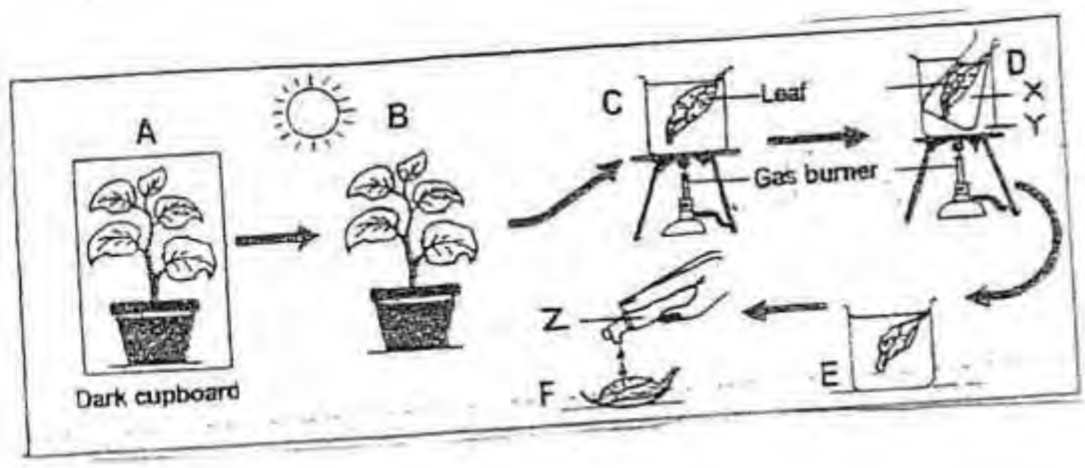
8. The main photosynthetic tissue in an angiosperm leaf

____

APPENDIX A Continued

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 aim of doing stage A?

3. Which energy transformation is going to take place during stage B?
____

4. Supply suitable labels for parts X, Y, and Z.
____
____

5. State **ONE** safety measure that should be taken during stage D.
____
____

6. What is being done at stage D?____

Explain your answer in 6

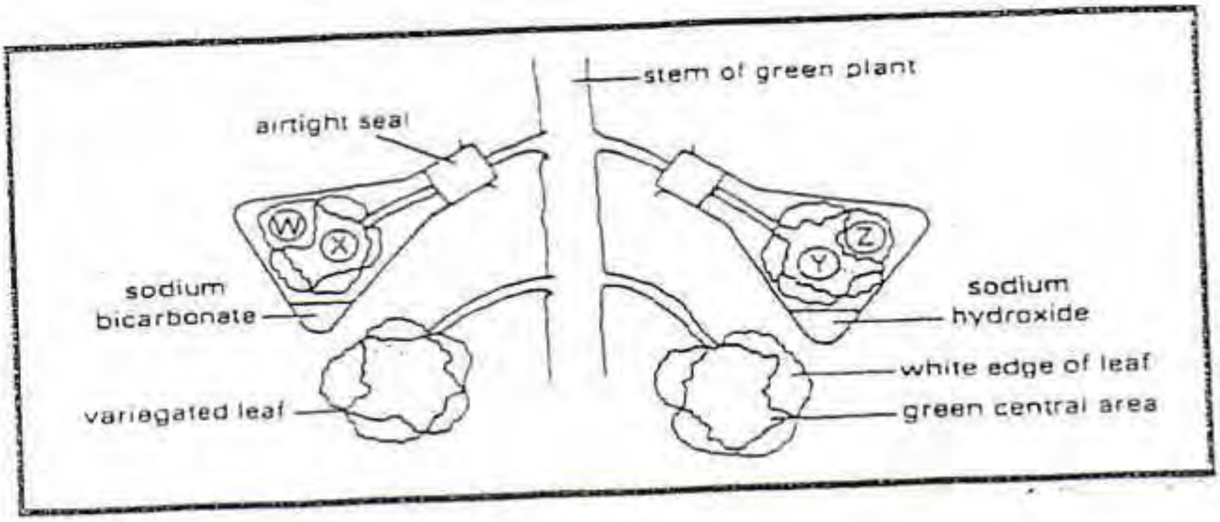
____
____

7. What is the expected colour change at F? _________________________________

APPENDIX A Continued

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. 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? ________________________________

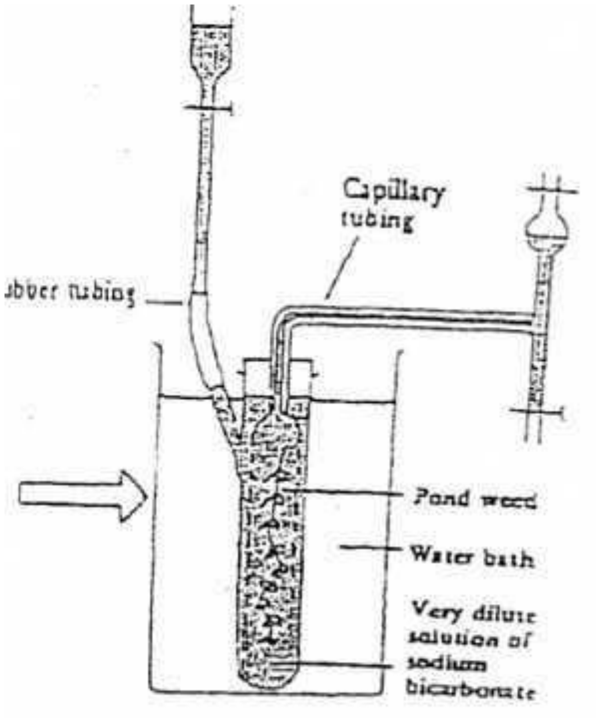
5. Leaf discs W, X, Y and Z from both flasks were tested for starch. What result is expected in each of the following leaf discs:

(i) X?____

(ii) Y?____

APPENDIX A Continued

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?

APPENDIX A Continued

(a) tap water is too alkaline

(b) tap water often contains bacteria

(c) tap water may contain pollutants

(d) the bicarbonate solution is clearer than tap water

(e) the bicarbonate solution provides optional carbon dioxide

3. Compare with atmospheric 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 oxygen produced?

(a) nucleus

(b) vacuole

(c) chloroplast

(d) mitochondrion

(e) golgi apparatus

APPENDIX A Continued

QUESTION: 5

When a piece of water plant/ pond weed (Elodea plant) is placed in a solution near a bright light, it gives off bubbles of gas as 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 figure 2 below.

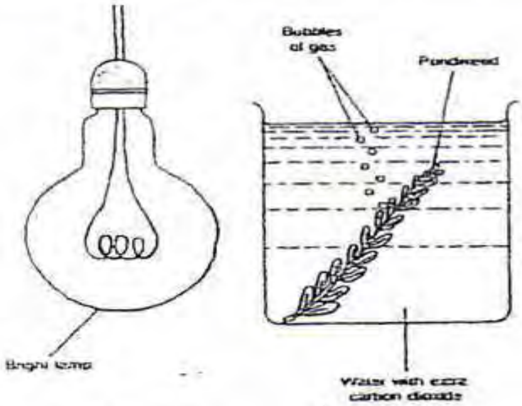


Figure 1

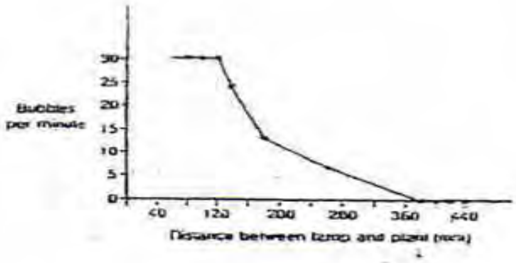


Figure 2

1. Which one of the following statements best describes the aim of this investigation?

Write 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. What was the rate of bubbling when the lamp was 180mm from the plant?

____

3. How far was the lamp when the rate of bubbling was 5 bubbles per minute?

____

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

5. Name the gas that is in the bubbles.________________________

APPENDIX B

POST INTERVENTION TEST

Photosynthesis and cellular respiration

Instructional worksheet

Answer all questions

1. Photosynthesis is a(n) ___________ reaction because it combines simple molecules into more complex molecules.
2. a. Is photosynthesis an endergonic or exergonic reaction?

   b. Explain why.

   c. Energy from the __________ is stored in the bonds of the sugar ___________.

3. What serves as the carbon source for photosynthesis?
4. Sunlight is absorbed as packets of energy called ____________.
5. Besides CO_2, ___________ is also used in photosynthesis to produce _____________ molecules such as the sugar _____________.

Where Does Photosynthesis Occur?

1. Plants can make their own food so they are called ______________.
2. Photosynthesis occurs mainly in the _____________ of plants.
3. Pores on the underside of leaves are called ____________, while the cells in leaves that contain chlorophyll are called ______________ cells.
4. The organelle in mesophyll cells that contains chlorophyll is called the _______________.
5. Name two gases exchanged through the stomata of a leaf.
6. Besides gases, ___________ vapor can be lost from a leaf.
7. Sketch a stoma and label the cells that open and close the pore. Include arrows to show the direction of gas movement.

APPENDIX B Continued

8. In what cell in a leaf does photosynthesis occur? Sketch and label one of these cells.

9. Sketch and label a chloroplast.

10. How many membranes does a chloroplast have?

11. Describe the outer membrane of a chloroplast.

12. What is the thick fluid in the inside of a chloroplast called?

13. ______________ are organelles containing chlorophyll.

14. Stacks of thylakoids are called _____________ and are ____________ to each other.
15. Grana make up the __________ membrane of a chloroplast.

Why Plants Are Green?

16. Why are plants green?

17. a. Chlorophyll molecules are located in the ___________ membranes and harvest light _____________ .

    b. Chlorophyll has a _____________ ion in their center.

18. Chlorophyll and other pigments absorb ______________ of light from 400nm to 700nm.
19. Chlorophyll absorbs __________ and ________ colors of light the best.

APPENDIX B Continued

Fall Colors

20. During the fall, what happens to the amount of chlorophyll being produced by plants?

21. ____________ are plant pigments that include __________, orange, and __________ colors.

22. Why do leaves turn colors in the fall?

23. What is a redox reaction?

24. __________ is the loss of electrons, while _________ is the addition or gaining of electrons.

25. Write the summary equation for photosynthesis and label each compound.

26. _______ is oxidized and ________ is reduced in photosynthesis.

Cellular Energy

27. What is the ultimate energy for life on Earth?

28. Plants store ___________ in the chemical bonds of ____________.

29. Chemical ___________ is released from sugars during _____________________.

30. ATP stands for __________________________.

31. Name the parts of ATP?

32. Describe the bond attaching the last phosphate group to ATP.

33. What happens if the last phosphate bond on ATP is broken?

34. Name 3 things released when the last phosphate bond on ATP is broken.

35. The process of making ATP from ADP and a free phosphate is called _______________.

APPENDIX B Continued

36. Energy released from photosynthesis is available for cellular ________________.

Parts of Photosynthesis

37. Name the first part of photosynthesis.

38. Light reactions use energy from the _________ to produce _______ and the energy carrier _______.

39. The second part of photosynthesis is called the __________ cycle.

40. Does the Calvin cycle require light energy?

41. The Calvin cycle is also called the __________ fixation or the ______ pathway.

42. Where do the light reactions of photosynthesis take place in a chloroplast?

43. Name the two possible routes energized electrons can take during the light reactions of photosynthesis.

44. The cyclic electron flow only uses _______________ I in the thylakoid membranes and has chlorophyll a molecules at the photosystem's reaction center that absorbs ________ wavelength of light.

45. The only energy generated in the cyclic electron flow is _________.

46. Diagram the cyclic flow of electrons.

47. The Calvin cycle is also called the __________ fixation or the ______ pathway.

48. Where do the light reactions of photosynthesis take place in a chloroplast?

49. Name the two possible routes energized electrons can take during the light reactions of photosynthesis.

APPENDIX C

Pre and post intervention scores of students in 3vsc1

3VSC1 PRE INTERVENTION N=45

51	34	67	64
78	56	46	63
66	64	64	65
3	58	53	54
55	50	58	56
45	45	67	56
35	54	42	52
27	56	51	53
16	67	50	52
24	75	52	53
50	55	51	52

POST INTERVENTION

54	64	58	74	90
68	68	51	76	91
72	60	56	51	91
82	50	63	52	76
82	51	65	53	58
84	83	72	74	
85	82	72	56	
90	74	72	66	
53	70	72	68	
51	72	73	67	

APPENDIX C Continued

N=45

3VSC2 PRE INTERVENTION DATA

61	29	51	25	27
49	29	62	11	
45	39	29	20	
45	40	25	19	
46	43	66	19	
46	45	50	21	
46	56	45	22	
47	58	45	62	
50	39	45	40	
49	40	51	44	
39	41	45	43	

POST intervention scores

62	54	73	65	52
63	60	55	62	51
61	62	54	63	51
60	63	54	69	53
56	74	66	68	54
53	78	80	65	
51	51	51	64	
51	51	53	64	
73	51	66	64	
65	51	66	63	

APPENDIX D

UNIVERSITY OF EDUCATION, WINNEBA

QUESTIONNAIRE FOR STUDENTS

Dear respondent,

This study is purely for academic purposes. Kindly read through each of the items carefully and indicate the opinion that is the nearest expression of your views on each of the issues raised. Your anonymity is assured.

GENERAL INSTRUCTION

Please tick the box [ ] to the answer you have chosen fill in the blank space where necessary.

1. Which of these methods of teaching would you consider effective to the learning of biology?

   (a) Activity [ ]

   (b) Lecture [ ]

   (c) Demonstration [ ]

2. I) Do you have a laboratory for biology practical work?

   (a) Yes [ ] (b) no [ ]

ii) How frequently did you visit the laboratory during the teaching and learning of photosynthesis and cellular respiration?

(a) Very frequently (c) occasionally

APPENDIX D Continued

(b) frequently (d) rarely

iii) Was your visit to the laboratory beneficial?

(a) Yes (b) no

3. If your answer in 2(iii) is yes, in a short sentence explain……………………………………………………………………………
………………..………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………………………………………..………
………………..

4. Which method does your biology teacher use during biology lessons?

(a) Activity [ ] (b) Enquiry [ ] (c) Demonstration [ ]

5. How often did you do group work in biology lessons conducted this term?

(a) Frequent [ ] (b) Quite frequent [ ] (c) Very frequent [ ]

6. To what extent has the use of student centered learning approach helped you to understand photosynthesis and cellular respiration?

(a) Very adequate [ ] (b) Adequate [ ] (c) Inadequate [ ]

APPENDIX D Continued

7. To what extent can you explain photosynthesis and cellular respiration to someone who doesn't understand the two concepts?

(a) very well [ ] (b) can't explain [ ]

(c) well [ ] (d) Any other specify [ ]

8. To what extent do you agree peer teaching improved your understanding of photosynthesis and cellular respiration?

(a) Strongly agree [ ] (c) disagree [ ]

(d) Agree [ ] (b) strongly disagree [ ]

9. (a) Can you now construct your own meaning of photosynthesis and cellular respiration?

(a) Strongly agree [ ] (c) Disagree

(b) Agree [ ] (d) strongly disagree

(ii) Has the use of reading comprehension during the teaching and learning of photosynthesis and cellular respiration challenged you to understand the two concepts well?

(a) Very important (c) of little importance

(b) Important (d) unimportant

10. Are you allowed by your teacher to explore on new materials?

(a) Yes [ ] (b) No [ ]

APPENDIX D Continued

11. How often does your teacher allow you to explore on new concepts?

(a) Very often [ ] (c) occasionally

(b) Often [ ] (d) rarely

12. Misconceptions are addressed based on student responses when new material is introduced during biology lessons

(a) Almost always true [ ] (c) Occasionally true

(b) Usually true [ ] (d) usually not true

13. My interest in biology lessons this term has gone up

(a) Strongly agree (c) disagree

(b) Agree (d) strongly disagree

APPENDIX E

RELIABILITY INDEX CALCULATION

X	Y	XY	X^2	Y^2
61	62	3782	3721	3844
49	63	3087	2401	3969
45	61	2745	2025	3721
45	60	2700	2025	3600
46	56	2576	2116	3136
46	53	2438	2116	2804
46	51	2346	2116	2601
47	51	2397	2209	2601
50	73	3650	2500	5329
49	65	3185	2401	4225
39	54	2106	1521	2916
29	60	1740	841	3600
29	62	1798	841	3844
39	63	2457	1521	3969
40	74	2960	1600	5476
43	78	3354	1849	6084
45	51	2295	2025	2601
56	51	2856	3136	2601
58	51	2958	3364	2601
39	51	1989	1521	2601
40	73	2920	1600	5329
41	55	2255	1681	3025
51	54	2754	2601	2916
62	54	3348	3844	2916
29	66	1914	841	4356
25	80	2000	625	6400
66	51	3366	4356	2601
50	53	2650	2500	2809
45	66	2970	2025	4356
45	66	2970	2025	4356
45	65	2925	2025	4225
51	62	3162	2601	3844
45	63	2835	2025	3969
25	69	1725	625	4761
11	68	748	121	4624
20	65	1300	400	4225
19	64	1216	361	4096
19	64	1344	441	4096

21	64	1408	484	4096
22	63	3906	3844	3969
62	52	2080	1600	2704
40	51	2244	1936	2601
44	51	2193	1849	2601
43	53	1431	1849	2809
27	54	1458	729	2916
$\sum x = 1830$	$\sum y = 2662$			

n=50

$(\sum x)^2 = 3348900$

$(\sum y)^2 = 7086244$

$\sum x^2 = 82988$

$\sum y^2 = 163807$

$\sum xy = 109083$

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2]\,[n - (\sum y)^2]}}$$

$$= \frac{50\,(109083) - (1830)\,(12662)}{\sqrt{[50\,(82988) - (3348900)]\,[50\,(163807 - 7086244)}}$$

= 0.97