This is to certify that the

thesis entitled

A UNIT ON PHOTOSYNTHESIS AND CELLULAR RESPIRATION FOR SECONDARY BIOLOGY STUDENTS

presented by

Kathy R. Pollock

has been accepted towards fulfillment of the requirements for

Masters of Science degree in Interdepartmental Biological Science

Major professor

Date 23 July 98

DATE DUE	DATE DUE	DATE DUE
JUN 1 0 2002 05 09 02		

A UNIT ON PHOTOSYNTHESIS AND CELLULAR RESPIRATION FOR SECONDARY BIOLOGY STUDENTS

By

Kathy R. Pollock

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTERS OF SCIENCE

College of Natural Science
Division of Science and Mathematics Education

1998

ABSTRACT

A UNIT ON PHOTOSYNTHESIS AND CELLULAR RESPIRATION FOR SECONDARY BIOLOGY STUDENTS

By

Kathy R. Pollock

A unit on photosynthesis and cellular respiration was developed for a high school Biology I course. Several new laboratory investigations were incorporated into an existing curriculum. These laboratory investigations centered around an inquiry format. This format was chosen in an attempt to minimize students' misconceptions and to increase students' understanding and retention of the concepts. The laboratory investigations were designed to present the students with situations that would conflict with their misconceptions. The goal is for students to formulate correct ideas based on their own observations, and therefore retain these concepts instead of holding on to their misconceptions. A pretest and a posttest were used to evaluate students' understanding. A separate laboratory evaluation form was used to measure students' understanding of laboratory objectives, the data collected, and its relationship to the key concepts. Results on the laboratory evaluation varied depending upon the laboratory investigation being assessed. Student scores on the posttest demonstrated a marked increase in understanding of key concepts. A t-test was used to compare mean scores on the pretest and posttest, the results prove significant beyond the 0.001 level.

To all dedicated high school teachers and their students.

ACKNOWLEDGEMENTS

Many people have contributed to the development and implementation of this thesis as well as the completion of my Masters degree. I would first like to thank my professors, whose dedication to education is an inspiration to the teachers they guide. I thank Merle Heidemann and Ken Nadler for sharing their knowledge and love of Cellular and Molecular Biology and for helping me during my research. I thank Howard Hagerman and Martin Hetherington for all the enjoyable, yet extremely educational experiences at Kellogg Biological Station. I also thank all the guest speakers who presented for, "Frontiers in Science". Their expertise allowed me to gain a deeper understanding of applications of science to the real world. Special thanks goes to the Towsley Foundation for their financial support.

I would also like to thank my classmates who shared in my exploration to become a better teacher. I accomplished much more with their help then I ever could alone. Next, I would like to thank my students. Their curiosity and willingness to try new laboratory investigations made the success of this thesis possible. I thank my colleague, Bruce Boughner, who went out of his way to make sure I had a computer to use each summer. I thank my good friends Dave and Anna Collier who provided a bed and breakfast service to me during "Frontier" weekends.

Most of all I thank my husband, Dave, who has shared in my happiness during times of success and has tolerated me during times of frustration. In particular I thank him for proofreading and editing all of my written work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Statement of Problem and Rationale

In five years that I have been teaching high school biology, I have noticed that students lack an understanding of how energy flows through a community. The core of this problem is that students have difficulty understanding cellular respiration and photosynthesis, their relationship and role in energy flow through a community. One part of the problem stems from their lack of understanding of basic biochemical processes. Perhaps the primary part of the problem is that many students often demonstrate similar misconceptions about these concepts, especially those related to plant nutrition. I developed a laboratory based unit on photosynthesis and cellular respiration to correct students' misconceptions and to improve their learning and retention of these concepts. Further, I measured the effectiveness of the laboratory investigations for this unit.

The main misconceptions held by my students centered around the plants' role in starch production for themselves, as well as for the community. Students could often write a description of a food chain. They could also define a producer as an organism that makes its own food and identify plants as producers. However, when asked, "What is food for plants?", they often answered that plants got their food from the soil. Students also stated that plants did not perform cellular respiration. They lacked the ability to describe how energy flowed through a food chain. They did not grasp the relationship between photosynthesis and cellular respiration. The misconception that plants did not do cellular respiration demonstrates that students miss the point that starch production was done by the plants for themselves. They seemed to think that food made by producers was only for consumers. Students failed to see the relationship between energy from sunlight and energy stored in starch. Most students seemed to think that plants got energy from the sun and that they got "their food" from the soil.

I chose the concepts of photosynthesis and cellular respiration not only because of student misconceptions, but also because these are fundamental biological processes. Understanding these processes is essential to understanding many other concepts in biology. Previous studies concerning teaching of these concepts have been conducted for similar reasons. Eisen and Stavy (1988) stated that: "The main reason for the decision to teach photosynthesis in junior high lies in its importance for a basic understanding of how the world functions as an ecosystem.". Hazel and Prosser (1994) stated: "...we focus on students' learning of the concept photosynthesis--the importance of which is reflected in its being taught at all levels of the education system." Amir and Tamir (1994) also noted that: "Photosynthesis is one of the most important biological topics. It is repeatedly taught in school at different age levels." Anderson, et. al. (1990) described the importance of these concepts, with respect to my study, the best way:

> We chose to focus on the related processes of respiration and photosynthesis because of their curricular significance. For example, our digestive systems, circulatory systems, and respiratory systems all function as they do largely because of the needs of our body cells to engage in respiration. Similarly, the demands of photosynthesis dictate many characteristics of plant structure and function. Even more important, an understanding of photosynthesis and respiration is a prerequisite for any systematic understanding of ecology.

I had very similar reasons for enhancing my unit on photosynthesis and cellular respiration. In addition to teaching a specific unit on these processes, I refer to them when teaching about other concepts in biology. Students need to understand these processes when learning about human and/or animal body systems and when relating plant structure to function. The textbook, "Biology Living Systems", which I use, includes both plants and animals in the chapters explaining life processes. One example is Chapter 20: "Nutrition and Digestion", which includes a section on nutrition in autotrophs. Another example is Chapter 21: "Transport", it includes a section on plant nutrient transport as well as a section on animals transport. Therefore, this unit was developed not only in hopes of improving students' understanding about the specific processes involved, but also to help students build a foundation that would increase their ability to understand other biological concepts in a more comprehensive manner.

Demographics of Classroom

The school is located in a rural area. The district's 120 square miles include 50 lakes, many farms, and 30,000 acres of State recreation lands. The number of students in the district is growing as farmlands are turned into subdivisions. There are three elementary schools, one middle school, and one high school. In 1998 a new facility will be completed for the increasing high school population. Approximately 16,500 live in the school district, of these about 4,000 live in the village. The district serves approximately 2,800 students, with 840 at the high school. The population is mainly Caucasian.

Biology I is a survey course taken by almost all freshmen students. Because many topics are included in the course, I must emphasize main biological themes as they relate to various topics. Students range from advanced college bound to those with extremely low motivation. Of the approximately 225 students that take the course, only about 40 will take another life science course in high school. This means that for about 185 students, this is the only life science class they will have before graduating. The biological knowledge they gain in this class will be their only preparation for college or it could be their last if they go straight to the work place.

Review of Scientific Literature

Since students seem to have the most misconceptions regarding plant nutrition, photosynthesis, and its role in energy flow through a community, I have highlighted many significant historical findings related to these topics. Most of the information was gathered from Wandersee (1985). Studies on just about any scientific concept can be traced back in history to Aristotle, perhaps the oldest and most famous "scientist". He is often mentioned in high school science books. Dating back to 335 B.C., Aristotle theorized that plant food was elaborated in the earth itself under the influence of heat and that the elaborated food was taken up, in predigested form, by the roots of a plant. Aristotle also made assumptions that the leaves serve to shade the shoot and its organs. More correct ideas about the function of plants and their parts did not develop until much later. In 1583, Cesalpino noted that leaves serve to absorb the sun's heat and soil contains raw materials to make food.

Perhaps the most famous experiment showing that plants make food, was conducted by Jan Baptista van Helmont in 1648. It was one of the first carefully designed biological experiments reported (Dempsey, 1990). He planted a willow tree in an earthenware pot and recorded the weight of the plant and the amount of soil. He watered the plant as needed. After five years he again measured the tree and the amount of soil. The tree obviously gained a lot of weight, however, the soil had lost very little. "Van Helmont concluded that the willow tree had derived all its growth from the water, none from the soil or air. ...His conclusion was erroneous....yet, the experiment van Helmont conducted paved the way for scientists like Priestly, Ingenhousz, and van Niel to shape the new theory of photosynthesis" (Dempsey, 1990).

In 1772, Joseph Priestly discovered that when a green plant was placed into a glass container of air "damaged" by a burning candle or suffocating mouse, the green plant restored the air so that a candle could again burn in it or a mouse could live in it. This "restoring" factor is now known as oxygen. In 1779, Jan Ingenhousz observed this same type of complementary process whereby air spoiled by the breathing of animals was restored by plants. However, he noted that this spoiled air also served as a food source for plants. Jan Ingenhousz is credited with demonstrating that carbon dioxide is the major raw material plants use to make their own food.

It should be noted that although biologists have known the general equation for photosynthesis for almost 200 years, the first details of photosynthesis were not discovered until the early twentieth century (Wessells and Hopson, 1988). Early models of photosynthesis speculated that carbon dioxide was split and then water was added to the carbon to make glucose. In the 1930s, this idea was challenged by C.B. van Niel, a graduate student at Stanford University (Campbell, 1987). Van Niel hypothesized that plants split water as a source of hydrogen, releasing oxygen as a by-product.

Today photosynthesis, as we understand it, is the process by which light energy is trapped by chlorophyll and transformed to the chemical energy in sugars catalyzed by enzymes. Glucose is made by combining carbon dioxide and water. Glucose, a simple sugar, is then incorporated into more complex forms such as carbohydrates and starch. Such terms are often used in generalized statements about photosynthesis. Photosynthesis is often summarized by a fairly simple equation: water plus carbon dioxide yields glucose plus oxygen. Photosynthesis actually involves two sets of partial reactions. These two steps are known as the light reactions and the dark reactions.

In the first step light is absorbed by chlorophyll and drives a transfer of electrons from water via a series of electron acceptors to a final acceptor, nicotinamide adenine dinucleotide phosphate, NADP+, reducing it to NADPH. The water is oxidized or split in the process releasing oxygen during photosynthesis. In addition, adenosine triphosphate (ATP) is produced. ATP is a molecule that stores energy for biological work.

The second step, the dark reactions, incorporates carbon dioxide from air into organic material, a process known as carbon fixation or carbon reduction reactions. These are called dark reactions because carbon dioxide reduction to carbohydrates does not directly use light. ATP and NADPH produced in the light reactions serve as the energy source and reducing power, respectively, to drive conversion of carbon dioxide to carbohydrates (Alberts, et. al., 1994).

Carbohydrates produced in photosynthesis contain energy needed by most living things. Cellular respiration is the process by which living things acquire energy from these carbohydrates. As with photosynthesis, cellular respiration can be summarized in a fairly simple statement, despite its real complexity: glucose plus oxygen yields carbon dioxide and water. Some textbooks such as, Wessells and Hopson (1988), state that photosynthesis is chemically the reverse of cellular respiration. Other textbooks such as, Campbell (1987), use the term "complementary" when relating cellular respiration and photosynthesis. This points out that the waste products of respiration, carbon dioxide and water, are the very substances that chloroplasts use as raw materials for photosynthesis, which in turn makes glucose and returns oxygen to the air. Emphasis needs to be put on the fact that it is the chemical elements essential to life that are recycled, and that energy is not.

Cellular respiration has three stages: glycolysis, the citric acid cycle, and electron transport. As with the stages of photosynthesis, the stages of cellular respiration may be defined by different names by different textbooks. The citric acid cycle, for example, is also known as the Krebs cycle, named after its discoverer, British biochemist Sir Hans Krebs in 1937 (Wessells and Hopson, 1988).

Glycolysis is the initial sequence of reactions used to break six-carbon glucose molecules into two molecules of the three-carbon compound pyruvate. Glycolysis itself has nine reaction steps, resulting in the net production of two molecules of ATP, two molecules of nicotinamide adenine dinucleotide (NADH), and two molecules of pyruvate.

The pyruvate molecules derived from glycolysis are shunted into a metabolic pathway, the Krebs cycle, while other products go to the electron transport chain. Pyruvate formed during glycolysis is oxidized to an activated from of acetate, acetyl CoA. This releases one carbon dioxide molecule for each pyruvate. The acetyl CoA enters the Krebs cycle where, in a series of reactions, the carbon skeleton of each acetyl group of the acetyl CoA molecule is rearranged and two carbon dioxide molecules are produced. Two ATP molecules are produced, as well as NADH and flavin adenine dinucleotide ($FADH_2$), which are formed by the reduction of NAD+ and FAD.

During the last stage of reactions, the electron transport chain, NADH and $FADH_2$ are oxidized and oxygen is reduced to water. Otto Warburg did his Nobel Prize-winning work in 1930 showing that cytochrome is the cellular agent that uses oxygen during respiration (Wessells and Hopson, 1988). Cytochromes are pigment proteins that are distinctive carriers in the electron transport chain. As a result of the electron transport chain thirty-two molecules of ATP are produced. Overall thirty-six molecules of ATP are produced from the three stages of cellular respiration: two from glycolysis, two from the Krebs cycle, and thirty-two from the electron transport chain.

In summary, photosynthesis is the process by which plants, and other autotrophs, trap light energy to make glucose, which is then converted and stored as complex carbohydrates. Cellular respiration is the process by which most organisms release energy from food. The energy released from food is converted to ATP, from which organisms derive energy directly to do cellular work.

High school students need to first grasp this overall conception before they can understand the complex steps involved in these biochemical processes. Even the college textbook I used states that: "The processes are complex and challenging to learn... it is important that you keep sight of the objective to discover how cells use the energy stored in food molecules to make ATP" (Campbell, 1987). The summary equations for photosynthesis and cellular respiration provide a starting point from which many students build their knowledge about how materials and energy flows through a community. However, students at the high school level are also expected to develop an understanding of their complexity.

For these reasons, the focus of this study was mainly on student understanding of the overall process of how energy flows through a community. Due to student misconceptions an emphasis was placed on plant nutrition.

Review of Pedagogical Literature

The study of plants in science education has long been discussed. Many science educators state that not enough emphasis is placed on plants. There are educators who argue that the study of nutrition in plants should get equal time to the study of nutrition in animals. Since the process of photosynthesis is crucial to all life upon earth, an understanding of the concept of photosynthesis is one of the most fundamental elements to scientific understanding of the world (Honey, 1987). It seems that in 20th century scientific culture botany has taken a back seat to other biological sciences (Flannery, 1991). Some credit this trend to how teachers' interests in science were influenced by their own educational experiences (Hershey, 1993).

The importance of plants in the community is not debated. As stated in the rationale for this study, many other studies have been conducted to research student understanding of plants' structure and function. Plants are too important to biology and our future to continue to deprive students of adequate plant-biology training (Hershey, 1993). The need for understanding plant processes remains important as ever because of their role in the biosphere, an especially human life (Uno, 1994). Plants provide virtually all our food, oxygen, fossil fuels, clothing, and paper. In addition, they offer potential solutions to many of our global environmental problems and are extremely important in improving human health (Hershey, 1993).

Despite agreement on the importance of teaching concepts of plant nutrition and photosynthesis, many science educators disagree on the way in which plant biology should be taught. Some believe that certain methods are inadequate. Some activities, such as those that use preserved plants or prepared slides of plant parts, are not active, and promote the idea that plants are boring (Honey, 1987). Even some of the methods used in this unit (see Implementation) have been deemed inappropriate (Honey, 1987).

Coneceptual complexity results, Honey (1987) insists, from combining plants and animals in chapters on biological processes, leading to confusion. He also states that: "Teaching photosynthesis largely by testing for starch in green leaves grown in varying conditions may trivialize a subject of immense importance." However, the availability of better laboratory exercises is limited. In an article that appeared in The Science Teacher (November, 1996), a high school biology teacher, Sammy Chan, complains: "Although photosynthesis is one of the most important biosynthetic processes, I have found few laboratory exercises suitable for high school biology. Many exercises described in the literature are either too difficult or the necessary materials and equipment are too complex or expensive to procure." Even those people dedicated to the study of plants at the university level recognize this problem. "There is still a need for new textbooks and hands-on exercises that present plant biology in a context relevant to citizen's everyday experiences with plants.... Too often such real-world connections of plant biology are missed in biology education" (Hershey, 1992).

Although there is much debate about plant biology teaching specifically, one theme about the teaching of science stands out -- the constructivist theme. Unlike the opinions mentioned earlier, that were not based on pedagogical studies, the following discussion is based on results of many science teaching studies. Research indicates that science learning is a constructive process (Glasson and Lalik, 1993). Some researchers have identified stages or levels of learning whereby students incorporate new knowledge into an existing framework (Lumpe and Staver, 1995). Other researchers state that they base their investigations on the assumption that the individual tries to understand something new with the help of existing conceptions (Andersson, 1986). These existing conceptions or frameworks consist of naive concepts that the students have developed on their own from real life experiences. These naive conceptions, are commonly called misconceptions, alternative conceptions, or alternative frameworks (Lumpe and Staver, 1995). The teacher's role is envisioned as the constructor of the conceptual bridge between the learner's point of view, or naive conceptions, and the intended objectives of science teaching (Ebenezer and Zoller, 1993). In order for new knowledge construction to occur there must be active participation on the part of both the learner and the teacher (Glasson and Lalik, 1993).

In order to 'bridge the gap' between student misconceptions and the intended science objectives, teachers are advised to present situations from the natural world that conflict with the student misconceptions, forcing them to question their initial ideas (Edwards, 1997). Many types of activities that are designed to correct student misconceptions advocate using an inquiry based format. Consequently, the nation's science reform committees have released recommendations that stress inclusion of inquiry into school science programs (Chiappetta, 1997). In order for teachers to plan activities that stimulate perplexity among students and develop classroom tasks that promote efforts at knowledge construction, teachers must find ways to understand student viewpoints (Glasson and Lalik, 1993). Therefore, it is argued, the more teachers know about these misconceptions, the better they are able to provide learning experiences that stimulate pupils to modify their initial conceptions (Andersson, 1986).

Several studies have been conducted that directly asked students about their perception of science teachers and science teaching. The major findings of one study (Ebenezer and Zoller, 1993) were that students did not appreciate the most prevailing contemporary practices in science classes. They perceived them as mainly copying teacher's notes, and they prefered science teaching and learning in which they took an active and responsible part. Responses of students in another study (Eichinger, 1992) also support that they are more interested in science when they are actively involved. Students in this study indicated that they prefered, discovery-oriented techniques, especially those based on real problems, as opposed to lectures, texts, memorization, and quizzes/tests which they recalled as the most common classroom activities (Eichinger, 1992).

The activities least preferred by students are based on the traditionally accepted view that science is a discipline consisting of precepts that are first fed to the student by the teacher, rather then being acquired through self-teaching (Ebenezer and Zoller, 1993). This view of learning does not accommodate the naive concepts that students acquire before instruction. In contrast, using inquiry to help students construct their own knowledge may force students to confront their misconceptions and increase their understanding of the true scientific concepts at hand. Many researchers also state that these inquiry activities work best when students conduct experiments in small groups which provide students with a greater opportunity to share, justify, and negotiate their ideas so that they may eventually come to a consensus in line with scientific thinking (Ebenezer and Zoller, 1993).

Keeping in mind these general themes in science education, attention needs to be focused on the concepts of photosynthesis and cellular respiration, the topics of this thesis. Several studies about student misconceptions regarding photosynthesis and cellular respiration have been conducted. I found several studies specifically dedicated to misconceptions about photosynthesis, but only two which include misconceptions about both photosynthesis and respiration. Barrass (1984) lists two common misconceptions about photosynthesis and respiration: some students believe that respiration occurs only in animals and photosynthesis occurs in green plants, and others, who believe green plants respire, think the plants only respire at night and photosynthesize in sunlight.

All age groups have been studied to find out their understanding of plant nutrition and photosynthesis. Eaton, et. al. (1983), studied fifth grade students and asked the question: "What is food for plants?" It is not surprising that the most common answers were water, soil, and fertilizer. What did surprise the researchers was how little most students learned during the units on light and plants. After conducting a cross-age study of student understanding of photosynthesis, Wandersee (1985) compared the misconceptions held by students to societal views throughout history. He found some similarities, but no direct correlation. His comprehensive work is often referenced in other papers. Bell (1985) studied secondary students and assessed their ideas about plant nutrition. Eisen and Stavy (1988) compared biology majors and non-biology majors understanding of photosynthesis. Both of these studies revealed similar misconceptions about plant nutrition, for example, the idea that plants get food from the soil through their roots.

Two representative studies that also assessed student understanding of respiration are: Haslam and Treagust (1987), and Anderson, et. al. (1990). Haslam and Treagust (1987) developed a two-tier test to ascertain secondary student misconceptions about photosynthesis and respiration in plants. The misconceptions diagnosed all related to when and where respiration takes place. Some students even confused photosynthesis and respiration. The most interesting of their results revealed that students' misconceptions about photosynthesis and respiration in plants are retained throughout secondary school years despite these concepts being taught each year. Anderson, et. al. (1990) gave tests to college non-science majors designed to reveal student conceptions of respiration and photosynthesis before and after course instruction. They noted that the misconceptions students demonstrated were consistent with findings from other studies, and that the similarities were often striking. For example, students again stated that roots absorb food from soil.

Based on the results of the test, Anderson, et. al. (1990), concluded that the current materials/instruction were ineffective in changing misconceptions.

Three of the studies I found looked for correlations between specific actions and student understanding of photosynthesis. Hazel and Prosser (1994) compared student study strategies and their success at learning photosynthesis. They found that students who employed study strategies that focused on deep understanding of the concepts had more success than those that employed surface study strategies such as rote memorization. Lumpe and Staver (1995) compared students who used peer collaboration to learn photosynthesis with students who worked individually. They concluded that peer collaboration provides an avenue for students to compare and discuss ideas helping them to overcome misconceptions. Amir and Tamir (1994) administered a paper and pencil test to 11-12th grade students to determine their misconceptions about photosynthesis and respiration. They also provided remedial instruction which consisted of using various graphs and questions that required students to apply their knowledge about specific concepts of photosynthesis and respiration. Their results showed that by using the remedial materials, significant improvement in understanding was achieved.

Many reasons for student misconceptions have been described in these studies. As stated earlier, students tend to develop naive conceptions based upon observations they make of the natural world. After conducting a cross-age study of misconceptions about photosynthesis and comparing these misconceptions with the study of photosynthesis through out history, Wandersee (1986) states:

> It appears that students commonly anthropomorphize their concepts and therefore perceive animals as relating more directly to their own experiences. It has been noted that humans, as heterotrophs, have great difficultly imagining what it would be like to be a plant and to live without eating.

Other researchers note that social cues may influence students' views. For example, fertilizer packets seen on supermarket shelves may affect student notions of plant food (Hazel and Prosser, 1994). Some point out the limits of current instructional practices. For example, animals are used in many respiration demonstrations; and if plants are used, light must be excluded. This leads students to think that respiration either does not occur in plants, or that it only occurs in the absence of light (Barrass, 1984). Biology is often taught before chemistry; such curricular sequencing may limit students' ability to grasp the chemical processes involved in photosynthesis and respiration (Anderson, et. al., 1990). Students at this level who lack adequate ideas of atoms and molecules can often misinterpret statements teachers make about chemical reactions (Andersson, 1986). In addition, the use of summary equations, in which photosynthesis is represented simply as the opposite of respiration, may cause some pupils to think that they are alternatives -- that both processes can not occur at the same time (Barrass, 1984).

In summary, all of the studies share common findings: very similar misconceptions about photosynthesis and respiration in plants are shared by students in all grade levels; these misconceptions persist despite instruction; and study techniques and remedial instruction can help a few students overcome misconceptions. Although the studies discussed earlier identified students' misconceptions and some actions to remedy the problem, I found none that specifically described laboratory investigations, which is the focus of this thesis.

IMPLEMENTATION OF UNIT

Introduction

I developed a laboratory based unit on photosynthesis and cellular respiration for a high school biology course while doing research at Michigan State University. At the high school where I teach, there are nine Biology I classes and I teach four of these. Two other teachers teach the remaining five classes. There exists a strong expectation that all biology teachers teach in a similar way and follow the exact same curriculum. Due to such constraints, I incorporated these new laboratory investigations into an existing curriculum. The unit for this thesis is therefore diffuse. I incorporated new laboratory investigations into three different units over a three month period. This situation had good aspects in that some concepts were repeated, but also had bad aspects, in that it was difficult to connect some concepts together.

Unit Outline

The main concepts were taught in three units. The first, Unit One: "Community Biology", was used to introduce the concept of organisms in a community. General ideas about consumers and producers provided an introduction to cellular respiration and photosynthesis. Later in the school year, during Unit Three: "The Flow of Energy", these concepts were taught in much greater detail. During Unit Two: "Matter and Energy", students developed an understanding of biological compounds such as carbohydrates, and the relationship between glucose, starch, and glycogen. This unit helped students develop an understanding of how chemical reactions take place in living things.

Due to curricular demands it should be noted that these units were not covered in sequential order. Unit One: "Community Biology" was taught first, then a series of units on classification, adaptations, and evolution, and finally units on cellular structure and processes followed. This last sequence included Unit Two: "Matter and Energy", and Unit Three: "The Flow of Energy". A complete list of objectives and daily lesson plans for Units One, Two, and Three can be found in Appendix A. A summary of the unit is outlined below:

Unit One: "Community Biology"

Time frame: 8 days, September 4 - 15

Objectives:

-identify the components of a community

-state the flow of energy in a community

-classify organisms in a community based on energy flow

-list raw materials needed by each type of organism

Unit Two: "Matter and Energy"

Time frame: 7 days, October 13 - 21

Objectives:

-identify and describe the four main types of biological compounds: carbohydrates, lipids, proteins, and nucleic acids

-distinguish between condensation and hydrolysis reactions used in making or digesting these compounds

-describe the means by which an enzyme carries out a cellular reaction

Unit Three: "The Flow of Energy"

Time frame: 9 days, November 6 - 18

Objectives:

-distinguish between endergonic and exergonic reactions

-explain how ATP is used in linking exergonic and endergonic reactions

-compare the processes of aerobic respiration, anaerobic respiration, and fermentation

-recognize and separate different plant pigments and describe how these interact with light

-describe the events of the light reactions and Calvin cycle of photosynthesis

-analyze the relationship between photosynthesis and cellular respiration

New Teaching Techniques

Since the Biology I course is taught by three teachers, and since I am the newest, I have adopted many of the teaching methods of my colleagues. For a typical unit students define vocabulary terms, complete study guide worksheets from the textbook readings, perform laboratory investigations from the provided laboratory manual, take quizzes, and a test. Although in the past the laboratory investigations were the same for each teacher, the methods for presenting concepts varied among the teachers. For this unit I developed new methods of presenting concepts through the use of verbal and written questioning techniques. I also developed new laboratory investigations that I introduced into the existing curriculum. Each new activity or laboratory investigation is indicated by an "*" on the daily lesson plans in Appendix A. A summary list of all laboratory investigations for each unit can be found in Appendix B. These new teaching techniques and laboratory investigations were designed specifically to address students' misconceptions about cellular respiration and photosynthesis.

To overcome strongly held misconceptions about photosynthesis and cellular respiration I presented several verbal examples from students' everyday life to help students make connections between plants, starch, and energy. In one example, I asked students if they had ever had a potato sprout and start to grow in a dark cupboard. I then proceeded with further questions that would lead them to the conclusion that the plant was using the starch as an energy source. Such questions included:

"Can a potato, which is brown, not green, do photosynthesis?"

"Can the new green leaves of the potato plant do photosynthesis in a dark cupboard?"

"Does the texture and/or size of the potato change as the new sprouts grow?"

"What type of nutrient makes up a potato?"

"Where are these new sprouts getting the energy to grow?"

"How did the original potato plant make the potato?"

Such questioning techniques helped students to start thinking about the relationship between energy in sunlight and energy stored in starch. However, if students did not understand the last question, "How did the original potato plant make a potato?", they might answer that the food in the potato is absorbed from the soil. A detailed understanding of photosynthesis and cellular respiration was needed to make the connection between the original potato plant, the starch in the potato, and the source of energy used by the new growing sprouts.

When teaching Unit Three: "The Flow of Energy" (Appendix C), I incorporated an activity sheet that I developed to help students understand the details of energy transfer during cellular respiration. This activity sheet contained two-dimensional structural formulas which students used to make a model of adenosine triphosphate (ATP). After building the model, they answered several questions about the relationship between glucose, cellular respiration, and ATP.

Since elements of the key concepts such as food chains, cellular respiration, and photosynthesis, were presented in different units that were not consecutive, I made connections between units whenever possible. Students needed to understand terms for the various forms of carbohydrates, such as, starch, glycogen, and glucose. They also needed an understanding of how enzymes worked in converting the various forms. Making connections between the concepts of each unit helped students to see "the big picture".

Laboratory Investigations

In addition to the new laboratory investigations that I developed, I continued to use some provided in the laboratory manual: "Probing Levels Of Life" (Glencoe, 1994), because these demonstrated many principles that the students needed to learn and curricular expectations. However, the additional laboratory investigations that I developed specifically confronted students' misconceptions. All laboratory investigations were performed by students in groups of two to four. Each individual student turned in a written laboratory report which was graded.

The new laboratory investigations were designed to allow students to observe phenomena related to either cellular respiration or photosynthesis. It is difficult for students to understand these concepts since they can not actually see processes happening. I based the laboratory investigations around three main elements: 1. gasses involved, 2. production and/or use of starch, and 3. energy flow. The investigations are describe below and are grouped according to these three main elements.

Element 1: The gasses involved.

The first focus that I chose was on the gasses involved in cellular respiration and photosynthesis. Students tested for gasses given off by cellular respiration and/or used in photosynthesis. They used a pH indicator, Bromothymol Blue (BTB), to test for the presence of carbon dioxide. When carbon dioxide is exhaled through a straw into a test tube of BTB solution, the color turns to green and then yellow as the pH becomes lower. In addition to having students learn that cellular respiration produces carbon dioxide and photosynthesis produces oxygen, I wanted to stress that plants perform both cellular respiration and photosynthesis.

Lab: "What Gasses Are Released From Plants and Animals?"

During Unit One students did the laboratory investigation: "What Gasses Are Released From Plants and Animals?" (Appendix D). Students filled test tubes with BTB solution, and then added zebra mussels or *Elodea* plants. The test tubes were divide into two groups. In one group students exhaled through a straw to turn the solution yellow. One test tube from each group was placed in the dark. After 24 hours, students recorded the color of each test tube. They answered questions about the type of gas released and/or used during the 24 hour period. They also answered questions about the type of organism involved and the environmental conditions. The test tubes that were controls did not change color. All test tubes containing zebra mussels showed that carbon dioxide was released. Test tubes containing *Elodea* that were in the light showed that carbon dioxide from the solution was used. Test tubes containing *Elodea* that were in the dark showed that carbon dioxide was released. By placing the test tubes containing *Elodea* and BTB indicator in the dark, the carbon dioxide given off during cellular respiration could accumulate in the solution and turn it from blue to yellow. This last set of test tubes demonstrated to students that if a plant was not able to perform photosynthesis they could observe cellular respiration taking place.

Lab: "Do Plants Respire?"

When studying information in Unit Three students performed the laboratory investigation: "Do Plants Respire?" (Appendix E). This laboratory investigation used the same BTB solution. Students filled four test tubes with the solution. In one test tube they exhaled through a straw turning the solution from blue to yellow. In two of the test tubes they placed germinating bean and corn seeds. The last test tube was not changed as a control. After twenty minutes they observed that the solution containing germinating seeds had turned yellow. Students answered several questions which were designed to lead them to the conclusion that plants do respire, or carry out cellular respiration. I chose to use germinating seeds because I knew that they are often used in respiration devices and I wanted students to see the results in one class period.

Element 2: The production and/or use of starch.

A second focus was on the production and use of starch. I especially wanted to emphasize that plants not only made starch, but that they used it as a food source. The use of germinating seeds in the test for carbon dioxide provided a good base for this activity, but I wanted to show students that the ultimate source of glucose for cellular respiration was in the seeds. The first step was to show that the starch stored in the seeds was being broken down into glucose for use in cellular respiration. By making an agar plate containing corn starch and placing drops of saliva on the agar I could show digestion of starch. When iodine was poured over the agar it turned dark purple in all places except where the saliva had converted the starch to glucose. The next step was to show that germinating seeds also contained enzymes to convert starch to glucose.

Lab: "Do Seeds Digest Starch?: Testing For Enzymes in Germinating Seeds"

This was accomplished during Unit Two in the laboratory investigation: "Can Plants Digest Starch?: Testing for Enzymes in Germinating Seeds" (Appendix F). Students placed dormant (dry) and germinating bean and corn seeds on the agar plate containing corn starch. After sitting on the agar overnight the germinating seeds had digested the starch in the agar. When iodine was flooded over the agar it turned a dark purple in all places except where the germinating seeds had been.

Lab: "Light and Starch Production in Leaves"

The investigation "Light and Starch Production in Leaves" (Appendix G), during Unit Three, also used iodine to test for starch in leaves. After placing several geranium plants in the dark for two days, students covered part of a leaf with a small piece of black construction paper. The plants were then placed in the light for 24 hours. The leaves that had been covered were then removed and tested for starch. Areas containing starch turned dark purple, the area where the paper had blocked the light did not, due to a lack of starch. Students witnessed that starch was produced in the areas that were exposed to light, and that without light starch could not be produced. This provided a good base for students' understanding that the process of photosynthesis depended on light energy.

Element 3: The flow of energy.

A third focus was on the flow of energy during cellular respiration and photosynthesis. Students needed to make the connection between light energy and the energy stored in foods. Many class discussions were dedicated to the energy flow through food chains to help students relate food and energy. Students also completed an activity sheet on ATP, showing how energy is transferred from glucose to ATP during cellular respiration. In addition to discussing, reading, and writing about energy, students performed two relevant laboratory investigations.

Lab: "Light and the Rate of Photosynthesis"

When studying Unit Three students performed the laboratory investigation: "Light and the Rate of Photosynthesis" (Appendix H) to observe the relationship between light and photosynthesis. Students measured the amount of oxygen produced when a light was at various distances from a plant. *Elodea* plants were placed under a funnel in a clear glass container containing a 0.5% sodium bicarbonate solution. During several trials the number of bubbles given off in one minute were counted when a light source was 10 cm away from the plant. Students also performed this procedure with the light at various distances. Students then graphed the average rate of photosynthesis for each of the various distances the light was placed from the plant. Students proposed that there was a direct relationship between the amount of light and the rate of photosynthesis.

Lab: "How Can We Measure Energy In Food?"

To demonstrate that food contains energy and to help students gain an understanding of how the amount of energy is measured, the laboratory investigation: "How Can We Measure Energy In Food?"(Appendix I), was used. This investigation was adapted from their lab manual, using a different apparatus from the one suggested. In this laboratory investigation, students burned pieces of peanut and walnut. The apparatus was changed to reduce the amount of heat lost during the investigation. Students massed each peanut or walnut in grams before and after burning. The heat given off by the burning nut was used to heat 10 ml of water. The temperature change of the water was measured using a thermometer. For each nut sample, students calculated calories, calories per gram, kilocalories, and kilocalories per gram. Students compared their values with known values. They learned the definition of a calorie, and how scientists calculate the number of calories in food.

Summary

Throughout the lessons I continually used verbal questioning techniques to help students make connections between the various laboratory investigations and to help students gain a deeper understanding about the production and use of starch by plants. Students needed to relate the energy of light to the energy of glucose. Students were expected to connect starch production in leaves to the starch stored in potatoes or seeds. Finally, students were to conclude that the plant was using this starch through cellular respiration.

EVALUATION

Pretest and Posttest Results

A pretest was given to students before starting Unit One. The pretest consisted of ten open-ended questions (Appendix J). Each question was formulated to assess students' understanding of key concepts related to photosynthesis and cellular respiration. A posttest was given after completing Unit Three. The posttest consisted of ten questions similar to the pretest questions (Appendix K). Based on Merle Heidemann's suggestions, the questions on the posttest were modified slightly from how they appeared on the pretest, but the assessment was the same for each.

Both tests were graded using the same rubric (Appendix L). The rubric for each question consisted of a point system for each answer that ranged from zero to three. Blank or totally incorrect answers earned a score of zero. Simple unexplained answers earned a score of one. More complete answers earned a score of two. Answers of extremely high quality earned a score of three. The total possible score for each test was 30 points.

Eighty-four students took the pretest. This was taken on the second day of class and students were very willing to try their best. The mean score on the pretest was 11.16 with a standard deviation of 3.86. The posttest was taken three months later after six students had dropped the class. Seventy-eight students took the posttest. It should be noted that a handful of students demonstrated a complete lack of effort on the posttest. When I compared these individuals' pretest and posttest, it was obvious that their answers on the posttest did not really reflect their understanding of the concepts. Despite this I included their scores when calculating the mean. On the posttest the mean score was 16.38 with a standard deviation of 5.43. Using a t-test to compare the pretest and posttest means proved significantly different beyond the .001 level. Figure 1 shows a graphic analysis of the total scores.

An analysis of the answers given for individual pretest questions revealed some common misconceptions for various key concepts. A comparison between the answers given for the pretest questions and posttest questions shows how students developed a greater understanding of the key concepts. A detailed discussion of the analysis and comparison of answers follows. Since the questions were slightly different on the posttest, I have included each question so that they can be compared. To summarize students' responses and the resulting scores for each individual question, I have included the rubric used to score each question, a quantitative analysis of the scores, and examples or descriptions of typical students' responses. The analysis of each question follows Figure 2 which shows a comparison of the pretest's and posttest's mean scores for each individual question.

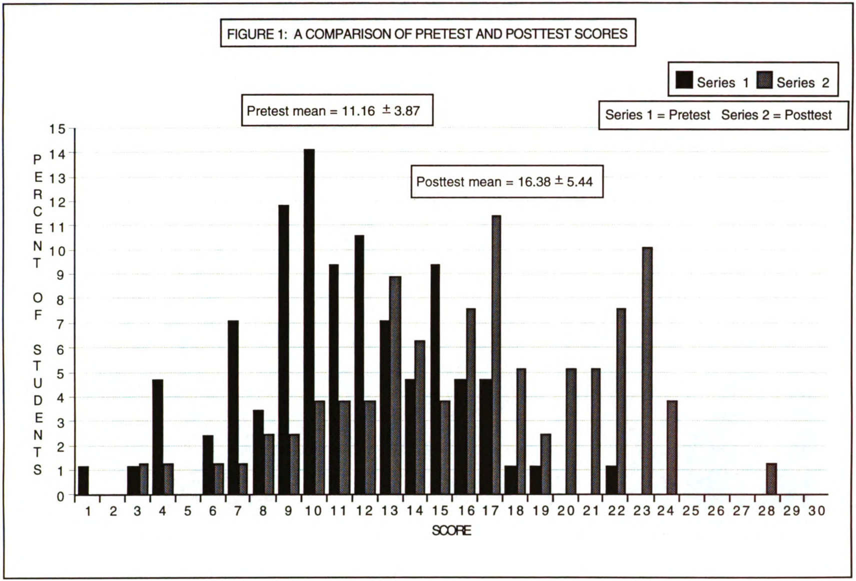
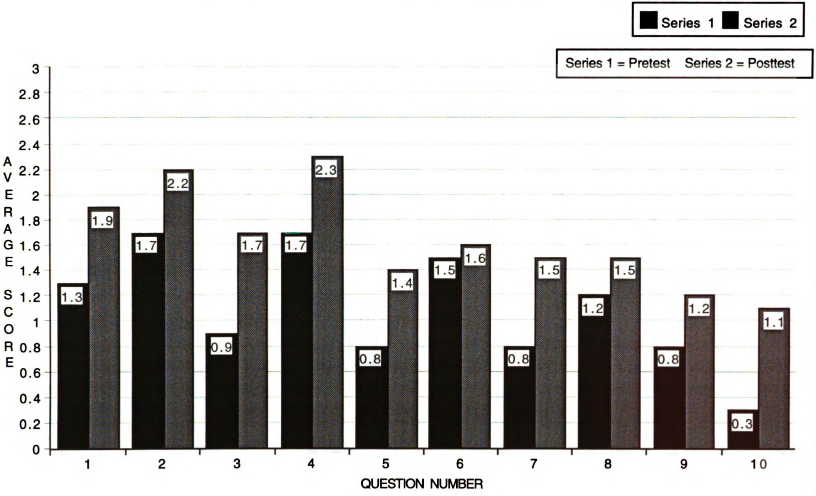


FIGURE 1: A COMPARISON OF PRETEST AND POSTTEST SCORES
Series 1
Series 2
Pretest mean = 11.16 ± 3.87
Series 1 = Pretest Series 2 = Posttest
Posttest mean = 16.38 ± 5.44
PERCENT OF STUDENTS
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
SCORE

FIGURE 2: A COMPARISON OF SCORES ON INDVIDUAL QUESTIONS ON THE PRETEST AND POSTTEST



Question 1 Pretest mean = 1.33 Posttest mean = 1.86

Pretest What are the needs of living things?

Posttest Write several sentences describing the needs of living things.

Scoring Rubric:

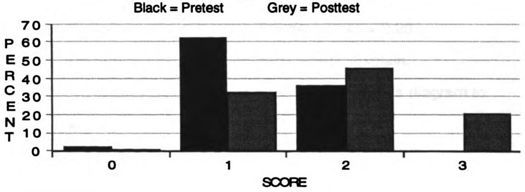
0----No Answer

1----Food and Air (one or two items)

2----Food and Oxygen(two or more items more specific)

3----Food for energy or sunlight to make food, oxygen and carbon dioxide shelter, water, nutrients, minerals and vitamins to grow and make tissues protein, sugar etc...(very detailed list with reasons)

FIGURE 3: SCORES ON QUESTION 1



On the pretest 62% of the students earned a score of one with answers similar to this example: "food, shelter, and air". Answers such as this lacked explanation. On the posttest 46% earned a score of two and 16% earned a score of three. These answers contained more detailed explanations. Several examples of "2" and "3" answers follow:

"The needs of all living things are sunlight, food, and air. Plants use light for photosynthesis, animals use light to see and for direction and heat. All things need food to survive. Air, whether CO_2 or O_2, is needed to do certain functions."

"Living things need energy in some form whether it comes from the sun or other food sources. Living things need to take in water and food, breathing O_2 or CO_2 releasing O_2 or CO_2."

"All living things need starches to turn into sugar for energy. Most of the processes need oxygen, or are more efficient with it. Plants require sunlight for photosynthesis to produce their food, whereas more animals and organisms consume their food."

"In order to survive, living things must have a source of energy from food whether they produce it themselves or consume it. Living things must reproduce in nature. Living things need either carbon dioxide or water to promote cellular respiration and/ or photosynthesis. Living things also need a community in which they survive with their own species as well as others."

Question 2 Pretest mean = 1.70 Posttest mean = 2.20

Pretest Do organisms depend on each other? Explain.

Posttest Do organisms depend on each other? Draw a diagram to explain.

Scoring Rubric:

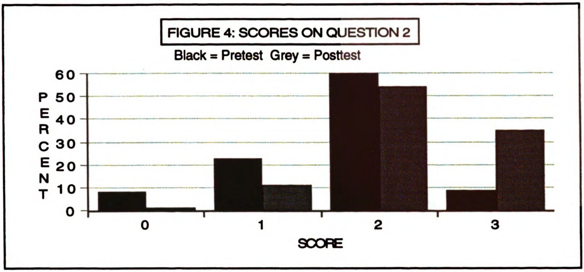
0----No answer or NO

1----Yes, but can not explain why

2----Yes, for food chain

3----Yes, food chain, producers make food, consumers, decomposers recycle

On the pretest 60% earned a score of two and only 9% a score of three. On the posttest this shifted to 53% with a score of two and 35% with a score of three.



On the pretest, one student wrote that living things need each other for "reproduction and companionship". Most wrote that they need each other for food, but several answers seemed to indicate that this need was for hunting, for example: "Yes, when an organism hunts it hunts better with more than one organism". Another wrote: "I think organisms depend on each other because of things like help finding food, protection, and basically just a companion." Yet another wrote: "most always, some organisms work as a team and help each other gather food. Sometimes organisms do not need each other to breathe. All and all organisms do work as a team and need each other".

None of the answers on the posttest demonstrated this type of confusion. Most diagramed a food chain and explained it. For example: "Organisms do depend on each other for every day energy and food needs. Sun --> plant --> rabbit --> fox --> bear."; and "Energy passes from plant, who uses the sun to make sugar to the rabbit and so on, who uses sugar to make energy." Other answers included the gasses used. For example: "Yes. Consumers need the oxygen and food energy from producers. Producers need the carbon dioxide from consumers."

Question 3 Pretest mean = 0.87 Posttest mean = 1.69

Pretest What types of organisms make up a community?

Posttest What types of organisms make up a community?

Scoring Rubric:

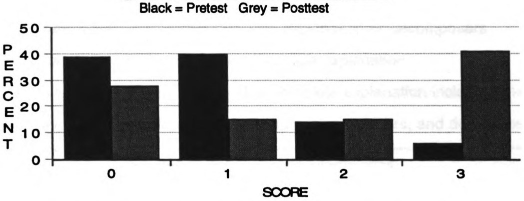
0----No answer

1----Animals and plants

2----Consumers and producers with better explanation

3----Consumers, producers, and decomposers, with better explanation

FIGURE 5: SCORES ON QUESTION 3



On the pretest 79% scored zero or one and only 20% two or three. On the posttest 43% scored zero or one whereas 56% scored two or three. The mean score on the posttest is almost double that of the pretest.

Since this question was looking for specific terminology(producer, consumer, and decomposer) it is expected that student scores would greatly increase after being taught these terms. It is interesting to see what types of terms students came up with on their own, before being taught. On the pretest such responses included: "mammals, amphibians, insects, and bacteria"; "In a community there should be different types of plants, animals, and sorts of bacteria to fulfill the whole cycle."; and "plants, animals, people."

On the posttest more students, 53%, used the correct terms: producer, consumer, and decomposer. However, 43% of the students still used terms like animals and plants earning them scores of zero or one.

Question 4: Pretest mean = 1.68 Posttest mean = 2.27

Pretest What is a food chain? Write a possible food chain.

Posttest What is a food chain? Write a possible food chain and explain the role of each type of organism.

Scoring Rubric:

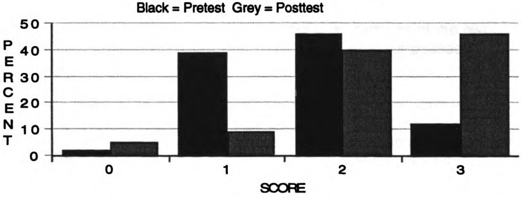
0----No answer

1----An example food chain with no explanation or decomposers

2----An example food chain with a vague explanation

3----An example food chain with a complete explanation including the role of each type of organism: producers, consumers, and decomposers

FIGURE 6: SCORES ON QUESTION 6



On the pretest 41% scored zero or one, 46 % two, and 12% three. On the posttest 14% zero or one, 40% two and 46% three.

Students had clearly been introduced to the concept of a food chain before taking high school classes. On the pretest a few students even used the term "energy" when describing a food chain. For example: "A food chain is the chain of energy, starting off with simple organisms and ending in more complex ones. Example: fungus --> small fish --> larger fish --> humans." Yet this example shows that the student lacked an understanding of the producers role in trapping sunlight energy to make food. Most other students used phrases such as: "A food chain is a process in which organisms eat to survive. fly --> spider --> snake --> hawk --> bear." Again this student is missing a producer.

On the posttest students demonstrated that they had gained a clear understanding that producers are the basis for the food chain. Many more students earned a score of at least two. Others also included decomposers which earned them a perfect score of three. Some examples included:

> "A food chain is the order of energy passed from one organism to another, each receiving 10% of energy from last organism." (2)
>
> "A food chain is the passing of energy from one organism to the next. An example is shown above in number two. The sun begins with 100% energy which is given to the plant(producer makes starch), it is consumed by the field mouse and the owl, finally the mushroom or decomposer consumes the dead remains of the owl. Each time energy is passed, only 10% of the energy is passed on 90% is lost." (3)
>
> "A food chain is the flow of energy between organisms. Sun -- > grass (produces oxygen and large amount of energy) --> deer(consumes the grass-intakes energy) --> decomposer-worms, maggots...(breaks down the parts of the dead deer, making it useful for the grass to grow in)" (3)

Question 5	Pretest mean = 0.80	Posttest mean = 1.41
Pretest	How are the needs of plants different than those of animals?	
Posttest	Compare and contrast the needs of plants versus animals. Make a table or chart to help you show similarities and differences.	

Scoring Rubric:

0----No answers

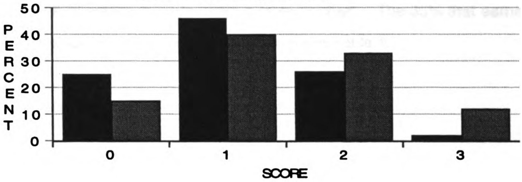
1----Plants need sun and soil, but no explanation, Animals need food and water

2----Plants need sun, soil, carbon dioxide, water, but not explained well, Animals need food, water, and oxygen

3----Plants need sunlight, water, and carbon dioxide to make food, they need minerals from the soil to make tissue, they make sugar, but need oxygen to get the energy out of the sugar. Animals food and water and they need oxygen to get energy out of the food.

FIGURE 7: SCORES ON QUESTION 5

Black = Pretest Grey = Posttest



On the pretest 25% scored zero, 46% one, 26% two, and only 2% three. On the posttest 15% scored zero, 40% one, 33% two, and 12% three.

Pretest answers varied a lot. Some students demonstrated extreme confusion: "They need soil, and sunlight. Some animals don't need soil. Owls can live without sunlight. Plants don't need another plant to reproduce with, cause they can't reproduce." Most student answers revealed common misconceptions about how plants get food such as: "Plants also need nutrients but they receive them in different ways (through roots and tiny pores in their leaves)"; "Animals eat things using mouths which plants suck things up from their roots and the sun." ; and "Plants can eat the same thing over and over. Animals like to have a variety." These confused answers earned a score of zero. Other answers were more specific: "Plants have roots that need soil, and breathe in carbon dioxide and give off oxygen. An animal does not have roots and an animal breathes oxygen and gives off carbon dioxide." Many answers which scored one or two included that plants need sunlight and/or make their own food. Examples include: "Plants do not need food like animals do. They make there own food, kind of."; "Plants need light for photosynthesis."; and "Plants need the sun, water, soil, and carbon dioxide. Animals need plants, animals, oxygen and water."

On the posttest students answers were much more complete. This may be the result of asking them to make a table or chart. The 33% that earned a score of two had answers such as this example in Table 1:

Table 1: Example 1 of a "2" answer for Question 5

PLANTS	ANIMALS
Plants take in CO2, sun energy, water for energy	Animals take in oxygen for energy plus glucose
Plants make oxygen and glucose	Animals make CO2
Plants trap sunlight	Animals take glucose from plants and other animals
Plants have chloroplast	Animals don't
Plant cells square	Animals cell round
Both have cells.	Both have cells

I was extremely impressed with the 12% of students who earned scores of three. These students included that plants do both photosynthesis and cellular respiration. Three examples follow in Tables 2, 3, and 4:

Table 2: Example 1 of a "3" answer for Question 5

PLANTS	ANIMALS
Plants-producers	Animals-consumers
Plants-chlorophyll	Animals-no chlorophyll
Plants-multicellular	Animals-multicellular
Plants-reproduce	Animals-reproduce
Plants-photosynthesis and cellular respiration	Animals-cellular respiration

Table 3: Example 2 of a "3" answer for Question 5

"Plants need sunlight, CO2, food they make, O2 to use food and water. Animals need O2, food, and water."

	sunlight	water	oxygen	carbon dioxide	food
PLANTS	X	X	X	X	X
ANIMALS		X	X		X

Table 4: Example 3 of a "3" answer for Question 5

	sun	get food	make food	photosynthesis	cellular respiration
PLANTS	X		X	X	X
ANIMALS		X			X

Question 6 Pretest mean = 1.46 Posttest mean = 1.63

Pretest Do plants breathe? If so, what type(s) of gas? Explain.

Posttest Do plants breathe or use gasses? What types of gasses? Explain.

Scoring Rubric:

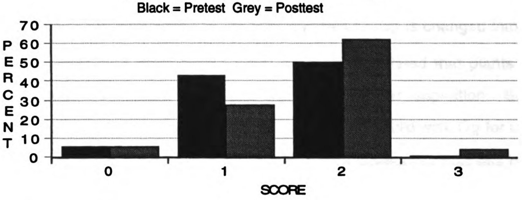
0----No answer or NO

1----Yes, but can not explain

2----Yes, carbon dioxide to make food

3----Yes, plants use carbon dioxide to make food and oxygen to use this food. They obtain gasses through pores on the surface of leaves and stems, or through the roots via gasses dissolved in water in the soil.

FIGURE 8: SCORES ON QUESTION 6



On the pretest 6% earned a score of zero, 43% one, and 50% of the students answered that plants used carbon dioxide earning a score of two. Only 1% earned a score of three with a more complete answer. On the posttest 6% still earned a score of zero, 28% one, 62% two, and 4% three.

Many students remembered from some previous instruction that plants used carbon dioxide, for example, "Yes, plants do breathe, but they breathe in carbon dioxide during photosynthesis." Of these, about half also stated that plants produce oxygen, for example, "Yes plants breathe, they breathe in carbon dioxide and breathe out oxygen." Only 6% left this answer blank or stated that plants do not breathe. Some knew that they used gasses, but could not name the gasses, for example, "Yes, I'm not sure what kind of gas though." or "They breathe through pores on the leaves I think. I don't know what kinds of gas." Some used the term "air", for example, "Yes, carbon dioxide which gets turned into air."

Six percent still scored zero on the posttest. However, the number of students that could identify that carbon dioxide was used and oxygen released, increased from 50% to 62%. They also had much better explanations. On the pretest students simply stated which gas was used and which gas was produced. On the posttest students used the phrases such as: "during photosynthesis" or "to make their own food" or "to make starch". One example is: "They use CO_2 in making O_2. In photosynthesis CO_2 is changed into O_2 with light, water, and chlorophyll." Only 4% correctly stated that plants use carbon dioxide for photosynthesis and oxygen for cellular respiration. Some examples include: "Yes, they use CO_2 to get material to build with, O_2 for using their food." and "Yes, CO_2 and O_2, when they photosynthesize they use CO_2, when they cellular respirate they use O_2." It should be noted that in question five, 12% correctly stated that plants do both photosynthesis and cellular respiration. I do not know why the percentage of students answering these two questions correctly is not consistent.

Question 7 Pretest mean = 0.81 Posttest mean = 1.51

Pretest What is food for plants? Do plants eat?

Posttest What is food for plants? Do plants eat? Explain.

Scoring Rubric:

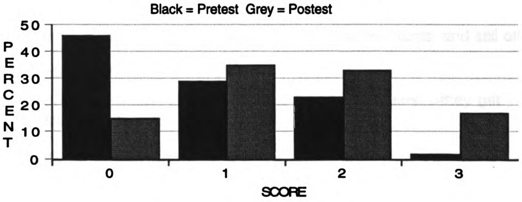
0----No answer or soil and water

1----Water and Sunlight or Plants make their own food

2----Plants make their own food with sunlight, water and carbon dioxide

3----Plants make their own food by photosynthesis. They use energy from sunlight and water and carbon dioxide to make sugar. This sugar is then stored as starch for use by the plant later. The starch is then converted back to sugar(glucose) and the plant uses oxygen through the process of cellular respiration to release energy from the glucose. This process produces carbon dioxide and water as waste products.

FIGURE 9: SCORES ON QUESTION 7



On the pretest 46% earned a score of zero, 29% one, 23% two, and 2% three. On the posttest 15% earned a score of zero, 35% one, 33% two, and 17% three. The mean score on the posttest was almost double that of the pretest. This question is extensively reviewed below to emphasize students' misconceptions about plant nutrition, which is a focal point of this study.

Students clearly had misconceptions about what is food for plants. One student answered this question: "bugs, organisms in ground." Other examples of "0" answers included:

> "Plants eat things that come through the soil. From this they receive nutrients."
>
> "Plants eat minerals that are in the soil."
>
> "Plants do not eat with fingers or hands, but they do eat through their roots. They get nutrients from the soil."
>
> "Nutrients from the ground. No, they soak it up through their roots."

Other common answers included that plants use water as food, such as:

> "The food for plants is water. They eat water like we eat food."
>
> "Water is food for plants, and that what they eat."
>
> "Plants eat water and minerals from the dirt."
>
> "A food for plants is proteins in soil and water."

A few students incorrectly referred to fertilizer as food for plants, and still others added sunlight to the list, for example:

> "For house plants-->food already made up. Outdoors-->they get water, nutrients from the soil."
>
> "They eat fertilizer, water, and take in sunlight."
>
> "Fertilizer, most plants get energy from the sun."

These last quotes demonstrate that the students were confused between food and energy. Some students tried to use terminology previously learned, but obviously did not know what these terms meant. "Food for plants is a simple sugar called chloriphyl and this helps the plant to keep living and growing. Plants (except for the Venus fly trap) don't 'eat' but it works like a blood stream."

Very few students, 2%, had good "3" answers such as this: "Plant 'food' is the sugars produced through photosynthesis, so yes, plants eat."

On the posttest 15% still did not state that plants make their own food. These students still thought that soil was food for plants; however they also stated that plants got energy from the sun. For example: "Plants use their roots to 'soak up' nutrients from the soil. They also use sunlight for energy." or "the sun energy and minerals in the soil is a plants food and it collects these through its roots and through its leaves." The other 85% of the students did state that plants make their own food. Those students that also included an explanation, earned scores of two or three depending upon how well they explained the process of photosynthesis and whether or not they stated that the plants used the food they made. Several examples of "2" answers included:

> "Sun, the chloroplast traps the light which makes it into food."
>
> "Food for plants is water, sun, carbon dioxide, and sugar."
>
> "Glucose and other proteins. Yes they make sugar out of water and carbon dioxide that they get from photosynthesis."
>
> "Plants' food is energy from sunlight rays. They take the energy and form simple products such as starch and glucose."
>
> "Sugar is plant food. Plant's don't eat but they do take in nutrients. They make their own food through photosynthesis."
>
> "Food for plants is sugars. Plants eat something that they make with help from water, carbon dioxide and sun."

The following "3" answers demonstrate that students knew plants used the food they made:

> "Food for plants is sugar, plants make sugar then use it for energy."

"Food for plants is starch, because they use it to produce energy. Plants don't eat the way we do. They produce starch and then use it when energy is needed."

"Food for plants is sugars. Plant's don't eat they produce the sugars made and then use them."

"Plants make their own food-sugar through photosynthesis. The plants then go through cellular respiration to use the sugar they made and convert it into energy."

Question 8 Pretest mean = 1.23 Posttest mean = 1.50

Pretest In animals, after food is digested, what happens to it? How is it used by the body?

Posttest In animals, after food is digested, what happens to it? How is it used by the body?

Scoring Rubric:

0----No answer

1----It goes into the blood and is used, not explaining how

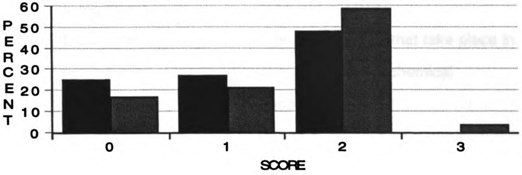
2----It goes into the blood and then to all body tissues and is used for energy or stored as fat, etc...

3----It goes into the blood and sugars will be used by cells for energy through the process of cellular respiration, amino acids will be used to make protein, and fats will be stored as energy reserves. Excess glucose will be stored as glycogen.

This question was included to see if students could connect the food we ingest to the sugar used in each cell during cellular respiration. On the pretest 25% scored zero, 27% one, 48% two, and 0% three. On the posttest 17% scored zero, 21% one, 59% two, and 4% three.

FIGURE 10: SCORES ON QUESTION 8

Black = Pretest Grey = Postest



Many students on the pretest stated that the food was used for energy. Of the 25% scoring zero, many wrote that after food was digested it left the body as waste. For example: "The body then gets rid of it by going to the bathroom, and that is what they do to get rid of it all.".

On the posttest more students answered that the food was used for energy. Some included the term "cellular respiration" and others referred to "ATP"(adenosine triphosphate). For example: "In animals, after food is digested, it is used as energy for the body to carry out everyday functions. We convert the starch to ATP for energy and use it that way." Since it is unclear from this quote whether the student understood energy was transferred from sugar to ATP, and that the starch was not changed into ATP, it received a score of two instead of a perfect score of three. Only 4% of the students earned a perfect score of three, because so many of the other answers were unclear, like the example.

Question 9 Pretest mean = 0.83 Posttest mean = 1.15

Pretest List and/or describe any chemical reactions that take place in living things.

Posttest List and describe types of chemical reactions that take place in living things. Please list and describe all the chemical reactions that you can remember.

Scoring Rubric:

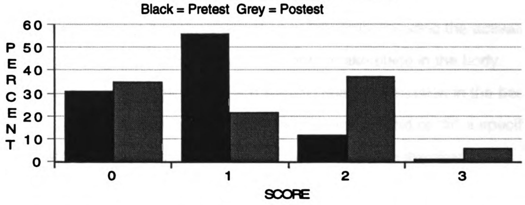
0----No answer

1----Photosynthesis or cellular respiration

2----Breakdown of food and one of the above

3----Photosynthesis, cellular respiration, hydrolysis or condensation reactions, protein synthesis, etc... Antigen-antibody reactions, digestion

FIGURE 11: SCORES ON QUESTION 9



On the pretest 31% scored zero, 56% one, 12% two, and 1% three. On the posttest 35% scored zero, 22% one, 37% two, and 6% three.

I expected that students would not be able to name very many chemical reactions on the pretest. Only 13% of the students could name more than one chemical reaction. On the posttest scores earning two or three increased to 43%. I was disappointed to see many posttests where students described photosynthesis and/or cellular respiration when answering other questions, but they did not list these as chemical reactions when answering question nine. Thirty-five percent could not name one chemical reaction, and 22% could only name one. Further questioning of the students would be needed to determine the reasons behind their poor answers.

Question 10 Pretest mean = 0.32 Posttest mean = 1.13

Pretest What is an enzyme? What do they do? How do enzymes work in living things?

Posttest What is an enzyme? What do they do? How do enzymes work in living things?

Scoring Rubric:

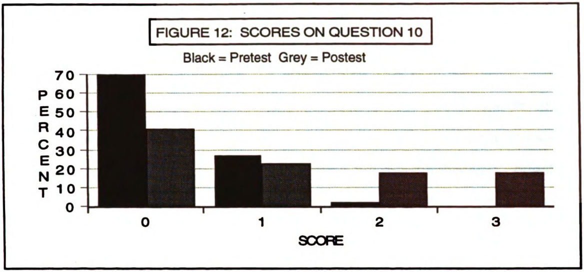
0----No answer

1----Enzymes digest or breakdown food

2----Enzymes are catalysts for chemical reactions

3----Enzymes are proteins that act as catalysts by lowering the activation energy needed for all chemical reactions to take place in the body. Enzymes are very specific. Each specific chemical reaction in the body requires a specific enzyme. Enzymes chemically bond or "fit" a specific substrate. Enzymes are not used up or consumed in the chemical reaction and can be used over and over again.

On the pretest 70% scored zero, 27% one, 2% two, and 0% three. On the posttest 41% zero, 23% one, 18% two, and 18% three.



This question was included because it related to Unit Two. Student understanding of enzymes was required to understand the complex steps of cellular respiration and photosynthesis. With 70% scoring zero on the pretest, students clearly did not have any ideas about enzymes before studying the unit. I was disappointed that on the posttest 41% still could not describe anything about enzymes. However, the mean score on the posttest was more than triple that of the pretest. Students tend to have difficulty understanding chemical reactions in general and due to the curricular demands of Biology I, time spent on enzymes was limited. Student understanding of chemical reactions should greatly increase when they take a chemistry course.

Laboratory Evaluation

To assess the effectiveness of the new laboratory investigations, I developed a laboratory evaluation sheet to measure student understanding of laboratory objectives, the data collected, and its relationship to the key concepts. This assessment instrument asked questions relating to specific laboratory experiences (Appendix M). The results of this evaluation varied depending upon the question and the laboratory investigation being assessed.

When describing the new laboratory investigations I grouped the investigations into three groups based on the key elements involved in cellular respiration and photosynthesis. I again used these three categories for evaluation: 1. gasses involved, 2. production and/or use of starch, and 3. energy flow. The laboratory evaluation sheet consisted of nine questions. Questions one, two, and three centered around the gasses involved, questions four and five(a) centered around the production and/or use of starch. Question five(b) and six centered around the flow of energy. Questions seven, eight and nine centered around enzymes, which were included for my own information for future instruction and were not directly relevant to the unit. For each question I calculated the percentage of students answering correctly. Since there are no other results to use for comparison, such as a pre-laboratory assessment, and since there are no known expected values, I have assumed that if at least 70% of the students answered a question correctly, then they have gained a solid understanding of the concept.

Element 1: The gasses involved.

Lab: "What Gasses Are Released From Plants and Animals?" and

Lab: "Do Plants Respire?"

Question one of the laboratory evaluation sheet students asked: *"When a student uses a blue indicator solution of Bromothymol Blue (BTB), what does it mean when the solutions turns from blue to yellow?"* For this question, 74.3% of the students answered correctly, that the presence of carbon dioxide causes the solution to turn from blue to yellow. For question two, students were asked to complete a data table by predicting the color of the solution in seven test tubes with different contents after 24 hours. This table is shown below in Table 5:

Table 5: Question Two from the Laboratory Evaluation

Test Tube #	and Contents	Color at Start	Color after 24 hours
1	nothing	blue	
2	exhale through straw	blue	
3	zebra mussels	blue	
4	*Elodea*	blue	
5	water plant	blue	
6	germinating seeds	blue	
7	goldfish	blue	

All of the students answered correctly, that the test tube containing nothing would remain blue. For the second test tube, 94.6% answered correctly. It should be noted that only 74.3% knew carbon dioxide caused the solution to turn from blue to yellow, yet almost all knew if they exhaled through a straw it would turn yellow. Although some students could not name the gas involved, they remembered what happened during the experiment. I assume this is because they were an active participant in the experiment. In predicting the results of test tubes containing animals, zebra mussels and goldfish, 89.2% and 83.8%, answered correctly, respectively. Students clearly had an understanding that animals exhaled the same gas as humans. Because I thought students might have trouble identifying *Elodea* as a water plant, I included both in the table. For *Elodea*, 56.8% answered correctly, but this number does not really reflect student understanding about plants, since it is not clear that students identified *Elodea* as a plant. Only 55.4% could correctly answer that the solution containing water plants would remain blue. However, 73.0.% correctly answered that the solution containing germinating seeds would turn from blue to yellow. I am not sure if this response was simply memorized or if students truly understood that germinating seeds produce carbon dioxide because they preform cellular respiration. Note: only 9.5% explained this correctly when answering the next question. Overall student understanding of the gasses produced and/or used by plants was difficult to assess, since 73.0% answered correctly for the germinating seeds, yet only 55.4% demonstrated that they understood the water plant would perform photosynthesis.

The next question, number three, asked: *"Explain how you made these predictions (on the data table) by describing what process is carried out in each organism."* The answers for this question varied so much that I decided to group them into five categories in order to summarize the results. These categories and percent answering correctly are listed below:

1. 25.7% -- totally incorrect answers,or no answer at all
2. 13.5% -- simply stated "carbon dioxide is released" or "oxygen is taken in and carbon dioxide is released"
3. 25.7% -- classified that "Animals exhale carbon dioxide, and plants release oxygen"
4. 25.7% -- used the term "cellular respiration"
5. 9.5% -- those explaining that "animals do cellular respiration, plants do photosynthesis"

Placing some answers in these categories was difficult since some students did not explain how they made predictions for each test tube. They made general statements such as: "If it was cellular respiration and if carbon dioxide was given off." Other students explained the results from all the test tubes except the one containing the germinating seeds. For example: "The consumers (us, zebra mussels, and gold fish) release carbon dioxide through cellular respiration. The producers (*Elodea*, water plant) produce oxygen and would not cause a color change." or "The plants carry out photosynthesis which takes in carbon dioxide and gives off oxygen. The others carry out cellular respiration which takes in oxygen and gives off carbon dioxide." Answers which further explained that germinating seeds either released carbon dioxide like animals or that germinating seeds performed cellular respiration, were mixed among answers in categories three, four, and five. Only 9.5% of the students had such answers. Examples included:

> "I though if carbon dioxide would be present or not. All animals give off carbon dioxide and seeds do by cellular respiration."
>
> "We do cellular respiration like goldfish, germinating plants and zebra mussels, which means we take in oxygen and release carbon dioxide. As long as there is a light source, plants photosynthesize, which means they take in water and carbon dioxide and release oxygen."
>
> "Exhaling, zebra mussels, germinating seeds, gold fish used oxygen and produced carbon dioxide. Elodea, water plant produced oxygen."
>
> "Carbon dioxide is exhaled into the solution making it yellow. Zebra mussels, germinating seeds, and gold fish all produce carbon dioxide through cellular respiration, the rest produce oxygen through photosynthesis."

After sorting through all the data and carefully analyzing the results, I believe using the BTB indicator was successful in demonstrating to students the gasses involved in cellular respiration and photosynthesis. By subtracting the 25.7% that did not answer, or answered incorrectly, I have come to the conclusion that 74.3% understood that the solution turned from blue to yellow due to the presence of carbon dioxide. This is consistent with the scores for Question One, in which 74.4% answered that carbon dioxide causes the solution to turn from blue to yellow. I would also conclude that 35.1% correctly identified cellular respiration as the process which produces carbon dioxide. In addition, 9.5% also correctly identified that photosynthesis produces oxygen. Only 9.5% had more complete answers which either stated that germinating seeds released carbon dioxide or that germinating seeds performed cellular respiration.

Element 2: The production and/or use of starch.

Lab: "Do Seeds Digest Starch: Testing For Enzymes In Germinating Seeds"

Question four was:

> *"A student cuts a germinating corn seed in half and places each half on agar containing starch. Twenty-four hours later the student removes the seed and floods the agar with iodine. Draw a picture and describe the color and appearance of the agar. Explain."*

Although many students drew a correct picture of the results, only 33.8% of the students could correctly explain the results of this lab. Students were clearly confused. I believe that students need to develop a greater understanding of enzymes and the laboratory investigation needs more explanation.

Lab: "Light and Starch Production in Leaves"

Question five was:

> *"A student cuts a heart shape from some black construction paper and puts this over a healthy leaf of a plant. The student then places the plant in a well lit area. After 24 hours the student removes the leaf and tests for the presence of starch. Predict what areas of the leaf will test positive for starch. ...What biological process produces starch in leaves? ... What is the energy source?"*

In response to the first part of the question: What biological process produces starch in leaves?", 68.9% correctly described the areas of the leaf that would contain starch and identified photosynthesis as the process that leads to the production of starch in leaves. The number of correct student responses is close to 70%. However, I expected many more students to be able to identify photosynthesis as the process that ultimately produces starch in leaves. Some of the students, 10.8%, wrote "cellular respiration" as the answer. A few of the students, 9.5%, left the question blank. Perhaps they did not know how to sketch the leaf and did not bother to answer the rest of the questions pertaining to this laboratory investigation. The remaining 10.8% had incorrect answers such as "chlorophyll".

In response to the second part of the question: "What is the energy source?", 66.2% of the students correctly answered that light was the energy source. Again, I expected a much higher percentage of correct responses. I am not satisfied with the results. This laboratory investigation needs improvement (see Discussion and Conclusion).

Element 3: The flow of energy.

Lab: "Light and the Rate of Photosynthesis"

Question six had two parts:

> *"A student places a light source 10 cm from a water plant and counts the number of bubbles released from the plant. What type of gas is given off by the plant? ...*
> *Will the number of bubbles increase or decrease when the light source is moved to 30 cm away?"*

In response to the first part, 77.0% of the students correctly stated that oxygen was given off by the plant. In response to the second part, 77.0% also correctly predicted that if the light source was moved farther away from the plant that the number of bubbles would decrease. These results indicate that students could identify oxygen as the gas produced and that light was the energy source needed. I believe students understood this laboratory investigation better than the one in which they tested for starch, because they collected quantitative data. They also manipulated the distance of the light source and were able to "see" a direct relationship between the distance of the light source and the number of bubbles produced.

Summary

Overall the results of the posttest provided evidence of students' increased understanding of key concepts. All answers to questions on the posttest showed improvement from the pretest. The increase in scores was most likely due to instruction through class discussion, written activity sheets, and the laboratory investigations. In addition, overall results of the laboratory evaluation sheet were favorable. Some laboratory investigations were more effective than others. A more specific discussion on the particularly effective methods and areas that need improvement is the focus of the next section.

DISCUSSION AND CONCLUSION

Particularly Effective Aspects

As stated earlier, the results of the posttest provided evidence of students' significant increased understanding of key concepts. The fact that all answers to questions on the posttest showed improvement from the pretest reflects that the increase in scores was most likely due to a variety of instructional methods. I could not give credit to one method over another. The various methods complemented each other. Instruction through class discussion and written activity sheets helped to reinforce the concepts students developed while performing the many laboratory investigations. Since the focus of this study was on the laboratory investigations, these are discussed in the most detail.

Results of the laboratory evaluation sheet were favorable. Some laboratory investigations were more effective than others. Three of the laboratory investigations stand out as being successful: "What Gasses Are Released From Plants and Animals?", "Do Plants Respire?", and "Light and the Rate of Photosynthesis".

The first two laboratory investigations used BTB indicator to show the presence of carbon dioxide. Overall student performance demonstrated an understanding that the solution turned from blue to yellow in the presence of carbon dioxide. Many students could predict what color the solution would turn when different organisms were placed in a test tube containing the solution. Students clearly understood that humans and animals produce carbon dioxide. Most impressive was that most students remembered that germinating seeds produced carbon dioxide.

Results for the laboratory investigation: "Light and the Rate of

Photosynthesis", indicate that over three-fourths of the students could identify oxygen as the gas produced during photosynthesis and that light was the energy source needed.

Analysis of Effective Aspects

The use of the BTB indicator was particularly effective since the results were easily seen, understood, and remembered. I believe that the students remembered this experience because they were active participants and results were quick and dramatic. Because these two experiments were performed about two months apart, repetition helped students remember. The students were able to see results when a variety of organisms were used which helped them formulate generalizations. On the laboratory evaluation, most students had no problem making predictions about what gas would be released from organisms not used in class. The use of both green plant parts and germinating seeds allowed students to see conflicting phenomena, which let some students accept the fact that plants performed cellular respiration.

The laboratory investigation: "Light and the Rate of Photosynthesis", was successful for many of the same reasons. I believe students understood this laboratory investigation better than some of the others, because they collected and graphed quantitative data. They varied the distance of the light source and were able to "see" a direct relationship between the distance of the light source and number of bubbles produced. On the laboratory evaluation many students demonstrated an understanding of the relationship between the distance of a light source and the amount of oxygen produced by a plant.

Aspects Needing Improvement

The laboratory investigations that centered around starch digestion and production needed the most improvement. The evaluation for the investigation: "Do Seeds Digest Starch?: Testing For Enzymes in Germinating Seeds", showed that many students could correctly draw a picture, but most could not correctly explain the results. Students were clearly confused: they did not understand that starch stored in the seeds was converted to glucose and then used in cellular respiration. I believe that students who could state the relationship between starch and glucose, did not apply their knowledge to the results in the experiment because they were confused about the role that enzymes played in the conversion.

This laboratory investigation may have been better if the relationship between starch and glucose was emphasized more in the questions, and if the role of enzymes was made clearer. In the future I would not use germinating seeds until we study cellular respiration in detail during Unit Three. Instead, while studying enzymes during Unit Two, I would have students use their saliva to test for the digestion of starch. Note: This was done as a demonstration only. Having the students use their saliva should help them understand the role of enzymes better as well as making it more memorable. Then, during Unit Three, I would have the students repeat the experiment using germinating seeds.

The results of the laboratory evaluation for the investigation: "Light and Starch Production in Leaves", showed that close to 70% of the students understood starch production in leaves. However, I expected many more students to be able to identify photosynthesis as the process that drives starch production in leaves. I am not sure why this investigation was not as successful as I expected. In response to the second part of the question, only

66.2% of the students correctly stated that light was the energy source. I expected a much higher percentage.

When comparing this laboratory investigation with more successful ones, it should be noted that students did not see or record results until the end. To improve this experiment I would try to incorporate aspects that made other laboratory investigations more successful, such as manipulation and quantitative measurements. Students could investigate how long it takes for the covered parts of leaves to lose all of the stored starch. They could then compare these results and discuss the role of both light and chlorophyll in starch production.

Besides assessing individual laboratory investigations, laboratory evaluation results showed that students had difficultly making connections between laboratory investigations and concepts. On the lab evaluation 68% correctly identified photosynthesis as the process that ultimately produced starch and 66% identified sunlight as the energy source. Yet only 34% correctly answered that seeds "digested" or used starch. However, 72% correctly predicted that germinating seeds produced carbon dioxide. These numbers suggested that although students had memorized specific outcomes from lab activities or specific phrases, such as, plants make their own food, they did not make the connection between these events in class. Part of the reason may be that the laboratory investigations were performed during three different units over a period of three months.

Information gathered from the pretest, posttest, and laboratory evaluation will be used to continue to improve teaching techniques in the future.

Overall Evaluation and Conclusion

After reviewing all data it should be noted that some misconceptions still persisted, despite well planned instruction. This phenomenon is noted in many other studies, for example: Amir and Tamir (1994); Anderson, et.al. (1990); Bell (1985); Eaton, et.al. (1983); Eisen and Stavy (1998); Haslam and Treagust (1987); and Wandersee (1985). However, the misconceptions that students demonstrated on the posttest were not as severe as those on the pretest. On the posttest, for example, many students stated: "Plants make their own food through photosynthesis", instead of "plants get food from the soil." When asked to explain, some students still could not clearly explain what happened to the food once it was made. These students still did not know how this food was stored by the plant and used later for energy via cellular respiration. On the other hand, I was impressed with 17% of the students who indicated that plants use the food they produce.

Considering that the pretest and posttest were designed and scored so that a perfect score of 30 would probably only be achieved by experts, i.e, college biology majors, biology teachers, professors, etc... the scores on the posttest were respectable. Students clearly gained knowledge. For example, knowing that plants make their own food, and overcame misconceptions, such as, plants get food from the soil. The students should gain a deeper understanding of how plants use this food, if they take more advanced biology courses.

In summary, a comparison of the results of the pretest and posttest provided evidence of students' increased understanding of key concepts. All answers to questions on the posttest showed improvement from the pretest. The significant increase in students' scores can be attributed to the combination of class discussions, written activity sheets, and the laboratory investigations. This significant increase in scores on the posttest was beyond what was expected based on the achievement of other high school and even college students on similar tests in other studies. Although some aspects need improvements, I conclude that the unit was successful.

APPENDICES

APPENDIX A

UNIT LESSON PLANS

Unit One: "Community Biology" Lesson Plans, 8 days

Objectives

Class Introduction
- learn rules and class procedures

Section 1
- discuss the zebra mussel invasion and relate this to our study of biology
- identify the characteristics of living things

Section 2
- identify the components of a community
  - state the flow of energy in a community
  - classify organisms in a community based on energy flow
  - list raw materials needed by each type of organisms

Section 3
- use knowledge of biological needs to list methods to control zebra mussels

Day-by-Day Plan

Day I

Introduce class rules and procedures
Assign Textbooks, Lab Manuals, and Notebooks
Start discussing zebra mussels, do study guide 1-1 in class
Assign: Read Characterizing Life pgs 8-9, know Vocab terms

Day 2

QUIZ 1-1: Rules and Life Characteristics
*Pretest
Discuss Life Process
Explain Lab Report write-up and lab prep
Assign: study guide1-2, Prep Lab 1

Day 3

QUIZ 1-2: Types of Organisms in a Community
Assign lab partners and Start Lab 1

Day 4

Complete Lab 1
*Start Activity " What gasses are released from animals and plants?"
Assign: Lab Report 1 and Science Article Summary 1

Day 5

Collect Lab 1 and Science Aritcle Summary 1
QUIZ 1-3: Lab 1 Observations
Review Communities -Concept Map
*Complete Activity " What gasses are released from animals and plants?"
Discuss needs of producers, consumers, and decomposers
Assign: Prep Lab 2

Day 6

Do Lab 2
Assign: Lab Report 2

Day 7

Collect Lab 2
Students work in groups to suggest ways to solve the zebra mussel problem
Solutions must be based on the life processes of the organisms
Assign: Review 1, 3, 4, 6, 11, 13, 14, 20, 22, 24

Day 8

Collect Review
Test Ch 1
Assign: Thinking Activity for Chapter 12

Unit Two: "Matter and Energy" Lesson Plans, 7 days

Objectives

Section 1

-identify the components of atoms, molecules, and ionic compounds
-demonstrate through writing structural formulas how the certain atoms form covalent bonds
-contrast covalent and ionic bonds

Section 2

-Identify and describe the four main types of biological compounds: carbohydrates, lipids, proteins, and nucleic acids
-distinguish between condensation and hydrolysis reactions used in making or digesting these compounds

Section 3

-distinguish between potential and kinetic energy
-recognize the need for activation energy for cellular processes
-describe the means by which an enzyme carries out a cellular reaction

Day-by-Day Plan

Day 1

Do Study Guide 3-1 together as a class(skip balancing equations)
Discuss types of bonds: covalent and ionic
Assign: Prep Lab 6 & Draw structural formulas

Day 2

Check structural formulas
Do Lab 6
Assign: Lab Report 6

Day 3

QUIZ: The Structure of Atoms and Molecules
Look at food labels and Discuss the four types of biological compounds
Discuss Hydrolysis and Condensation reactions
Assign: Study Guide 3-2 Modified

Day 4

Collect Study Guide 3-2 QUIZ: Concept Map
Discuss types of energy
Introduce Enzymes with Video
Assign: Study Guide 3-3, prep Enzyme Lab

Day 5

Collect Study Guide 3-3
*Start Lab: "Can Plants Digest Starch?: Testing for Enzymes in Germinating Seeds"
Do Enzyme Lab: "What Effects the Rate of Enzyme Activity?"
Assign: Complete Enzyme Lab

Day 6

Collect Enzyme Lab
Discuss and Review
*Complete Lab: "Can Plants Digest Starch?: Testing for Enzymes in Germinating Seeds"
Assign: Review 1, 5, 7, 9, 10, 11, 15, 17, 18, 23

Day 7

Collect Review
Test Chapter 3

Unit Three: "The Flow of Energy" Lesson Plans, 9 days

Objectives

Section 1

-distinguish between endergonic and exergonic reactions
-explain how ATP is used in linking exergonic and endergonic reactions
-compare and processes of aerobic respiration, anaerobic respiration, and fermentation

Section 2

-recognize and separate different plant pigments and describe how these interact with light
-describe the events of the light reactions and Calvin cycle of photosynthesis
-analyze the relationship between photosynthesis and cellular respiration

Day-by-Day Plan

Day 1

Demo: liver and hydrogen peroxide, Define exergonic and endergonic reactions
Describe ATP, make analogies to forms of currency: paper money
*Students complete a activity sheet on ATP and cellular respiration.
Assign: Vocab p.149 - 151

Day 2

Collect ATP Activity sheet
*Inquiry Activity: "Do plants respire?"
Assign: Study Guide 6-1, Prep Lab 11

Day 3

Collect Study Guide 6-1
Do Lab 11: Energy in Food: Burning a Peanut and Walnut
Assign: Lab Report 11

Day 4

BIG QUIZ: ATP, Aerobic, Anaerobic, & Fermentation.
Discuss Light , plant pigments, overview of photosynthesis
Explain the Light Reactions
Assign: Study Guide 6-2, Prep Lab 13

Day 5

Collect Study Guide 6-2
Do Lab 13: Chromatography: Leaf Pigments
*Students Cover Geranium Leaves
Assign: Lab 13 Report

Day 6

Collect Lab 13
Review the Light Reactions
Discuss Calvin Cycle
Assign: Prep Lab 14

Day 7

*Do Labs: "Light and Starch Production" & "Light and the Rate of Photosynthesis"
Assign: Lab Reports

Day 8

QUIZ: Photosynthesis
Do Study Guide 6-2 page 3 in class
Assign: Review 1, 3, 4, 7, 10, 12, 14, 15, 19, 20

Day 9

Collect Review
Test Chapter 6
*Posttest and Laboratory Evaluation
Assign: Ch 7 Describe three ways that Scientist tested the theory of spontaneous generation

APPENDIX B

List of Laboratory Activities for Units One, Two, and Three

Unit One: Community Biology

1. Life Characteristics: Identifying Common Characteristics in Living Things
2. * "What Gasses are Released from Animals and Plants?"
3. Life in a Square Meter Community

Unit Two: Matter and Energy

4. Building Molecular Models
5. *"What Effects the Rate of Enzyme Activity?"
6. *"Can Plants Digest Starch?: Testing for Enzymes in Germinating Seeds"

Unit Three: The Flow of Energy

7. *"Do Plants Respire?"
8. "How Can We Measure Energy In Food?"
9. Chromatography: Leaf Pigments
10. *"Light and Starch Production in Leaves."
11. *"Light and the Rate of Photosynthesis"

Notes: *Indicates a new lab developed during research for the unit

APPENDIX C

ATP Activity

Name:________________________
Date:______________Hour:_______

ATP, or adenosine triphosphate, the source of chemical energy produced in cellular respiration, is made of the molecules adenine, ribose, and three phosphates. On a separate sheet there are structural formulas and a model of each of these parts.

1. Examine the structural formulas and models for each part of the ATP molecule
2. Cut out the paper models of adenine, ribose, and phosphate. You will need 3 phosphate models.
3. Attach the five pieces to form ATP or adenosine triphosphate. For help refer to page 145 in your text book and remember from Chapter 3 how bonds are formed.
4. Glue your model in the space provided.
5. Answer the questions.

Paste Model Here:

Questions:

1. Name the parts of the ATP molecule.

2. What must be removed when you link adenine with ribose?

3. What is formed when adenine and ribose are joined?(Hint: what do the letters ATP stand for?)

4. What does the prefix "tri" refer to in ATP?

5. How is ATP converted to ADP?

6. Is energy released when ATP is converted is ADP? Is this reaction endergonic or exergonic?

Study the following equation. This shows how ATP is formed from ADP in the body.

$C_6H_{12}O_6 + 6O_2$ ------> $6H_2O + 6CO_2$ + *ENERGY*

ENERGY + 36 ADP + 36 P ------> 36 ATP

7. What is the name of the process summarized by the first reaction above?

8. Where is the energy coming from?

9. For each molecule of $C_6H_{12}O_6$, how many molecules of ATP are formed?

10. If we compare these processes to our system of currency, What would be similar to $100 bills? What would be similar to $1 bills?

11. Study figure 6 -3 on page 146 of your text. Is this chemical reaction hydrolysis or condensation?

12. Is this chemical reaction endergonic or exergonic?

13. Is the reaction ATP ------> ADP + P endergonic or exergonic?

14. Once ATP is made from the energy released in glucose, how is this energy made available to do work in the body? (Hint: page 146 has an example)

15. Read about anaerobic respiration on page 149. Is the reaction at the top of this page aerobic or anaerobic? How do you know?

16. Study the equation for anaerobic respiration on page 150 of your text. If 2 ATP molecules are needed for activation energy, how many molecules of ATP are gained over all?

17. Which produces more ATP aerobic or anaerobic respiration?

18. When do human muscle cells stop doing aerobic respiration and start doing anaerobic respiration?

APPENDIX D

"What Gasses Are Released From Animals and Plants?"

Name:____________________________
Date:________________Hour:________

Purpose: To compare what gasses are released from animals and plants.

Materials:

- 8 large test tubes
- test tube rack
- 6 zebra mussels
- 4 *Elodea* sprigs
- distilled water
- BTB - 0.5% Bromothymol Blue Solution
- graduated cylinder

Procedure:

1. Label/number the eight test tubes using a wax pencil.

2. Fill each test tube with 15 ml of distilled water using a graduated cylinder.

3. Place 3-5 drops of BTB indicator solution in each test tube and stir or mix up the solution. The solution should be very light blue.

4. In test tubes 1, 3, 5, and 7 hold a straw at the top of the solution and gently exhale through the straw just until the solution turns yellow STOP EXHALING AS SOON AS THE SOLUTION TURNS YELLOW

5. Fill each test tube with the following contents:
   - test tube 1- nothing
   - test tube 2- nothing
   - test tube 3- three zebra mussels
   - test tube 4- three zebra mussels
   - test tube 5- *Elodea* plant 5 cm long
   - test tube 6- *Elodea* plant 5 cm long
   - test tube 7- *Elodea* plant 5 cm long place in a dark cupboard
   - test tube 8- *Elodea* plant 5 cm long place in a dark cupboard

6. Record the color of each test tube after 24 hours.

Data Table:			
Test Tube Number & Content	Color at start	Color 24 hours later	gas released or used

Discussion Questions:

1. Why did some of the test tubes have nothing in them?

2. What was the purpose of exhaling into some of the test tubes?

3. What gas is given off when you exhale? Do zebra mussels give off the same gas? Explain your answer using lab data.

4. Did the *Elodea* plants in the light give off this same gas? In the dark?

5. Why would it make a difference whether the *Elodea* plants are in light or dark conditions? (test tubes 5 & 6 compared with 7 & 8)

6. What are the two chemical processes that either use or give off this gas?

Conclusion:

What gas is released by consumers? What is the process that produces this gas?

What two gasses are released by producers? What are the names of these two processes and under what conditions do these processes take place?

Teacher Notes:

Students will use an indicator, BTB, to observe the release of carbon dioxide from Zebra Mussels and use of carbon dioxide by *Elodea* plants in light. Student should also observe the release of carbon dioxide from *Elodea* plants that are placed in the dark.

Bromothymol Blue 0.5% Solution Preparation:

Add 0.5 g bromothymol blue powder to 1 liter of distilled water.
You may need to add a few drops of ammonia to the solution to turn it blue.

Care of Zebra Mussels:

Zebra Mussels do best at cooler temperatures. They are best keep at 17 degrees Celsius or 62 degrees Fahrenheit.

APPENDIX E

"Do Plants Respire?"

Name:________________________________

Date:__________________Hour:_________

Materials:

4 test tubes
test tube rack
Bromothymol Blue Solution
germinating corn and bean seeds
distilled water
25 ml graduated cylinder
plastic drinking straw
plastic dropper
wax pencil

Procedure:

1. Label the test tubes 1 - 4.
2. Place 15 ml of distilled water in each test tube.
3. Place 10 drops of BTB solution in each test tube.
4. Using the table add the specific material to each tube.
5. Record the color of each solution at various times on the table. For test tube #1, place a straw at the top of the solution and gently exhale through straw until the solution turns yellow

Data Table:

Test Tube Number & contents	Color at start of activity	Color after 20 minutes	Carbon dioxide released?
1. exhale through straw			
2. germinating beans			
3. germinating corn			
4. nothing			

Questions:

1. Write the chemical equation for cellular respiration. Then, describe this process in your own words.

2. What type of food is stored in the bean and corn seeds?

3. Do the bean and corn seeds have enzymes to help digest this stored food?

4. What is the final form of the food after digestion? Is this part of your equation for cellular respiration?

5. Did the germinating bean and corn seeds produce carbon dioxide? How can you tell?

6. What was the purpose of test tube 4? Test tube 1?

7. Based on your observations, do plants respire?

8. Do animals do cellular respiration the same way as plants?

9. Where do we get our food?

10. How did the plant get this stored food? Where did it come from?

Conclusion:

APPENDIX F

"Can Plants Digest Starch?: Testing for Enzymes in Germinating Seeds"

Name:____________________________
Date:__________________Hour:________

Background:

Amylase is an enzyme that digests starch. This enzyme is present in saliva as well as in juices released from the pancreas for digestion of starch in the small intestine. If a plant is to make use of stored starch it would have to contain the enzyme that digests starch. Since seeds contain a lot of starch, we will test germinating seeds.

Purpose:

To test for the presence of the enzyme amylase in various germinating seeds. Students will use an indicator, Gram's iodine, to observe the digestion of starch by germinating bean and corn seeds. Digestion of starch will be proof of enzyme activity.

Materials:

starch agar plates
dry bean and corn seeds
germinating bean and corn seeds

Procedure:

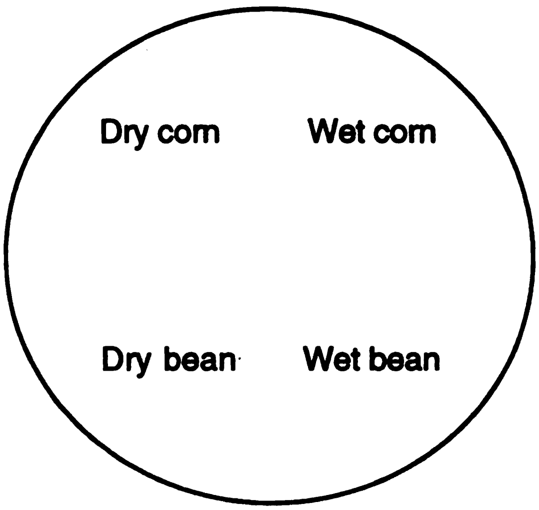
1. Obtain a starch agar plate from your teacher.
   This is a petri dish that contains an agar made with starch.
2. Using a wax pencil, label the bottom of the petri dish as shown in Figure 1.
3. Obtain one dry bean seed and one germinating bean seed, one dry corn seed and one germinating corn seed. Note: You will need to completely cut the corn seeds, but the bean seeds should come apart into two pieces once you cut through the seed coat. CUT THE DRY SEEDS FIRST so that the blade is not moistened, then cut the germinating seeds.
4. Cut each seed in half with a razor blade.
5. Place each seed cut side down on to the agar according to Figure 2.
6. Place the cover back on top of the dish and label this with your name, hour, date, and time.
7. Wait 24 hours, or the next class period.
8. Using forceps or tweezers carefully remove the seeds.
9. Cover the agar with gram's iodine and wait 1 minute
10. Dump off any excess iodine and note the color of the agar

Data:

Sketch the dish by coloring Figure 2. Use a colored pencil to shade the areas that were stained and contain starch.

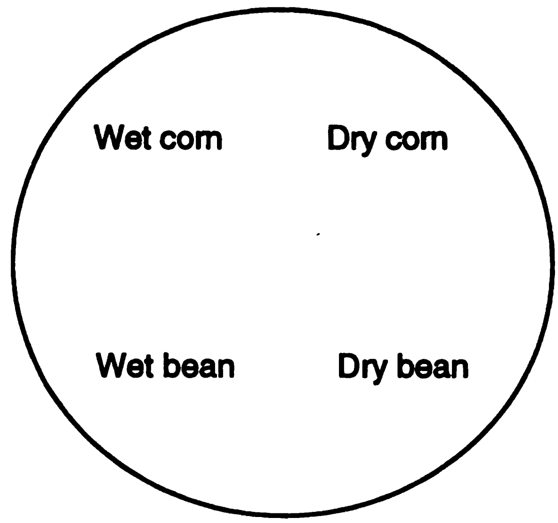
Note: writing on the bottom appears opposite with the dish is right side up.

Figure 1: Label your petri dish on the bottom.



On the top write your Name, Date, and Hour

Figure 2: Place seeds in petri dish



Shade in this figure as Data

Discussion Questions:

1. Under which seeds did the agar stain purple?

2. Under which seeds did the agar NOT stain purple?

3. Which seeds contained the enzyme, amylase? How do you know?

4. After the germinating seeds break starch down into simple sugars like glucose, what do the cells do with the glucose?

Conclusion:

Teacher preparation of starch agar plates

Boil 2g of corn starch in 100ml of distilled water for 1 minute
Cool and filter through a coffee filter
Add distilled water until there is 1 liter
Add 30 g of agar
Sterilize in autoclave or pressure cooker for 30 minutes
Cool and pour into petri dishes (should be enough for 36-40 petri dishes)
Allow more time to cool at room temperature and refrigerate until needed

Teacher preparation of Seeds-Surface Sterilization

Rinse beans in 95% ethyl alcohol for 30 seconds
Cover with 20% bleach solution or bleach diluted 5 fold
After 5 minutes pour off the bleach solution and rinse with water several times until no bleach odor remains
Soak seeds in water for 24 hours
Wrap beans in moist paper towel and place in a plastic bag

Source: Idea from Ken Nadler, MSU: NSC 899, 1997

APPENDIX G

"Light and Starch Production in Leaves"

Name:__________________________
Date:__________________Hour:______

Purpose: In this laboratory exercise you will determine the effects of light on starch production in leaves.

Materials:

Geranium plant	beaker tongs
dark construction paper	hot plate
paper clip	petri dish
scissors	95% alcohol
two 250 ml beakers	iodine solution
600 ml beaker	water
forceps	

Procedure:

1. Cut a small shape from a piece of dark construction paper.
2. Write your initials and hour in part of the piece of paper.
3. Cover a geranium leave with this construction paper and fasten with a paper clip. Make sure the paper covers both the top and bottom of the leaf, except where you cut out the shape. Also make sure your initials and hour can be seen.
4. Place the plant in direct light for two days.
5. Sketch the covered leaf.
6. After two days, carefully remove the leaf from the plant.
7. Carefully remove the construction paper.
8. Place the leaf in a 250 ml beaker half full of water.
9. Boil the water and leaf on a hot plate for 3 - 4 minutes.
   This will kill the tissue. CAUTION: *Be careful around hot plates.*
10. Remove the beaker from the hot plate using beaker tongs.
11. TURN OFF THE HOT PLATE.

Using forceps remove the leaf from the hot water and bring the leaf to your Teacher and he/she will do Steps 12 - 19

12. Fill a 600 ml beaker one third full of water.
13. KEEP ALCOHOL AWAY FROM THE HOT PLATE.
    Place 90 ml of 95% alcohol in a 250 ml beaker.
14. Place the beaker of alcohol into the beaker of water.

15. Using forceps place the leaf into the beaker of alcohol.
16. Place the 600 ml beaker with the 250 ml beaker in it, on the hot plate.
17. Gently boil this using medium temperatures. Boil until the leaf loses its green color.
18. TURN OFF THE HOT PLATE
19. Using beaker tongs, remove the 600 ml beaker from the hot plate.
20. Using forceps, remove the leaf from the beaker of alcohol, and place it in a petri dish.

Return to your lab station.

21. Flood the leaf with iodine and let it stand for 1 minute.
22. Drain off any excess iodine and observe the color of the leaf.
23. Sketch the leaf.

Data:

Questions:

1. What happens when iodine comes in contact with starch?
2. In what area of the leaf was starch present?
3. In what area of the leaf was starch not present?
4. Why did some areas of the leaf contain starch and others did not?
5. What is the name of the process by which plants make starch?
6. Besides water and carbon dioxide, what else is needed for the plant to make starch?
7. How did this lab demonstrate this need?

Conclusion:

APPENDIX H

"Light and the Rate of Photosynthesis"

Name:_____________________________
Date:__________________Hour:________

Purpose: In this laboratory exercise you will determine the effects of light on the rate of photosynthesis. You will measure the rate of photosynthesis by counting the number of oxygen bubbles produced by *Elodea* sprig under various lighting conditions.

Materials:

large jar or 1000 ml beaker
glass funnel
test tube
3 rubber stoppers
100 or 200 watt lamp
0.5% sodium bicarbonate solution
Elodea sprig
metric ruler

Procedure:

1. Fill a 1000 ml beaker or large jar three-fourth full of 0.5% sodium bicarbonate solution.
2. Place an *Elodea* sprig under a glass funnel in the beaker or jar.
3. Set the funnel up on three rubber stoppers.
4. Place a lamp 10 cm away from the beaker or jar.
5. When bubbles begin to escape at a steady rate, count the number of bubbles that escape in one minute. Record this number in the Table
6. Repeat 5 times. Record on the Table.
7. Move the light to 20 cm from the beaker or jar.
8. Repeat steps 5 & 6.
9. Move the light to 30 cm from the beaker or jar.
10. Repeat steps 5 & 6.
11. On a sheet of graph paper, make a bar graph of the results.

Table:	Number of bubbles		
Time (minutes)	Distance (cm)		
	10	20	30
1			
2			
3			
4			
5			
Total			
Average			

Questions:

1. What is the gas produced by the *Elodea* plant during photosynthesis?
2. How was the amount of this gas measured during the experiment?
3. Why was the container filled with a 0.5% sodium bicarbonate solution?
4. Does the rate of gas escape increase or decrease as distance from the light source becomes greater?
5. What is the role of light in photosynthesis?
6. Summarize the process of photosynthesis by writing an overall chemical equation for photosynthesis, then explaining it in your own words.

Conclusion:

APPENDIX I

"How Can We Measure Energy in Food?"

Name:_______________________________
Date:_________________Hour:__________

Background:

You probably know that a calorie is a measure of energy in food, but just how much is a calorie? Can you answer this? Probably not. How long is an inch? I bet that was easier to describe.

Scientists have come up with a way to measure energy in easy to understand terms. Scientist describe and define a calorie as the amount of heat energy needed to raise the temperature of 1 gram of water 1 degree Celsius. This is a very small amount compared to the energy in food, therefore a scientific calorie is actually 1/1000 of a food calorie. In other words, the calories you read on a food label are actually large scientific kilocalories.

Purpose:

In this investigation you will measure the amount of heat released when nuts are burned. You will then calculate the amount of calories in different nuts.

Materials:

tin can calorimeter	water
50- or 100-ml beaker	various nuts
wooden block	beaker tongs
graduated cylinder	thermometer
matches	balance

Procedure:

1. Place exactly 10 ml of water in a beaker.
2. Measure the temperature and record in the table.
3. Find the mass of a nut and record in the table.(around 0.2g is best)
4. Place the nut on the end of the needle on the wooden block.
5. Light the nut on fire and QUICKLY place the tin can over the nut and QUICKLY place the beaker with water on top of the can.
6. After the nut has completely burned, measure the temperature of the water and record on the table. (CAUTION: The beaker is hot use tongs to hold it!)
7. Mass any remaining nut that did not burn and subtract this from the mass recorded on the table. Change the mass that you recorded.
8. Repeat this procedure with another peanut and two walnut samples.

Data Table:

	Peanut		Walnut	
	Trial 1	Trial 2	Trial 1	Trial 2
mass of sample burned				
mass of water 10 ml = 10 g				
initial water temperature				
final water temperature				

Calculations: see examples below

calories				
calories/gram				
Kilocalories				
kilocalories/gram				
team average				
class average				

Calculations: Remember that a calorie is the amount of heat energy needed to raise 1 gram of water 1 degree Celsius.

Example problem: How to calculate calories

(final temp - initial temp) X mass of water X 1 calorie/ C°grams
(30C° - 18C°) X 10g X 1 calorie/ C°grams = 120 calories

Example problem: How to calculate calories per gram

120 calories / 0.2 g = 600 calories/gram

Example problem: How to calculate kilocalories and kilocalories/g

120 calories/1000 = 0.120 kilocalories
600 calories/g / 1000 = 0.600 kilocalories/gram

Questions:

1. What is the relationship of a calorie to the chemical energy stored in foods?

2. Given the number of calories per gram of the sample, compare your data with these know values: peanut is 5.8 kilocaloires per gram and walnut is 6.2 kilocalories per gram. What difference do you notice? Give several possible reasons for your error.

3. How do your data compare with the class data? Explain any differences.

4. Most people can live on 1600 kilocalories per day. How many grams of peanuts would you have to eat to obtain this many kilocalories?

5. Would a diet of peanuts or walnuts be a proper way of getting your required calories? Explain.

6. Why are snack foods sometimes called junk foods?

7. Grizzly bears are known to eat the fatty parts of many animals. What property of the fatty tissue makes them a good food source for the bears?

Conclusion:

Source: "Probing Levels of Life: Laboratory Manual" Biology Living Systems
Glencoe Division of Macmillan/McGraw-Hill, 1994

APPENDIX J

Pretest

Name:______________________________

Date:_______________Hour:__________

Instructions: In order to better assess what you know about biology, please answer the following questions. Be as descriptive as possible. Because this is a pretest, there will be no right or wrong answers.

1. What are the needs of living things?

2. Do organisms depend on each other? Explain

3. What types of organisms make up a community?

4. What is a food chain? Write a possible food chain. (In a pond, for example)

5. How are the needs of plants different than those of animals?

6. Do plants breathe? If so, what type(s) of gas? Explain .

7. What is food for plants? Do plants eat?

8. In animals, after food is digested, what happens to it? How is it used by the body?

9. List and/or describe any chemical reactions the take place in living things.

10. What is an enzyme? What do they do? How do enzymes work in living things?

APPENDIX K

Posttest

Name:____________________________
Date:_________________Hour:_______

Instructions: In order to assess what you have learned about certain concepts in biology, please answer the following questions. Be as descriptive as possible.

1. Write several sentences describing and explaining the needs of living things.

2. Do organisms depend on each other? Draw a diagram to explain.

3. What types of organisms make up a community?

4. What is a food chain? Write a possible food chain and explain the role of each type of organism.

5. Compare and contrast the needs of plants versus animals. Make a table or chart to help you show similarities and differences.

6. Do plants breathe or use gasses? What types of gasses? Explain.

7. What is food for plants? Do plants eat? Explain.

8. In animals, after food is digested, what happens to it? How is it used by the body?

9. List and describe types of chemical reactions that take place in living things. Please list and describe <u>all</u> the chemical reactions that you can remember.

10. What is an enzyme? What do they do? How do enzymes work in living things?

APPENDIX L

PRETEST AND POSTTEST SCORING RUBRIC

Grading: Answers were scored on a scale from 0 to 3.
No answer or completely incorrect answers were given a score of zero.
Simple, unexplained answers were given a score of one.
More complete and explained answers were given a score of two.
Very detailed, well explained answers were given a score of three.

1. What are the needs of living things?

   0----No Answer
   1----Food and Air (one or two items)
   2----Food and Oxygen(two or more items more specific)
   3----Food for energy or sunlight to make food, oxygen and carbon dioxide shelter, water, nutrients, minerals and vitamins to grow and make tissues protein, sugar etc...(very detailed list with reasons)

2. Do organisms depend on each other? Explain

   0----No answer or NO
   1----Yes, but can not explain why
   2----Yes, for food chain
   3----Yes, food chain, producers make food, consumers, decomposers recycle

3. What types of organisms make up a community?

   0----No answer
   1----Animals and plants
   2----Consumers and producers with better explanation
   3----Consumers, producers, and decomposers, with better explanation

4. What is a food chain? Write a possible food chain. (In a pond, for example)

   0----No answer
   1----An example food chain with no explanation or decomposers
   2----An example food chain with a vague explanation
   3----An example food chain with a complete explanation including the role of each type of organisms: producers, consumers, and decomposers

5. How are the needs of plants different than those of animals?

0----No answers
1----Plants need sun and soil, but no explanation
2----Plants need sun, soil, carbon dioxide, water, but not explained well
3----Plants need sunlight, water, and carbon dioxide to make food, they need minerals from the soil to make tissue, they make sugar, but need oxygen to get the energy out of the sugar.

6. Do plants breathe? If so, what type(s) of gas? Explain .

0----No answer or NO
1----Yes, but can not explain
2----Yes, carbon dioxide to make food
3----Yes plants used carbon dioxide to make food and oxygen to use this food. They obtain gasses through pores on the surface of leaves and stems, or through the roots via gasses dissolved in water in the soil.

7. What is food for plants? Do plants eat?

0----No answer or soil and water
1----Plants make their own food
2----Plants make their own food with sunlight
3----Plants make their own food by photosynthesis. They use energy from sunlight and water and carbon dioxide to make sugar. This sugar is then stored as starch for use by the plant latter. The starch is then converted back to sugar(glucose) and the plant uses oxygen through the process of cellular respiration to release energy from the glucose. This process produces carbon dioxide and water as waste products.

8. In animals, after food is digested, what happens to it? How is it used by the body?

0----No answer
1----It goes into the blood and is used, not explaining how
2----It goes into the blood and then to all body tissues and is used for energy or stored as fat, etc...
3----It goes into the blood and sugars will be used by cells for energy through the process of cellular respiration, amino acids will be used to make protein, and fats will be stored as energy reserves. Excess glucose will be stored as glycogen.

9. List and/or describe any chemical reactions the take place in living things.

0----No answer
1----Photosynthesis or cellular respiration
2----Breakdown of food and one of the above
3----Photosynthesis, cellular respiration, hydrolysis or condensation reactions, protein synthesis, etc... Antigen-antibody reactions, digestion

10. What is an enzyme? What do they do? How do enzymes work in living things?

0----No answer
1----Enzymes digest or breakdown food
2----Enzymes are catalysts for chemical reaction
3----Enzymes are proteins that act as catalysts by lowering the activation energy needed for all chemical reactions to take place in the body. Enzymes are very specific. Each specific chemical reaction in the body requires a specific enzyme. Enzymes chemically bond or "fit" a specific substrate. Enzymes are not used up or consumed in the chemical reaction and can be used over and over again.

APPENDIX M

Laboratory Evaluation

Name:______________________________
Date:_________________Hour:________

Instructions: Read the following descriptions and answer the questions based on your knowledge and memory of laboratory exercises and activities we have done.

1. When a student uses a blue indicator solution of Bromothymol Blue(BTB), what does it mean when the solution turns from blue to yellow?

2. A student places several organisms into test tubes containing BTB. Complete the table by predicting what the color will be after 24 hours.

Test Tube #	Contents	Color at Start	Color after 24 hours
1	nothing	blue	
2	exhale through straw	blue	
3	zebra mussels	blue	
4	*Elodea*	blue	
5	water plant	blue	
6	germinating seeds	blue	
7	gold fish	blue	

3. What color did your predict for the majority of the test tubes? Which test tubes had different results from the majority?

   Explain how you made these predictions by describing what process is carried out in each organism.

4. A student cuts a germinating corn seed in half and places each half on agar containing starch. Twenty-four hours later the student removes the seed and floods the agar with iodine. Draw a picture and/or describe the color and appearance of the agar. Explain.

5. A student cuts a heart shape from some black construction paper and puts this over a healthy leaf of a plant. The student then places the plant in a well lit area. After 24 hours the student removes the leaf and tests for the presence of starch.
   Predict what areas of the leaf will test positive for starch.

   What biological process produces starch in leaves?

   What is the energy source?

6. A student places a light source 10 cm from a water plant and counts the number of bubbles released from the plant. What type of gas is given off by the plant?

   Will the number of bubbles increase or decrease when the light source is moved to 30 cm away? Explain.

7. A student puts 4 ml of hydrogen peroxide into 4 test tubes. The student then soaks 4 paper disks in 100%, 75%, 50%, and 0% enzyme solutions, respectively. Predict which disk will float up the quickest, when put into the test tubes containing hydrogen peroxide.

8. A student has three test tubes. The student puts 4 ml of hydrogen peroxide in the first test tube. In the second test tube they put 2 ml of hydrogen peroxide and 2 ml of distilled water. In the third test tube the student puts 4 ml of distilled water. The student puts a paper disk soaked in 100% enzyme into each test tube.
   Predict which disk will float up the quickest.

9. A disaccharide is digested into two simple sugars.
   Draw this chemical reaction showing the enzyme and substrate before, during, and after.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alberts, Bruce, et al. (1994) Molecular Biology of the Cell Third Edition, Garland Publishing, Inc. New York & London

Amir, Ruth and Tamir, Pinchas. (1994) "In-depth Analysis of Misconceptions as a Basis for Developing Reseach-Based Remedial Instruction: The Case of Photosynthesis." The American Biology Teacher. v 56 n 2 p 94-100

Andersson, Bjorn. (1986) "Pupils' Explanations of Some Aspects of Chemical Reactions." Science Education. v 70 n 5 p 549-563

Anderson, Charles W., Sheldon, Theresea H., and Dubay, Joann. (1990) "The Effects of Instruction on College Nonmajors' Conceptions of Respiration and Photosynthesis." Journal of Research in Science Teaching. v 27 n 8 p 761-776

Barrass, Robert. (1984) "Some Misconceptions and Misunderstandings Perpetuated by Teachers and Textbooks of Biology." Journal of Biological Education. v 18 n 3 p 201-206

Bell, Beverly. (1985) "Students' Ideas About Plant Nutrition: What Are They?" Journal of Biological Education. v 19 n 3 p 213-218

Campbell, Neil. (1987) Biology. The Benjamin/Cummings Publishing Company, Inc. Menlo Park, California

Chan, Sammy. (1996) "Focus on Photosynthesis." The Science Teacher v 63 n 8 p 46-49

Chiappetta, Eugene L. (1997) "Inquiry-Based Science." The Science Teacher v 64 n 7 p 22-26

Dempsey, Arthur D. (1990) "VanHelmont's Tree Revisted." Science and Children v 21 n 6 p 18-19

Eaton, Janet F., Anderson, Charles W., and Smith, Edward L. (1983) "When Students Don't Know They Don't Know." Science and Children. v 20 n 7 p 6-9

Ebenezer, Jazlin V. and Zoller, Uri. (1993) "Grade 10 Students' Perceptions of and Attitudes Toward Science Teaching and School Science." Journal of Research in Science Teaching. v3 0 n 2 p 175-186

Edwards, Clifford H. (1997) "Promoting Student Inquiry." The Science Teacher v 64 n7 p 18-21 Oct

Eichinger, John. (1992) "College Science Majors' Perceptions of Secondary School Science: An Exploratory Investigation." Journal of Research in Science Teaching. v 29 n 6 p 601-610

Eisen, Yehudit, and Stavy, Ruth. (1998) "Students' Understanding of Photosynthesis." The American Biology Teacher. v 50 n 4 p 208-212

Flannery, Maura C. (1991) "Biology Today: Considering Plants." The American Biology Teacher. v 53 n 5 p 306-309

Glasson, George E. and Lalik, Rosary V. (1993) "Reinterpreting the Learning Cycle from a Social Contructivist Perspective: A Qualitative Study of Teacher's Beliefs and Practices" Journal of Research in Science Teaching v30 n 2 p 187-202

Haslam, Filocha and Treagust, David F. (1987) "Diagnosing Secondary Students' Misconceptions of Photosynthesis and Respiration in Plants Using a Two-Tier Multiple Choice Instrument." Journal of Biological Education. v21 n3 p 203-211

Hazel, Elizabeth and Prosser, Michael. (1994) "First-Year University Students' Understanding of Photosynthesis, Their Study Strategies and Learning Context." The American Biology Teacher. v 56 n 5 p 274-279

Hershey, David R. (1992) "Making Plant Biology Curricula Relevant." BioScience. v 42 n 3 p 188-191

Hershey, David R. (1993) "Plant Neglect in Biology Education." BioScience. v 43 n 7 p 418

Honey, John N. (1987) "Where Have All the Flowers Gone? -- The Place of Plants in School Science." Journal of Biological Education. v 21 n 3 p 185-189

Lumpe, Andrew T. and Staver, John R. (1995) "Peer Collaboration and Concept Development: Learning About Photosynthesis." Journal of Research in Science Teaching. v 32 n 1 p 71-98

Oram, Raymond F. (1994) Biology: Living Systems. Glencoe Division of Macmillan/McGraw-Hill School Publishing Company. Westerville, Ohio

Saunders, Walter L. and Young, Gary D. (1985) "An Experimental Study of the Effects of the Presence or Absence of Living Visual Aids in High School Biology Classrooms Upon Attitudes Toward Science and Biology Achievement." Journal of Research in Science Teaching. v 22 n 7 p 619-629

Treagust, David F. (1988) "Development and Use of Diagnostic Tests to Evaluate Students' Misconceptions in Science." International Journal of Science Education. v 10 n 2 p 159-69

Uno, Gordon E. (1994) "The State of Precollege Botanical Education." The American Biology Teacher. v 56 n 5 p 263-267

Wandersee, James H. (1985) "Can the History of Science Help Science Educators Anticipate Students' Misconceptions?" Journal of Research in Science Teaching. v 23 n 7 p 581-597

Wandersee, James H. (1986) "Plants or Animals--Which Do Junior High School Students Prefer To Study?" Journal of Research in Science Teaching. v 23 n 5 p 415-426

Wessells, Norman K. and Hopson, Janet L. (1988) Biology. Randon House, Inc. New York, New York

GENERAL LABORATORY REFERENCES

Action Biology. "Chapter 6: All Food is Green" and "Chapter 8: Food and Gas Available." p (23) 215 - (26) 218 p (33) 225- (36) 228 Weinberg, Stanley L. Stoltze, Herbert, J. Allyn and Bacon Inc. Boston, Rockleigh NJ Allanta, Dallas, Belmont, Cal. 1977, 1974

Biological Science: Patterns and Processes, 3rd Edition. "42 Energy Relationships(program questions)"; "43 Chemical Indicators(Laboratory Activity"; " 44 Photosynthesis(Reading)"; "45 Light and Photosynthesis (Laboratory Activity)"; "46 CO_2 and Photosynthesis(Lab)"; "47 A Startling Discovery(Lab)" 1986,1970, 1966 by BSCS The Colordado College, Colorado Springs, Colorado, 80903

Biology Living Systems. Probing Levels of Life: Laboratory Manual "Lab 11: Measurement of Chemical Energy in Food" Glencoe Division of Macmillan/McGraw-Hill, 1994

Experiences in Biology Revised Edition To Accompany Exploring Biology 6th edition. "Chapter 10: Seed Plants and How They Live(Investigaing Photosynthesis p 115-118)" Harcourt, Brace and World Inc. 1967, 1960

Focus on Life Science: A Learning Strategy for the Laboratory. "Cellular Respiration 8" Kaskel, Daniel p 23-24 Merrill Publishing Company 1987, 86, 81, 77, 74 by Bell and Howell Columbus Ohio

Life Science: Laboratory Manual. Chapter 5 "Research Lab 5: Oxygen Production and Photosynthesis." Addison-Wesley Publishing Company p 77-78 1986

Life Science: Laboratory Manual. "24 Food Production in Photosynthesis"; "25 Organisms and Carbon Dioxide "; "Chapter 8: Vascular Plants" Prentice-Hall Inc. Englewood Cliffs, New Jersey 1988

Modern Biology. "Investigation 6: Photosynthesis and Cellular Respiration" Otto, Towle p. 35 - 38 Holt, Rinehart, and Wilson 1985