TEACHING ENERGY
TO
HIGH SCHOOL GENERAL BIOLOGY STUDENTS

By

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ABSTRACT

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The purpose of this energy unit was to teach the basic concept of energy to ninth and tenth grade general biology students. The unit addressed the general concept of energy, and compared physical and biological energy; laws of thermodynamics, energy stored in chemical bonds, and energy transfer in an ecosystem from the sun to living organisms.

The unit was built around a thematic approach to teaching science, and included several laboratory experiments and "hands-on" activities to promote conceptual understanding of energy. The instruction sought to incorporate writing across the curriculum and elements of the constructivist philosophy. An additional goal of the unit was to help students feel comfortable with science and scientific thinking.

Student interviews, comparison of pre-test and post-test scores, evaluation of journal entries, student writing samples, exit student evaluations, and cooperative learning group reports/projects were evidence that student learning was enhanced by the pedagogic methods utilized. The students were enthusiastic learners who constructed their own knowledge of energy.

I dedicate this thesis to

my mother June

and

my father George

whose example, encouragement, and love,

were my inspiration

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INTRODUCTION

Statement of the Problem and Rationale for the Study

Elkana (1974) observes that 'conceptual revolutions', 'conceptual evolutions', or 'conceptual frameworks' are talked about frequently, but never defined by those who discuss them. Concepts can be thought of as ideas scientists use when they plan new experiments or develop new mathematical formulas. The concept must be accompanied by content. Educators use these concepts to plan what content to teach. According to Elkana (1974), von Helmholtz proved correctly and generally the law of conservation of energy. However, he did not have a clear idea of the energy with which he worked. This illustrates what seems to be a general feature of how scientific concepts develop, namely that they are in a state of flux while the discovery is being made.

According to Richard Feynman (1975) the law of the conservation of energy states that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a certain quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same. Feynman also say it is very difficult to define and describe the idea of energy.

However, "energy is one cornerstone of the sciences. Energy may be the most powerful theme connecting and unifying the sciences" Martin (1992). Holman (1986) has suggested that teachers should develop five conceptual areas with regard to energy: the meaning of energy, energy transformation, the storage of energy in chemicals, the degradation of energy, and the conservation of energy during transformation.

Energy is a concept which many sources, including dictionaries, high school textbooks, and encyclopedias have defined. These are not scientific definitions. The American Heritage Dictionary (1992) defines energy as 1. The capacity for work or vigorous activity; vigor; power. 2.a) Exertions of vigor or power: *a project requiring a great deal of time and energy.* b) Vitality and intensity of expression: *a speech delivered with energy and emotion.* 3.a)Usable heat or power: b) A source of usable power, such as petroleum or coal. 4. The capacity of a physical system to do work. Holt, Rinehart, & Winston's, Biology, Principles & Explorations (1996), defines energy as capacity for doing work, often described as the ability to make things move or change. A scientific definition from a physics text may state that energy is the capacity to do work, work ultimately defined in terms of a force times a displacement. Perhaps these definitions of energy contribute to students' misconceptions.

It appears bioenergetics is more difficult for students to comprehend than energy usage in mechanical systems. The conversion of one form of energy into another is relatively straightforward in mechanical systems. A barrel of water on a mountain top has a certain amount of potential energy (energy of position), which is proportional to the height of the mountain (and, of course, to the quantity of water in the barrel). If the water is poured over the edge of a cliff, the potential energy drops as the water falls, but the kinetic energy (energy of motion) increases proportionately. When the water strikes the floor of the canyon, an amount of heat energy is released equal to the kinetic energy of the water just before it reached the canyon floor, and this amount, in turn is equal to the potential energy the water had on the mountain top (we neglect the effect of air friction and otherwise assume ideal conditions). If the water is allowed to strike a paddle wheel, on the other hand, a part of the energy may be obtained as work, although the rest is still converted into heat. Energy therefore, may be converted from one form to another but in these transformations, the total amount of energy remains constant. This idea of energy transference is more difficult to convey in living systems.

Incredibly, all the processes of life and, indeed, all the energy and matter in the universe obey two simple *laws of thermodynamics* . The first law of thermodynamics states that energy may neither be created nor destroyed, but it can be transformed. Although energy is transferred from one object to another and to some extent is even converted from one form to another, no energy is created or destroyed by transfer or conversion. This law does not apply to nuclear changes, where energy can be produced from small amounts of matter. The second law says that energy inevitably disperses, dissipates, and scatters on its way to becoming heat. In other words, within an isolated system, energy does run down in its ability to do work on its way toward being heat. Heat can be used to do work, but the energy transfer is always accompanied by a loss of order or organization.

Life represents a creation and maintenance of ordered (low entropy) structures. Entropy, often referred to as randomness, is the energy within a given system, that is no longer available to do work. Thus, within any isolated system, as energy exchanges occur, entropy increases. To form and preserve the highly ordered arrangement of molecules and the organized network of chemical changes in living organisms, they must continually get and use high-quality matter resources and energy resources from their surroundings. When these resources are used, they become disordered, low quality (high entropy) heat and thus, waste matter to the environment. All forms of life are tiny pockets of order (low entropy) maintained by creating a sea of disorder (high entropy) in their environment.

Of particular interest in this unit, is the energy that can be obtained from chemical compounds. In this respect, chemical energy is the energy a molecule has by virtue of the kinds of atoms it contains and the manner in which they are linked together; chemical energy may be considered as a type of potential energy. Explosions and flames are dramatic examples of reactions in which chemical energy is released. The heat and light that are characteristic of these reactions comes from the breakdown or rearrangement of the chemicals involved; that is, the energy released was present originally in the starting molecules as chemical energy. For example, in a battery, chemical energy is converted to an electric current. In turn, the energy can be used to run a motor which performs mechanical work.

To make matters more complicated, sources of energy flow through the biomass of plants, animals, and microorganisms in complex food chains on their way to becoming heat. Chloroplasts in plant cells manufacture sugar using the energy of sunlight, in the process called photosynthesis. Mitochondria, in both plant and animal cells, break down or utilize the chemical energy in sugar to make ATP (Adenosine Triphosphate), in the process called respiration. This seemingly simple design represents the flow of energy through life. Chloroplasts inside plant cells trap the energy from light and transfer it to the bonds of sugar molecules. Glucose, the storable and transportable fuel of the living world, is also living organisms' basic building material. Mitochondria use oxygen to burn (i.e., break down sugar, making ATP, a potential source of energy in the process). ATP provides energy by creating molecules that make life's work possible.

Energy involved in the synthesis of substances by a living organism is transferred when another organism eats and then oxidizes those substances. Not all energy from the oxidation is transferred to the living organism. A lot of the energy is transferred to the environment. This energy is said to be "lost" from the ecosystem since it cannot be transferred to building up new material or to other processes in living things. Thus, energy flows through the ecosystem; it is not cycled.

The relationship between life and energy is complex. If I could succeed in linking energy between mechanical and living systems, I could proceed with teaching the "big idea" or universal idea of energy. "Failure to convey the crucial role energy plays in all levels of life may interfere with the acquisition of biological understanding of energy and its importance in living systems." (MEGOSE, 1990) To be scientifically literate, students need to have a deep and connected understanding of the "big ideas" of science. This instructional unit attempts to integrate biological, chemical, and physical principles using energy as a platform. It is the first attempt I have made to help students better understand the interaction and inter-dependance of organisms and events in the world.

Teachers are encouraged by AAAS Project 2061, *Science For All Americans* (1990), to focus on the big ideas of science and not layers of technical detail. It is these details which often mask important ideas and turn kids off to science. Concepts learned in depth and with understanding can be applied to new situations or problems. Less is more, in teaching, means that exposure to fewer topics leads to deeper understanding. Traditionally, I have concentrated on the details of biology and I have expected my students to memorize facts and information. I would give out the information in lectures, we would read the chapter, do an activity, complete a study guide or reading guide, then take a test over the information. I rationalized this was perfectly all right because, after all, this is how I had learned.

When I began my research at MSU, I was developing labs and activities which involved the microbiology of food. After some careful reflection and consideration, I felt a detailed unit on food microbiology would be great for advanced science students. Unfortunately, this advanced study would not serve the needs of the majority of my students who were in my general biology classes. Therefore, during the development of the unit I found my focus changing to the big idea of energy usage in biological systems.

During the teaching of this new unit, I did not teach the details of respiration or photosynthesis. Students were not asked to memorize the Krebs cycle or the light and dark reactions of photosynthesis. Rather, I focussed in on the big idea of energy usage in living things and the relationships with physics and chemistry. The chemical equations for respiration and photosynthesis served only to show the relationship between the energy-producing and energy-using life processes. The *Laws of Thermodynamics* incorporated the physical aspect of energy dynamics. According to Martin (1992), themes link together the "big ideas" so that we can see connections among ideas in science. When we understand ideas in science we can describe their relationship to other ideas. It is possible to find relationships among batteries, photosynthesis, and respiration.

The decision to change and expand the 'energy' unit previously taught as photosynthesis, respiration, and energy flow through an ecosystem, came after I realized how superfluous details were when students did not see any connections between the concepts. Energy is a powerful integrating theme among widely different areas of science. For example, batteries can be "charged" with energy which is available for lighting a bulb or turning a motor. So too, in plants, the charging process involves conversion of energy in some form into potential energy. So plants and batteries are similar in that they both store energy.

Focussing on the"big idea" of energy allowed me to teach concepts in depth and with understanding which could be applied to new situations or problems. Dealing with fewer details lead to deeper understanding as evidenced by the data gathered from the assessment strategies.

Children become familiar with the neighborhood of science in the same ways that children become familiar with their own neighborhoods-by asking questions. I presented many ideas which encouraged students to ask questions and to invent answers to the questions they made up. In Kathleen Roth's paper (1991) she quotes Dr. Rutherford as saying, "students need to learn that...what you learn is worth learning, it can be fun, it can be helpful, it will enrich your life, and you ought to be doing it most of your life". She also suggests students need many opportunities to "do" science, to manipulate objects, to ask questions, and to make up stories to explain their own observations. Ms. Roth states, "to teach children how to use a compass to explore the neighborhood of science in meaningful ways, teachers must help students learn how to change their stories about their experiences so that they see science as a process of sense-making and a process of creating increasingly satisfying explanations of the natural world." I tried to accomplish these things with the activities and laboratories included in this unit.

Since I did not find the perfect set of activities to challenge students to rethink their naive ideas about energy, I captured the students interest with a variety of materials. Writing assignments were used as a tool to get students to share, try out, examine, contrast and revise ideas about energy. In the past, I used writing assignments to hold students accountable for completion of work and to enable me to grade them "objectively". During this unit, I used student writing to reveal student thinking and to guide my planning and teaching. I also used clinical interviews for the first time in this unit to illicit information regarding energy usage in biological systems from three students with varying ability.

In sequence, the energy unit followed the study of basic biochemistry, the study of cell structure, function, and reproduction, the study of Mendelian and human genetics and heredity. It preceded the study of evolution, the study of population dynamics, the study of ecosystems, and the study of diversity in living things.

Literature Review of the Pedagogic Problem of Teaching Energy

Across the field of research studies on pupil's ideas about energy, several recurring conceptualizations of energy have emerged. According to Driver, et. al., 1994, energy is seen as,

-associated only with animate objects;

-a casual agent stored in certain objects;

-linked with force and movement;

-fuel;

-a fluid, an ingredient or a product.

Furthermore, Hapkiewicz (1992) defined several misconceptions students have about energy. These include; 1) that energy is truly lost in many energy transformations, 2) there is no relationship between matter and energy, 3) if energy is conserved, why are we running out of it?, 4) energy can be changed completely from one form to another(no energy losses), 5) things "use up " energy, 6) energy is confined to some particular origin, such as what we get from food or what the electric company sells, 7) an object at rest has no energy, 8) the only type of potential energy is gravitational, 9) energy is a "thing". (This is a fuzzy notion probably because of the way we talk about newton-meters or joules. It is difficult to imagine an "amount of an abstraction") and, 10) the terms "energy" and "force" are interchangeable.

Solomon (1983) asked children to write 3 or 4 sentences showing how they would use the word 'energy'. Human activities, health, food, and fuels all figured prominently in pupils' responses. Solomon discovered four themes among the responses. Two of these were:

1. vitalism, in which energy is thought to be needed for life. ("When we run out of energy we need medicine and vitamins' and "Exercise is good for you, it builds up your energy)

2. activity, in which we are thought to need energy to move 'When we run

out of energy we need food and rest'. 'Exercises use-up energy, then you become tired.'

By the age of 11 most children have a fairly correct view of anatomy and the overall function of systems. Gellert (1962) found older students view some food as being turned into energy and children under 9 think that the food vanishes completely in the process. "Goodness" is extracted somehow. School pupils aged 13-14, do not grasp or are unaware of, the meaning of the word "food" as a material that serves as a substance for respiration. Simpson (1983) found a common misconception that digestion is the process which releases usable energy from food. It appears this misconception arises from students linking two acceptable ideas ('energy is obtained from food' and 'digestion is the breakdown of food').

Gayford (1986) reports that 17- and 18-year old biology students considered that energy flows (or is transported) from place to place in biological systems and that it can be stored like a material. They thought in terms of energy 'formed' or 'used' in biological processes rather than in terms of energy conversions. Of Gayford's sample, 79% did not understand that biological processes such as respiration involve energy conversions. They thought that respiration forms energy which is used in synthesis reactions. Children tend to believe that energy is used up by living things in general and that plants use up energy in growing. This includes the notion that plants make direct use of solar energy for vital processes and that plants convert energy from the sun directly into matter. Scientists' ideas contrast with this conception because plants use energy from the sun to convert carbon dioxide and water into sugars. Students appear to think that energy is created or destroyed in different life processes (Gayford,1986, Mintzes,1984, Smith & Anderson,1984).

Roth and Anderson (1985) found many children expressing the idea that plants make food for the benefit of animals and people rather than for the plants themselves. Children did not appear to recognize that photosynthesis is the process by which energy from the environment becomes available to plants and then to animals.

Children appear to consider chlorophyll as a food substance, a protection, a storage product, a vital substance like blood, or something that makes plants strong (Barker,1985). The role of chlorophyll in absorbing light energy was seldom appreciated by students, even after teaching. Only 29% of 12- to 13- year olds and 46% of 14- to 16- year olds in Simpson and Arnold's study understood chlorophyll as a converter of light energy to chemical energy (1982). Most of the students in Simpson's study (1983) did not understand energy transfers in living things; they believed that plants get the energy for all their processes directly from the sun and light was considered to be made of molecules.

Barker (1985) found most children use the words 'heat' and 'light' interchangeably in the context of photosynthesis. Nearly 80% of a sample of 13 year-olds thought that plants use heat from the sun as an energy source for photosynthesis. Most considered that the sun is one among many sources of energy for plants, others being soil, minerals, air and water.

Having learned that plants take in carbon dioxide, water, and minerals, pupils tend to regard these as the food of plants and when food is associated with energy, these inorganic substances are assumed to contain and supply energy.

Brumby (1982) found the integration of ideas about feeding and energy into an ecological perspective is not evident in the thinking of many students. Only half of a sample of undergraduate biology students, explained the phrases, 'life depends on green plants' and 'the web of life', in terms of food chains. A minority of these mentioned harnessing solar energy or photosynthesis as the reason why green plants are crucial in the food chain. Few students appear to relate their ideas about feeding and energy to a framework of ideas about interactions of organisms.

Several studies have found that most students interpret food web problems in a limited way, focusing on isolated food chains (Webb & Boltt, 1990, Griffiths & Grant, 1985). Little evidence exists that students reason about interdependence or energy flow in an ecosystem.

Review of the Literature That Supports the Instructional Approach to Teaching Energy

AAAS Project 2061 (1991) calls for scientific literacy for all Americans emphasizing the notion that all have a capacity for scientific ways of thinking and using scientific knowledge and ways of thinking for individual and social purposes. The Michigan Essential Goals and Objectives, K-12 (1991) emphasizes that students should 1) use scientific knowledge to describe, explain, predict, and design real-world systems or phenomena, 2) construct new scientific knowledge, through asking appropriate questions, developing solutions to problems, interpreting sources of information, reconstructing previously learned knowledge, 3) reflect on scientific knowledge, including justifying and testing beliefs with evidence and logic, criticizing arguments, describing limits to knowledge, making connections among ideas, taking a historical and cultural perspective on the development of knowledge, and describing interactions among science, technology and society.

In many cases there are significant differences between children's notions and "school" science. They use these naive theories to explain real world events before they have had any science instruction. The students' naive theories affect what they perceive to be happening in classroom demonstrations or laboratory experiments, and they continue to attach their naive meanings to technical terms. Children's ideas about science are shaped by personal experience with phenomena. Driver, et. al. (1994) state, "investigations have indicated that such ideas are to be seen as more than simply pieces of misinformation; children have ways of constructing events and phenomena which differ substantially from the scientific view." Studies also indicate that these notions may persist into adulthood despite formal teaching.

Once the teacher has identified the nature of any differences between pupil's thinking and the science viewpoint, then it becomes easier to plan activities which will support intended learning. The skillful teacher picks the teaching method to suit the teaching-learning situation. When one plans carefully, one is forced to become master of the material and the methods of teaching it.

Teaching is helping pupils to learn. In the final analyses the test of one's success as a teacher is how well the pupils have learned. Unfortunately, or perhaps fortunately, there is no one best method of teaching that will always generate a high degree of pupil learning. Rather, there are any number of strategies, tactics and techniques that may or may not be effective in a particular situation. The most effective teachers are those who can vary their styles, or whose styles are so flexible that they encompass a great number of strategies and tactics, and are therefore readily adaptable to the different sorts of teaching-learning situations that may develop.

There is not any one lesson plan form or unit plan form that will ensure that you will reach your class. The form of the plan is insignificant; it is the substance of the lesson, unit, or course plans by which you will succeed or fail in reaching your objectives. Planning is absolutely essential for effective teaching in that it points the instruction and subject matter in the course, unit, or lesson toward the learning.

In recent years, as in earlier ones of the century, many theorists and practitioners have attempted to make what goes on in the classroom more consonant with the reality of the world outside the classroom. They urge educators to give greater recognition to the various skills needed to function in society as human being, worker, citizen, consumer, parent; to develop a more sophisticated awareness of the uses of knowledge; and to become concerned not only with knowing about but also in knowing how. Planning is essential to accomplish this goal.

The notion that pupil learning is more meaningful, more thorough, and therefore more usable when pupils seek out and discover knowledge, has been held by educational theorists for centuries. If teaching will give pupils opportunities to draw conclusions from data that are provided or that they seek out for themselves, the pupils will benefit. Whether an individual's ideas are affirmed and shared by others in classroom exchanges has a part to play in shaping the knowledge construction process also.

In the early 1980's findings in cognitive science suggested new approaches to teaching in science and mathematics. The fundamental view of the learner that emerged was as follows: First, learners construct understanding. They do not simply mirror what they are told or what they read. Student naive theories are inevitable because learners construct meaning even in the absence of complete information. Second, to understand something is to know relationships and third, all learning depends on prior knowledge (Resnick, 1983). To learn something new you have to start with the cognitive structures and strategies that you already have (Michaels & O'Connor, 1990).

Constructivist research emphasizes that students construct knowledge in the sense that they interpret new experiences in the context of prior knowledge, experiences, episodes, and images. The constructivist model requires that teachers facilitate the learning process by 1) providing age appropriate materials, tools, and resources, 2) initiating interest (often with a discrepant event), 3) asking directed questions, 4) providing and encouraging a collaborative atmosphere, 5) encouraging student inquiry and exploration, 6) suggesting familiar and meaningful contexts for concepts, 7) providing time for reflecting, 8) encouraging verbal and written communication of ideas, and 9) assessing by student understanding (Yager, 1991).

Efforts to translate constructivist research into classroom practice is evident in the use of instructional models. *New Directions Teaching Materials* (1992) were created to help teachers develop scientific literacy and conceptual understanding for all students. One of the important goals of these materials is to connect students' developing scientific ideas with the ideas they already use to make sense of the world. I incorporated information from the *New Direction's "Food, Energy and Growth"* unit into my new energy unit.

Novak and Gowin (1984) state that we as teachers need to help students "learn how to learn". They introduced concept maps to convey understanding of a learning task and to relate what is known to the new thing being learned. Concept maps are structured hierarchically and the relationships between concepts are indicated by "linking" words. Two or more concepts linked together form a proposition. These propositions represent meaningful relationships between concepts. Concept maps often point out relationships between concepts or between concepts and specific examples that we assume students are making on their own, but that may require more direct teaching. This assessment of understanding provides teachers and students with an additional tool for nurturing understanding.

My pedagogic techniques, used prior to this unit, required students to learn a large amount of information, interpret that information, and use that information to solve scientific problems, all in a short period of time. I moved the students from one topic to the next with no explanation of the connections between those topics. Learning, especially when it involves abstract concepts such as energy, is a complex process. For most students it takes time to really learn something. Students required to learn too much material in too little time will not retain that knowledge to use it in their subsequent work in science. It requires activity, discussion, and establishing relationships among various components for students to learn scientific concepts.

In the words of Anderson and Roth (1989), "understanding consists of the ability to use scientific knowledge to describe, explain, predict, and control the world around us". Students should develop knowledge that is conceptually coherent and integrated with their personal knowledge of the world, as well as being scientifically accurate (Anderson and Roth, ibid). Students need time to develop the skills to learn how to learn; to use their knowledge to control their world.

A human being's experience always includes and is strongly influenced by our social interaction with other humans. We can only know what we have constructed ourselves, but such learning always takes place in a social context. Furthermore, social transactions play a critical role in the shaping of cognition. According to Richmond and Striley (1995), "language is a mediator of the cultural world and it becomes the essential partner of thought." Therefore, the unit incorporated group work and cooperative learning.

We use language to cope with our environment, to help us make sense of our world, and to communicate how we can use the meaning formulated. According to Anderson (1995), two problems that separate the successful from the unsuccessful student is a problem of language, the second is a problem of motivation or engagement.

Paul Gee (1991) defines a "discourse" as: "a socially acceptable association among ways of using language, of thinking, and of acting that can be used to identify oneself as a member of a socially meaningful group or social network." He contends we should think of a discourse as an "identity kit". This kit comes complete with the appropriate costume and instructions on how to act and talk so as to take on a role others will recognize. People come by a discourse through "acquisition" and/or "learning". All humans receive one discourse free through acquisition. This is our socio-culturally determined way of using our native language in communication with family and friends who share similar experiences. Gee refers to this as the "oral mode". For example, lower socio-economic black children use English to make sense of their experience differently than do middle-class children. They have different primary discourses using language, behavior, values and beliefs to give different shape to their experiences.

Gee proposes that literacy can be understood as the control of discourses that go beyond whatever discourse we first acquired within our family. Reading and writing may be a part of the picture, but only a part. Becoming literate in any particular domain involves learning a specific discourse-particular ways of thinking, acting and valuing. Socialization of an individual into knowledge learning of the language, and activities of the neighborhood of science, becoming a "member of the club", is very important for educators to accomplish. It is important to create a social context-a learning community of scientific inquiry-that will enable the "eliciting", "challenging", and "contrasting" of ideas; to support students in developing a connected, useful, and reflective understanding of science. Students home-based ways of thinking and using language should be extended and transformed by the teacher (Michaels & O' Connor, 1990).

Students rely on implicit schemas or frames: these guide interpretation, explanation, and problem solving, and ultimately enable them to comprehend or construct new knowledge in interaction with print. Reading and writing tasks require complex interpretive work and the development of new mental structures to integrate information, rather than rote memorization or routine manipulation of facts. My students were taught to memorize the facts and regurgitate that information on quizzes and tests, prior to this unit. I paid no attention to the differences in thinking or to the differences in discourses.

Teachers bring their prior conceptions to learning situations not only in terms of their subject knowledge but also their views of teaching and learning. These can influence their way of interacting in classrooms. Teachers must spend time developing and practicing new and somewhat unfamiliar pedagogical techniques. Teachers need to help students see the relevance of scientific theory in their lives. Science must be seen as a way of life. We must find what intellectual tools our scientific communities have produced that are useful to all people whether they are scientists or not (Anderson, 1995). The key challenge for schools is to introduce and culture students into school-based discourses, without denigrating their culturally specific values and ways of using language. The implications for educators is to focus on issues of cultural and social class differences in reasoning. We must help students use their different discourse assumptions and styles to become scientifically literate.

It is my intention in this unit to take the time necessary to help students to use what they know together with the discourse they used to learn that information to correct misconceptions. Writing assignments and discussions are going to be utilized to expose students to school based scientific knowledge. Students will be taught to use scientific knowledge and ways of thinking for individual and social purposes.

CHAPTER 2

CHAPTER 2

IMPLEMENTATION OF THE UNIT

Demographics of the Classrooms

This unit was implemented at an urban high school with a student population of approximately 1500 economically and ethnically diverse students. American Indians make up two percent (2%) of the population, Asians, six percent (6%), African Americans, twenty percent (20%), Hispanics, eighteen percent (18%), and Caucasians, fifty-four percent (54%). Sixty-eight percent (68%) of the students attend class at least eighty-five percent (85%) of the time. Well over half of the student population are eligible for the free or reduced lunch program.

The unit was introduced into three introductory biology classes with a total of 68 students. The classes predominantly were mixed freshmen and sophomores. None of the students had studied biology previously, although most had been exposed to the life and physical sciences in middle school. The population of these classes reflected the ethnic make-up of the school. The classes met for five, fifty-five minute periods per week for four 9-week marking periods.

Academically, the students gradepoints varied from below a 1.0 to a 4.0

on a 4.0 scale. Approximately, 10 %of the students carried 3.5-4.0, 15% carried 3.0-3.4, 30% carried 2.9-2.0, 30% carried 1.9-1.0, 15% carried under 1.0, prior to taking this class.

Pre-Unit Assessment

A behavioristic model dominated my pedagogy, as most American pedagogy has been dominated in the past. In the behavioristic approach to teaching and learning, the teacher's task consists of providing a set of stimuli and reinforcements that are likely to get students to emit an appropriate response. This instructor believes that the behavioristic approach is not successful in teaching understanding, synthesis and application, and the ability to use information in new situations. I believe learning is the product of self-organization and reorganization.

Traditionally, my biology curriculum included units on the scientific method, basic biochemistry, cells, genetics and heredity, evolution, plants, animals, microorganisms, human anatomy and physiology, and ecology. Each of these units included from 4 to 10 chapters in the textbook. Each unit took two weeks or less to complete. Very few laboratories were conducted. Each unit may have included one laboratory while in some units only dry labs were conducted. Furthermore, a whole lot of information was pressed into each unit. There was no connections in these units either. Using the thematic approach to teaching science gave me more time to connect scientific ideas.

A focus on themes is a fundamental part of a conceptual approach to biology. When I began teaching my unit, my district adopted "Biology: Principles & Explorations" by Holt, Rinehart and Winston. This was an opportunistic time for me to restructure the curriculum and align the curriculum with a thematic approach to teaching biological principles (laying the foundation for the study of individual organisms) and biological explorations (studying individual organisms). Themes are the relationships between ideas and it was the energy theme I utilized.

We, as educators, need to recognize that learning is a complex process, and that individual students learn differently. The learning environment I produced was varied to include different learning styles that students brought to my class. In providing more opportunities to investigate ideas, the students were learning to connect what goes on in class with other aspects of their lives. The investigations encouraged students to look for other examples and applications of concepts. Several students commented that they liked to work in the lab rather than work from the book, and they proved this by showing enthusiasm for each lab I planned. Traditionally, on lab days the students used to be upset and complain. Laboratories usually meant a formal lab report which the students did not like to do.

Before teaching the unit, I conducted clinical interviews with three students with different academic abilities. A clinical interview is a tool to assess how students think about the topic they study. This pre-assessment knowledge enabled me to adjust the curriculum to the needs of the students. A Synopsis of the results, illustrating the misconceptions, can be found in Figure 1 on page 30.

Detailed transcripts from the interviews can be found in Appendix B .

Description of the Clinical Interviews

My central question for the unit was, "How does the energy from the sun become the energy for life?" The model answer I expected was: "Energy enters an ecosystem as plants absorb the sun's energy for photosynthesis. This energy, in the form of radiant solar energy from the sun, is converted into potential chemical energy by photosynthesis. Energy flows through an ecosystem as one organism eats another organism. The chemical energy stored in food is then converted into mechanical and biological energy by the organisms that eat the food. Energy flows out of an ecosystem, at each trophic level, as organisms release metabolically generated heat to the surroundings.

To determine student understanding of this concept, I chose three students of varying academic ability. The student's school transcripts were utilized to determine their academic standing. I found Mary to be an "A" student, Justin, a "B/C" student, and Rhonda, a "D" student. I began the interviews by emphasizing to the students that this was not a test, and that right or wrong answers were acceptable. I wanted to know what they knew about energy. I used a tape recorder to record the interviews. I explained to the students how and why I would use the tape recordings, and I asked the student's permission to use the data in my research. The students were assured they would remain anonymous; I would only use first names.

First, I questioned the students on forms of energy. "What kinds of energy do you know about? Can you name them?" I probed for student knowledge on the general topic energy before I questioned them about specific forms.

In the second part of the interviews, I asked the students to tell me how people get their energy: "What do we use energy for? Do we get energy from food?" Then I asked, "How do plants get their energy? When we eat plants do we get the plant's energy or do we make our own?"

Next, I showed the students a stack of cards with various organisms on them (See Appendix B). I instructed the students to assume all of the organisms live together in a biological community and to place them in an order to show how energy flows through that community. Put sunlight and heat where they belong and try to include all of the organisms. Then explain why you arranged the cards as you did. I probed the students further on their ideas about heat and sunlight as forms of energy and how soil bacteria and mushrooms played a role in their model.

I concluded the interviews by asking the students to tell me all they knew about energy. I asked the students if they had questions about energy they would like to ask me.

What Happened During the Interviews

The first student I interviewed was Mary, the "A" student. Mary is a high-functioning, academically advanced ninth grader. She was very willing to answer the questions and she understood very well that I did not expect the right answer. Justin, the "B/C" student, is a slightly above-average ninth grader who also knew I did not expect the right answer. Both of these students had been participants in clinical interviews previously with other instructors. I did not know this prior to the interviews. Rhonda, the "D" student, is a low-functioning, below average, tenth grader. She had a hard time understanding why I did not expect her to give the right answer. As a result, she responded to several of the questions with, "I don't know." I had to probe her frequently to respond. Her answers were short and lacked detail.

The interviews began with asking the students to name all of the forms of energy they knew. The students gave me answers such as food, kinetic energy, hydroelectricity, nuclear energy, hype behavior, and light bulbs. The students were defining energy in a misconceived sense. Mary and Rhonda both thought of energy as vitalism. Mary added that we get energy from the amount of sleep we get and form nutrients. Justin said we get energy from the food we eat which comes indirectly from the sun, but he added that metabolism separates and burns food into energy. The students thought that humans can make their own energy.

I then asked the students to tell me how plants get their energy. Mary mentioned the term photosynthesis but, she could not explain the process. She and Justin thought that plants get their energy from the sun, water, air, soil, and soil nutrients. Rhonda thought "they got their energy through the roots from the soil." The students considered energy as food. Rhonda thought plants, like animals, consume food to get their energy.

I gave the students a task to do next. The task involved placing cards, containing organisms that might live together in a biological community, in an order to show the flow of energy through that community. The results of the activity were very interesting especially in the response of Rhonda, who did not include the plants in her community. Her sequence, in one case, went soil>bacteria>earthworm>Purple Martin. She had no conception that autotrophs secure the energy required by the entire ecosystem and that this energy is supplied by the sun. The other two students were cognizant of food chains and webs. Both Justin and Mary knew that energy flowed from the producers to the consumers. However, Justin thought that energy was "recycled" similar to nutrients.

I asked the students to include sunlight and heat in their models. All three students placed sunlight first in the sequence. Mary and Justin knew that plants needed the sun's energy to photosynthesize. Rhonda, on the other had, did not even include the plants. One of her sequences showed the sunlight giving energy to the hawk

Explaining heat was more difficult for all of the students. Mary said everything has heat in it and gives it off, so heat should be near an organism. Justin said all animals need heat to survive or their bodies would freeze. He also said living organisms get the heat they need from sunlight. After some probing by this instructor, he said that animals produce heat because they burn energy, and the heat goes off their bodies through "sweating" and into the air. Rhonda had no conception of heat energy. She said sunlight gives warmth and that this was heat.

When I asked the students the question,"What is energy used for?", they all answered it was needed to live and be active. Justin's answer was enlightening. He said, "energy is used during sleep to burn food that is being digested." He also said, "you need energy even to breathe." Mary's answer was likewise enlightening. She said, "energy had 'weak' and 'strong' forms and that we use the 'strong' forms of energy which come from a lot of nutrients from metabolism."

At the end of the interview, I allowed the students to tell me anything else they knew about energy. Rhonda said, "nothing." Mary said, "she had heard the term used a lot but never studied it in detail." She knew food chains and food webs involved the "use or energy" but, she was not sure how everything was "put together." Justin said, "We use energy everyday. We can't live without it. It gives us the strength to wake up."

Finally, I asked the students if they had any questions to ask me. Mary, as well as Rhonda said, "no." Justin asked me a question about how energy is stored in solar panels. He appeared to be interested in the practical application of this concept. I think he needed some concrete evidence of energy usage. I think the students were all relaxed and did an excellent job with this interview. I thanked them and sent them back to the class where my intern teacher from Michigan State University was conducting the lesson.

ISSUE	MARY	JUSTIN	RHONDA
I. Kinds of Energy	kinetic, hyper behavior, nuclear, to make a light-bulb work	solar, hydro electric, food	food, light-bulb way of acting
II. Where does energy come from?	from food and amount of sleep, from nutrients	from food, what is eaten, from sun	food
III. How do humans get energy?	from sleep, processing nutrients from food, make our own energy	metabolism separates and turns food into energy	rest, eating the right foods, get energy from water
IV. How do plants get energy?	photosynthesis from sun, water, air	from sun and soil, soil nutrients, and sun make grass	from soil through roots, they eat like humans
V. How does energy flow through a community?	from sun> producers> consumers	like recycling, sun>grass> animals> humans>grass	from sun> hawk> mouse> heat
VI. How do eco-systems involve sunlight and heat?	sunlight at beginning of food chain, everything has heat in it and gives it off	plants need sunlight-all animals need heat to survive or bodies would freeze, get heat from sun and burning energy, heat to air	sunlight gives warmth this is also heat
VII. What is energy used for?	every movement and everything we do, forms of energy used from metabolism	can't live without it, use it everyday, gives us strength to wake up,	everything, movement we need it

Figue 1 - Pre-Unit Synopsis of Focus Students' Understanding

Evaluation of Clinical Interviews As An Assessment Strategy

Overall, I felt the interviews were a huge success even though they took extra time to plan and implement. Knowing the focus student's knowledge of energy, gave me insight to plan for an effective unit which would address the misconceptions the students appeared to have.

Realistically, I would not be able to do clinical interviews before each unit. My intern teacher's presence in the classroom gave me the opportunity and the time to conduct the interviews. I realize it is very difficult to arrange three separate interviews which last about 20-30 minutes each. As a classroom teacher, who is given more to teach and less time to teach it each year, I could not find the time nor "find the energy" to do clinical interviews for every unit taught. My intent is to develop and conduct clinical interviews for all of the units I teach, feasibly completing one per year.

Outline of the Unit

The instructional unit in energy was based on chapters 4, 5, and 16-2, of Biology, Principles & Explorations, by Holt, Rinehart, and Winston, Inc., 1996. Previously, I took about 2 1/2 weeks to teach the information contained in these chapters. In general, I spent approximately one week on each chapter so that we could reach the end of the text by the end of the school year. In this unit, minimal textbook reading was supplemented by eight laboratory exercises, several activities and dry laboratories including a model building activity, lecture notes, overlays, laser disc images, and video tapes. I used a thematic approach to teach less information to insure students had time to construct their own knowledge. The unit took 29 days to complete (See Appendix A).

To make instruction fruitful, I utilized the data gathered from clinical interviews conducted before teaching the unit (See appendix B). During the unit, a variety of pedagogic techniques were utilized to address the different learning styles of the students. Using overhead transparencies, laser disc images, video tape presentations, and demonstrations, visual learners were engaged. Auditory learners were engaged through lecture, class discussion, and cooperative group work. Tactile, or kinesthetic learners were engaged by the use of a variety of "hands-on" activities.

The central question I developed for the unit, "How does energy from the sun become energy for life?", was the problem I established at the beginning of the unit. I hoped that students would see that although they did have important knowledge and beliefs about this problem, they could not solve this problem without additional knowledge. Students must learn to use the ideas presented to them to describe, explain, and predict or control the world around them, individually or in groups.

A gradual transition from mechanical to biological energy studies allowed students to gain an appreciation of how the principles of science can be used in both living and non-living systems. The purpose of the 8 laboratory exercises and the other learning involving manipulation of materials or ideas was to provide a learning atmosphere where the students felt comfortable with science and the new pedagogy. A synopsis of the weekly activities can be found in Figure 2 on page 35. I have indicated all new activities with an asterisk.

Energy, a connecting theme to other scientific concepts provides students with a framework and comfort level for studying other scientific concepts. Matter can be discussed before or after the energy unit. I had taught the concepts of matter, atoms and molecules before the energy unit, but I did not teach matter cycling until after the unit. My goal was to help students construct their own knowledge of energy by making connections with their real world lives. Furthermore, I wanted the students to see the connections between the physical and biological sciences and how science is integrated into their lives.

Evaluations of student learning and comfort with scientific ideas, included clinical interviews, student writing, exit evaluations, concept maps, quizzes, cooperative learning group reports, laboratory notebooks, and pre- and post-testing.

Audio-Visual Aids Used

As discussed in the introduction to this unit, the concept of energy is very difficult for high school students to understand. To make the concept as interesting and accessible as possible and to help the students understand the concepts, the unit incorporates use of cartoon overhead transparencies. These overlays are reproduced in Appendix F.

The book, The Way Life Works, by M. Hoagland and B. Dodson is a highly original book that takes you on a guided tour of the many ways all life grows, develops, reproduces itself, and dies. The authors merge science and art. "The visual presentations encourage the reader to make imaginative leaps from the panoramic world around us to the world within the cell and back again" (Hoagland and Dodson, 1995).

The laser disc, "Holt Biology Videodiscs to Accompany Biology: Principles and Explorations", provided images and pictures to enhance the lectures, discussions, and laboratories. I used several images from the laser disc when the unit addressed photosynthesis, respiration, and fermentation, particularly.

Student mastery of the concepts of photosynthesis and respiration and their roles in the flow of energy in an ecosystem was aided through animated videos. I showed the video tapes, "Energy Flow At the Cellular Level" (Films For The Humanities & Sciences), and "Cellular Respiration: Energy For Life" (Human Relations Media) which went into great detail on these processes. These details, which were not germane to the unit, confused the students. Therefore, the next time I use these tapes, I will edit the content and show only segments of each which are relevant to the "Big Ideas" of photosynthesis and respiration.

In the next section, I discuss the laboratories and activities in detail, including the new pedagogy, and how the new methods affected student learning.

* **<u>WEEK ONE - THERMODYNAMICS</u>**
  Pretest *
  Laws of Thermodynamics *
  Advertising Campaign *

* **<u>WEEK TWO - BIOENERGETICS</u>**
  Bioenergetics Introduced
  Overheads from, <u>The Way Life Works</u> *
  Lab 1-"Thermal Energy From Foods" *
  Video-"Energy Flow At The Cellular Level" *
  Lab 2-"Food Tests" *

* **<u>WEEK THREE - LIGHT/PHOTOSYNTHESIS</u>**
  Concept Map of Photosynthesis and Respiration Connections *
  Discussion of the Electromagnetic Spectrum and Light
  Lab 3-"The Separation of Plant Pigments By Paper Chromatography" *

* **<u>WEEK FOUR - PHOTOSYNTHESIS/RESPIRATION</u>**
  Lab 4-"Light and Chlorophyll Laboratory" *
  Discussion of How Heterotrophs Get Energy From Autotrophs
  Video-"Cellular Respiration: Energy for Life" *
  Marshmallow Models of Photosynthesis and Respiration *
  Lab 5-"Respiration Investigation" *

* **<u>WEEK FIVE - FERMENTATION/FOOD TECHNOLOGY</u>**
  Lab 6-"Variations in Carbon Dioxide Production: Using Instant Blend Dry Yeast *
  Discussion of Energy Flow Through An Ecosystem Including Use of Food Chains, Food Webs, and Energy Pyramids
  Lab 7-"Yeast Fermentation" *
  Lab 8-"Bacteriology of Yogurt" *

* **<u>WEEK SIX - ECOSYSTEMS</u>**
  Build Ecocolumns *
  Essay on the Journey of A Photon Of Light As It Passes Through An Ecosystem *
  Post Test
  Exit Polls *

Figure 2 - Synopsis of Agenda

Laboratory Exercises, Demonstrations & Other Activities

The demonstrations, comparing the different kinds of energy in mechanical systems, started the students asking questions about everyday energy phenomena. Journal entries (Appendix G), and the Energy Transformation worksheet (Appendix H), helped to evaluate student comprehension. A discussion of the *Laws of Thermodynamics* which followed preceded the cooperative activity which required the students to use the everyday phenomena they were aware of to explain two scientific laws. In this way, the students were constructing new knowledge out of pre-existing notions about energy in closed systems like the Earth. Some of the posters were hung outside of the room in the hall for public viewing. Students were proud to see their work displayed. A quiz, (See Appendix I), showed that students comprehended the laws of thermodynamics, but still failed to connect these laws to biological systems. When asked to make posters of the laws, students commonly used the demonstrations to explain the second law. Fallen pop cans supposedly are more organized when stacked, but less stable. When entropy (disorder) increases by knocking the cans down, the cans become more stable. Students were unable to relate this idea to energy in a closed system like an ecosystem. My goal was to help students realize this relationship by the end of the unit.

In the first laboratory, "Thermal Energy From Foods", (Appendix C) the objective was to show students that food does, in fact, contain potential energy that is transferred into thermal energy to heat the water. The energy contained in foods is measured in kilocalories or as food labels display "calories". After the lab, the students were able to see that the calories some of them count, and the calories they see on package labels, are the energy units that food contains. The students brought in and analyzed the energy content of foods by reading the labels. We discussed that burning the food which contains fuel for the body is very similar to burning gasoline in an automobile. I showed the portion of the video "Cellular Respiration: Energy for Life" which compared the human body's use of energy with an automobile's use of energy. The students wrote the similarities and differences in their journals. (Please refer to Appendix G for a complete list of journal entries.) This lab was quite successful in showing that food does contain thermal energy. The students observed and calculated the energy released by the burning of food which did increase the temperature of the water. The mathematical calculations were difficult for many students to complete. It became necessary to review examples before they calculated their results.

The second lab, "Food Tests", (Appendix C) was designed to build on the knowledge gained from Laboratory 1 concerning energy in food. This exercise allowed the students to test known foods and foods they brought from home for the presence of certain energy containing nutrients such as sugars, starches, proteins, and fats. Prior to the tests, a thorough discussion of the energy rich molecules found in food was conducted. This laboratory, together with Laboratory 1, provided the students with a conceptual model of energy found in food items as part of the everyday world rather than a concept which cannot be seen but only described in an equation. Evaluation of student learning took place through laboratory journal entries and a formal laboratory report for the second laboratory.

These lab reports showed that students understood what the nature of these indicators and tests were, and that these indicator tests could be used to discover what molecules are present in food. We discussed that the energy we get from food is stored in the bonds of these molecules. At this point, I used the information in the book by Hoagland and Dodson to show how energy is stored and transferred in atoms and molecules.

The second cooperative group activity incorporated the students' prior knowledge about photosynthesis and respiration. This exercise was intended to evaluate student understanding of the energy- producing and energy-consuming processes in both plants and animals. The exercise used pictures provided to the students, (Appendix D), 11" x 17" construction paper, and glue. In each group, all students had to agree on how to place the pictures in a concept map design so that the map made sense. This involved some discussion and consensus on the part of each group. No two maps were identical, which was helpful when the presentations were made to the class. A discussion followed after the presentations addressing which group had the "correct" map. Of course no one map was the only right answer.

Students discovered that concepts in science can be seen and comprehended by neighbors in the same community of science differently and still be acceptable. However, students also found out that scientists have convincing scientific jargon which does explain natural phenomena. After presenting the maps, we compared them with the textbook ideas to see the similarities and the differences.

It is evident from the maps that students know that plants need carbon dioxide, water, and sunlight. It was less evident from the maps that students knew that sugar and oxygen were the reactants in respiration. Students had various ideas as to where mushrooms belonged in the map as decomposers. Chlorophyll was a term they were familiar with, but they did not know that mushrooms do not have it and cannot photosynthesize. Mushrooms were considered to be plants by many students. Most of the students did know that bacteria were decomposers because we had discussed this. However, we did not discuss mushrooms as decomposers.

The students built models of the processes of photosynthesis and respiration using colored marshmallows and toothpicks (See Appendix J), to construct their knowledge of atoms and molecules. After evaluating students' perceptions about the "big ideas" photosynthesis and respiration, the objective of Laboratory Three, "The Separation of Plant Pigment by Paper Chromatography", and Laboratory Four, "Light and Chlorophyll", (Appendix C), was to illustrate the role light energy has in photosynthesis. It was an objective of the unit to help students realize how plants capture and store the energy from the sun analogous to solar cells' ability to capture and store the energy from the sun. Lab Three showed the hidden pigments plants possess to facilitate energy absorption. Prior to this lab, the lecture on light and the demonstration of the visible light spectrum revisited the characteristics of light, as the subject of light is taught extensively in eighth grade.

Laboratory Four, "Light and Chlorophyll Laboratory", was designed to show the students what colors of visible light are necessary for chlorophyll to develop and thus photosynthesis to occur in bean seedlings. This laboratory, in connection with Laboratory Three introduced the concept that radiant energy (sunlight) is absorbed by autotrophs and it is transferred into chemical energy used for growth. It was exciting for the students to see the bean seedlings emerge from the seed coat and actually grow without adding anything to the jar except sunlight. This may have addressed any questions about what plants need to survive.

Laboratory Four initiated student questions about plant growth and development. Plant morphology, etc., is discussed in detail later in the year when diversity of living organisms is addressed. However, a mini lesson on plants was necessary for the unit to proceed and for the students to conceptualize radiant energy being used for growth and development of plant tissue. This laboratory took seven to ten days to complete. Unfortunately, some of the students' data were inconclusive due to the fact that several seeds did not germinate. I assume this happened because the seeds were old or there was not enough moisture in the jar. Whatever the reason, some students were disappointed with their results. However, no activity or experiment should be considered a waste of time and discarded without discussion. This was an excellent opportunity to discuss how some laboratory exercises do not work out as planned. The inconclusive results gave the students an opportunity to analyze and synthesize which are higher order thinking skills. (Bloom, 1956)

In the next lesson, I used a demonstration. I attempted to show that the "energy" of molecules is stored in the bonds, and I wanted to demonstrate that electrons possess energy as a function of their distance from the nucleus of the atom. A rubber band represented the bond or distance between the electron and the nucleus of the atom. A flaccid rubber band or an electron close to the nucleus has little energy. However, if you stretch the rubber band, boost the electron to a higher energy level (further away from the nucleus), the energy of the bond is greater. Just let the rubber band hit something in both cases for effect, preferably not yourself or a student, to emphasize this concept. I wanted the students to see the energy absorbed by the molecules of chlorophyll gained energy by being boosted by the photons of light to a higher energy level. I told the boosting electrons metaphor so the students could visualize the concept. I could tell students were comfortable with the story of the bowlers found in Appendix K . They could identify that bowling balls falling from higher levels have more energy and thus can do more damage than those falling from a lower level. ATP was discussed only in that it is the energy currency of the cell; the energy being held in the phosphate bonds of the molecule.

Cartoons are a fun way of enabling students to show integration or application of scientific knowledge. The overlay by Calvin and Hobbes (1990) in appendix F , was adopted from material I acquired in the Cell and Molecular

Biology course at Michigan State University in the summer of 1992, taught by Dr. Clarence Suelter and Dr. Merle Heidemann. This overlay was very effective in showing how electrons are transported in the electron transport chain, and how much energy they possess at each step. The story of photosynthesis, found in Appendix L, helped especially auditory learners to conceptualize what happens in each step of photosynthesis without going into detailed facts.

Laboratory Five, "Respiration Investigation", (Appendix C), showed that respiration occurs in plants as well as animals, and how the rate of respiration of seeds can be determined. It is a common misconception of students to believe that only plants photosynthesize and only animals respire. This lab was adopted from the Cell and Molecular Biology Class I attended at Michigan State University, also. The next time I do this lab I may have some students set up the respirometer using seeds and some others using insects or other small creatures. This will further address the aforementioned ideas. After measuring oxygen consumption over time, the students realized that plants do indeed respire. They were able to see a colored bubble of soap move in a glass tube as the seeds consumed oxygen, and they were able to quantify how much oxygen was being consumed.

Fermentation activities concluded the lessons on energy usage in living organisms. The smallest organisms have a need for energy and with this energy they are capable of growth and development, movement, and reproduction, etc. The fermentation Labs made the students aware of how microorganisms function in their environments, and how they use energy.

Laboratory Six, "Variations in Carbon Dioxide Production: Using Instant Blend Dry Yeast", (Appendix C), introduced the students to the fact that yeasts use the energy stored in sugar to grow and reproduce and that they give off carbon dioxide in the process. Laboratory Seven, "Yeast Fermentation" and Laboratory Eight, "Bacteriology of Yogurt", (Appendix C), were especially successful. Two examples of microorganisms, yeasts in Lab Seven and bacteria in Lab Eight, were used in food labs to produce familiar food items. The students were excited to be able to eat their experiments.

One of the last assessment activities was writing a story about, "Your journey as a photon of light who got absorbed by an autotroph and then eaten by one or more heterotrophs." This writing assignment was difficult for several students. It required them to use all the information they had learned about energy and synthesize the pathway it follows in a particular sequence of steps. Some students still possessed naive ideas.

Prior to the last writing assignment, the very last concept discussed was energy in ecosystems. I gave the students notes including definitions of terms as well as an explanation and examples of food chains, webs, and energy pyramids (See Appendix M). The unit utilized a worksheet, (See Appendix N), to assess student understanding of energy in an ecosystem. After a thorough discussion of the energy requirements of an ecosystem, the students had to design an ecocolumn, which is a terrarium made out of two-liter pop bottles (See Appendix O). First, the students were to present their designs to the class to get the class approval. Then, in teams of two, they built their ecocolumns and added biotic and abiotic factors that would sustain the ecosystem. The ecocolumns were the center of much discussion and interest during the months following the completion of the unit. In fact, during the ecology unit, later in the year, we used the columns which were still in the classroom. The writing assignment asked the students to describe the relationships that existed in their ecocolumns. They included that the original source of energy for the closed systems was the sun. Several students talked about the ratio of producers to consumers. Energy transference from the sun to the producers to the consumers was discussed. The writing samples were used again during the unit on ecology which followed later in the year.

New Pedagogical Techniques

"Less is More," jargon for science education in the 1990's, reflects the new understanding and concern for scientific literacy in all Americans. In view of this, I decided to take a major concept and to focus my unit development on teaching strategies which would provide students with opportunities to construct the important ideas of science by providing them with fewer content topics taught in greater depth. It was also my intent to help students see connections among the sciences and between science and other school subjects. Students must engage in activities requiring higher order thinking before they learn basic scientific facts. Students must use scientific knowledge in combination with other kinds of knowledge about the world.

In this unit, I attempted to take "the relativistic conceptual framework where our thought-world incorporates the conversion of energy principle", a very abstract idea, (Elkana, 1974) and make it a framework to build unifying ideas in science. No minor deed, I might add. To accomplish this task, I incorporated the constructivist ideas of learning and teaching into this unit to engage students actively in the construction of new knowledge which would replace their naive knowledge through a more experiential and laboratory-based curriculum. The strategies I utilized were chosen to engage students to actively struggle with ideas rather than simply memorize the facts and "witness the teacher's performance" (Anderson & Roth, 1989).

Writing assignments were used as tools to get students to share, try out, examine, contrast and revise ideas. Writing stimulated students to clarify and articulate their positions and ideas. "It helped elicit ideas, contrast those ideas with those of others, and build onto and change their ideas" (Roth, 1992). Writing assignments did not consist of a collection of "neat assignments" plugged into a science unit, but were connected to the inquiry process. I felt it was important to create a social context-a learning community of scientific inquiry-that would enable the "eliciting, challenging, and contrasting to support students in developing connected, useful, and reflective understandings of science" (Roth, ibid.). Writing experiences were connected as closely as possible to genuine inquiry into what it means to learn, understand and appreciate science.

I tried to establish a learning-centered classroom rather than a work-setting one, as suggested by Roth (1992), with the activities I designed and carried out in the classroom (See Appendix P). To shape the learning-centered classroom, I made use of the 9-patch quilt metaphor articulating Kathy Roth's ideas about the ideal classroom (See appendix Q). I especially liked the part of the metaphor which described the quilters as "the teachers and the students are the quilters who work together to put the patches together patiently over time using consistent tiny stitches." Instead of imparting knowledge and expecting behavioristic learning, I engaged a curriculum geared toward empowering and enabling learners to construct their own knowledge using inquiry, questioning, and collaborating, etc.

In helping the students learn, I became a better learner, also. Preparation of concept maps proved to be a valuable tool in aiding students to acquire self-knowledge of how they best learn. I used these concept maps to learn how the students were learning and then I adjusted the lessons according to what I had learned.

Each day I assessed student mastery of the unit by asking students to tell me or write down one thing they learned that day and/or one thing they were confused about. With these pieces of information I was able to adjust the curriculum to meet the needs of the students. Students responded positively to this avenue of assessment because several had questions or did not understand something yet did not want to ask the questions publicly. Also, I addressed these concerns right away the next day, so students could have questions answered on a daily basis. This was a very effective strategy.

CHAPTER 3

CHAPTER 3

EVALUATION

Pre-Test and Post-Test Results

A test administered to the students before the unit was taught and again at the end of the unit measured student growth in mastery of the concepts presented in the energy unit (See Appendix R). The pre-test consisted of 26 multiple choice question, 19 true/false questions and 12 fill-in-the-blank questions. I attempted to distribute the questions evenly over all of the content areas taught in the unit, for a total possible 57 points.

No advance notice was given to the 68 students, mixed ninth and tenth graders, in three different sections of introductory biology, prior to administration of the pre-test. None of the students had been previously enrolled in a biology course.

I assured the students that the pre-test would not be used to determine their grade, but that they should try their best to answer every question. The students appeared to take the test seriously and completed it in about twenty-five minutes.

The post-test consisted of the same questions used in the pre-test. It was administered 28 days after the pre-test at the end of the energy unit. I added seven additional short answer questions to test the students ability to analyze, synthesize, and evaluate the major conceptual ideas presented in the unit. The students were informed about the post-test in advance. They completed the post-test in about forty-five minutes.

I pooled the data from the three classes to give an overall picture of the increase in knowledge achieved by the 68 students in the study (See Table 1).

	Pretest	Post Test
number of scores (n)	68	68
mean score (x)	14.99	43.26
standard deviation (s)	5.28	8.89
standard deviation ^{2} (s^2)	27.88	79.03
standard error of mean (s_x)	0.64	1.08
standard error of difference (s_{x-y})	1.26	
difference between means (x-y)	28.27	
degrees of freedom (df)	134	
t	22.44	

Table 1 - Pre- and Post Test Pooled Data of All Classes

The mean score on the pre-test was 14.99 which rose amazingly to 43.26 on the post-test. The standard deviation for the pre-test was 5.28, while that on the post-test was 8.89. The standard error of the mean for the pre-test was 0.64 while that on the post-test was 1.08. In comparing the pre- and post-test results, I found the standard error of difference to be 1.26. The t value was 22.44 with 134 degrees of freedom. The probability of these two sets of scores being different merely due to chance was less than 0.1% allowing me to reject the null hypothesis that the students did not show growth on the mean score. It is clear that students had shown growth on the mean score of the test.

The post-test constructed response section (Questions 58-64), allowed me to further assess student comprehension of energy principles. Responses to questions 58 and 59 showed that students were able to explain the relationship between photosynthesis and respiration. About 25% of the students wrote proper equations regarding photosynthesis and respiration and showed with a circular diagram how the atoms are shared and where energy is transferred. They were also capable of explaining their diagrams.

Almost all of the students knew that plants photosynthesize and respire and that animals use the food of the plant to get their energy through respiration. In 33% of the responses, a seed was pictured taking in oxygen and letting out carbon dioxide which was shown being taken up by a plant. The plant then was shown giving off oxygen to an animal that was eating it. The animal, was shown giving off carbon dioxide to the seed. Ninety-five percent of the students understood that sunlight is the ultimate source of energy for plants and animals. Several students wrote what I had hoped for, that plants need energy from the sun in combination with other ingredients to photosynthesize.

Answers to question 60 showed that 62 of the 68 students had learned a basic characteristic of light: the color we see is the color being reflected by the object. Approximately 75% of them knew about the other colors plants display and that chlorophyll has different potentials for absorbing the energy from photons. All of the students knew that a pigment was responsible for energy absorption, though 69% did not name the pigment chlorophyll.

Question number 61 asked students to diagram "energy" relationships among organisms. All of the students showed energy coming from the sun going to the producers, and then to the consumers. Heat was shown coming off the last organism in the chain. Very few students (3%) showed heat energy coming from all organisms. Perhaps this was due to the way food chains and food webs were addressed during the unit. Only 28% of the students knew where mushrooms fit in the diagram. We had not talked about fungus as decomposers prior to the energy unit. Most of the students thought that mushrooms were producers. Eighty-two percent knew where soil bacteria fit in as decomposers. The students were familiar with bacteria because we had discussed them in the unit. Eighty-six percent of the students drew food webs and 25% drew food chains. Of the 25%, 20% put more than one organism at each level of their diagrams similar to the concept maps they had produced. Eighty-seven percent of the students used arrows to show the direction of energy flow with 78% of them pointing the arrow in the correct direction of energy consumption. Those not using arrows drew lines or put similar organisms together in a group.

Questions number 62 and number 63 asked students about sources of energy for humans and the human food supply. One hundred percent of the students chose at least one food item, 76% chose at least two of the food items and 33% chose all three food items, milk, hamburger, and sugar as sources of energy. Fifteen percent of the students marked minerals and water as necessary sources of energy. Only two students marked sunlight striking the skin as a source of energy. Students know humans cannot use the energy from the sun like autotrophs can. Without transference of the sun's energy into the tissue of plants, higher organisms, such as humans, could not exist.

In answers to questions 63 and 64, the majority of the students explained that without grasses several consumers, that consume grasses and the by-products of grasses, would perish. Eighty-three percent said we would not have pork chops or roast beef. A smaller percentage, 61%, also included the animal by-products eggs and cheese. Ninety-two percent said that the other autotrophs would not be affected. Eight percent knew without grasses, all organisms would be affected.

Ninety percent of the students knew instructing an over-populated country to feed its people beef rather than vegetables was not good advice. They showed through an energy pyramid how less energy is available at each trophic level.

The responses to the questions in this section of the test indicated that students were able to apply what they had learned in the unit by constructing adequate answers. I was pleased to see the students' ability to apply the knowledge they had acquired to new situations.

New Teaching Strategies

It was clearly evident that the students enjoyed themselves during this unit. My enthusiasm affected the overall feeling of the classes. In teaching less, not only did I better understand what I wanted students to understand, but the students found it more enjoyable to memorize less and understand more.

By abandoning the traditional approaches and instead focussing on key concepts of energy use of organisms student understanding improved as evidenced in the post test results. Eight laboratories were conducted during this unit. The subjective performance assessments showed an increased maturity level of the students in the lab. Product assessments showed that the students were actively questioning scientific concepts and journal entries showed they were pursuing investigative options. Less intimidating information meant an opportunity for the students to enjoy themselves while learning useful scientific knowledge.

I measured student comfort in science with exit polls. I asked students to write down any thoughts they had after the unit was complete. I was surprised to find approximately ninety-five percent of the students had at least one positive thought about the unit. The five percent who were quite negative were either attendance or behavior problems.

Writing, for most students, was not easy. I believe this was due to a lack of experience in writing in a science course. Journal writing was a very valuable tool in stimulating students to clarify and articulate their positions and ideas. I did not find the exact set of assignments to produce "nice, neat assignments". However, I made an attempt to encourage students to write their thoughts and ideas, challenge them, then change them if they needed to be altered due to new knowledge. It was encouraging to see the gradual change from students reluctant to write, writing one sentence entries, to students enthused to write several paragraphs. In the exit polls, many students found the journal to be worthwhile and suggested it be used more often. One student commented, " This journal writing is easy and fun. I wish we could get an assignment everyday to put in it." This obliging attitude may have resulted because of the assessment strategy this instructor used. I did not grade on quantity or precision. Each entry counted equally. The journal represented a large fraction of their grade, 20%. Students came to know how and why they were doing an assignment. I watched writing assignments progress from two minute activities into ten minutes and longer. This data is evidence that the students contemplated the journal writings seriously . Forty-five percent of the students received an "A", 39% received a "B", 10% received a "C", 4% received a "D", and 2% did not turn a journal into me.

Concepts maps were a useful fool for assessing students' prior knowledge. This strategy was the most difficult for students to grasp. With so many options for connecting ideas, students were distressed over providing the "right" answer and organizing information in a way which made sense to them. It was inspiring to see the groups change the maps as each person contributed his/her ideas. The scene reminded me of a group of scientists all seemingly convinced their way is the right way until the next person presents the ideas in a different, yet, sensible way.

Students considered working in groups very beneficial to learning, and most felt comfortable, as many wrote this in their journals and suggested this in their conversations:

"I wish we could work in groups everyday."

"Working with others helps me to understand the material better."

"Two or three heads are better than one. We should work in groups to help us learn."

"What I may not know, another student in the group may know."

When students work together on a project, they learn in a more productive atmosphere. Subjective evidence and observational data I gathered pointed to the beneficial effects of cooperative activities on the personal and social growth of the students. As the teams learned science together, they also learned the importance of trusting and working with people of various backgrounds.

Student Interviews

The clinical interviews took extra time, but were hugely successful in learning about student's misconceptions. Armed with the evidence in appendix B, my teaching strategies were altered to address the misconceptions students had. Knowing where the students were gave me insight into how I would get them to where I wanted them to be. In the next section, I present an evaluation of the pre-unit interviews.

The students were able to name some, but not all, kinds of energy. They confused different forms of energy with sources of energy. They thought energy was stored in food like a material and that it may be associated with vitality. They did not consider biochemical and mechanical energy, or heat in their answers.

Photosynthesis and metabolism were brought up in the interviews as ways plants and animals, respectively, get their energy. Plants metabolize, also. This information was not evident in the responses. The students were not clear on how photosynthesis or metabolism are related to energy. Photosynthesis was defined as a plant's method for using air, water, soil, and sun to make its own food. Metabolism was defined by the students as a way animals get energy from food. There was no mention of respiration. However, Justin reported that body heat comes from burning energy. Energy, as defined by Justin, must be a material. Mary considered energy to be closely linked with amount of nutrients. Rhonda thought energy was food. She connected energy to the kinds of food we eat. For example, she said we were able to get more energy from lettuce than hamburger because it was healthier. Not one of the students discussed forms or conversions of energy.

The students were able to show food chain relationships between producers and consumers, but they had difficulty with the idea of the decomposers. Rhonda failed to include producers as well as the decomposers in her responses. They understood energy as flowing through a community and being recycled. Expending heat energy into the environment was not discussed. I do not believe the students thought about energy conversions when one organism consumes another.

Possessing this knowledge of student understanding of energy, I was able to plan an appropriate unit to address these misconceptions.

CHAPTER 4

CHAPTER 4

DISCUSSION AND CONCLUSIONS

Aspects of the Unit Which Were Effective

The goals of the unit were to help students construct their own conceptual understanding of energy and to feel comfortable with science. These goals were implemented by utilizing a thematic approach with a constructivist philosophy, additional "hands-on" activities, and written product based assessments including essays, journals, and a formal laboratory report. An additional goal was to present energy in a way that showed the relationships between the physical and biological concepts of energy. After discussing energy in physical systems, I wanted the students to incorporate these concepts into constructing knowledge about biological systems.

Writing assignments and journal entries demonstrated the effectiveness of this methodology in helping the students feel comfortable with the concept of energy. The product assessments displayed that the students were able to construct and integrate their ideas and show their understanding. This method of assessment provided for collaborative reflection by both this instructor and the students. Over the course of the unit, student to student and student to teacher conversations showed me that students preferred these assessments over the traditional selected response format.

Informal evaluation of student journals and the post-test results indicated the laboratories were very effective in accomplishing the goals of the unit. The students' favorite labs were those using the microorganisms' utilization of energy to make yogurt and root beer. Many exclaimed that they were going to try these experiments at home so parents and friends could taste the results. To take a scientific concept and to see its worth in everyday life helped to accomplish the goal of addressing student comfort with science; making the concept personally meaningful. Testing food for energy containing molecules was the next favored activity. Bringing food from home for testing was a popular, worthwhile activity. This activity displayed that students were taking ownership of their learning. Students wanted to pursue calorie content of food and how calories represent energy found in food molecules. We did not get into the mathematical details of calories. Perhaps in the revision of this unit, I will consider this.

The writing assignments were used as tools to get students to ask questions on paper as well as to share, examine, contrast, and revise their ideas. The writing enabled me to better understand each student's thinking. Monitoring student understanding through journal entries was a powerful tool enabling students to communicate their understanding to me. Writing stimulated students to clarify and articulate their positions and ideas. Through the students' writing about their ideas, I was able to plan whole class interactions that were conducive to student thinking. The post test constructed response questions, answered with complete, thoughtful answers, showed an understanding and appreciation for writing in science to articulate ideas.

Although the students were presented with less facts and details in the teaching of this unit, they showed an understanding for energy in both biological and physical systems represented in product and performance assessments. The advertisement campaign for the *Laws of Thermodynamics* and the concept mapping enabled the students to take scientific laws and make them germane to their own understanding and knowledge about the world around them.

Other methodologies also were effective in meeting the goals of this unit. Working in cooperative groups, to develop a final product which was accepted by the others, proved to be an excellent tool for utilizing everyday contexts in a learning-centered classroom. Students were encouraged to use ideas from their classmates. Everyone's ideas were valued and respected as useful in the learning process.

Concept mapping, also performed in groups, was less effective in making students feel comfortable with new concepts. However, this tool was helpful for constructing knowledge. I believe the student discontent with concept making was a direct result of this instructor's own uneasiness with this assessment tool. It is my intent to work with concept maps for the teaching of each unit so that I will feel comfortable and competent in using this tool.

The formal laboratory report required students to use the scientific method to justify conclusions. The High School Proficiency test in Michigan utilizes the lab format I required the students to use. The goal of exposing students to formal science writing was a hidden agenda in this unit. I wanted students, utilizing the constructivist idea, in part, to experience scientific writing close to their own discourse.

Visual learners showed great enthusiasm for the cartoons and graphic representations. A difficult concept like energy transference between atoms and molecules was simply taught using characters to represent the atoms. The cartoons were good stimuli for the writing assignment; "In your journals write a story about your life as a photon of light and your travels through an ecosystem as energy that changes form", found in Appendix G.

Finally, exit evaluations indicated student comfort was high during this unit. I have never before asked students to evaluate a unit. After students realized these were not quizzes and would not be graded, the questions and ideas flowed onto the paper. I was able to assess student mastery of the concepts in this unit as well as any lack of understanding. These evaluations were private acclamations of comfort and understanding.

Aspects of the Unit Needing Improvement

I was not successful in providing a learning-centered classroom as described by Kathy Roth (Appendix P). I still feel that the students simply valued "getting the right answer" and felt that learning was a private activity for completing the projects and other assignments. I believe "getting the work done" was the goal rather than "sense-making and learning" as the goal. I think students enjoyed science class because I was enthusiastic, cared about the students' learning, and had lots of activities to do. Kathy Roth expresses her concerns in the same way. We do not believe they became experts of making sense out of the natural world due to the methodologies used. My lack of experience and understanding of the learning-centered classroom may have contributed to this result.

I do not believe concept mapping, using cutting and pasting techniques, was a successful assessment tool. Since gluing parts in the concept maps restricts the alteration of ideas, I will leave them loose so that students could revisit the map for reexamination and alteration. A felt board, or an erasable board, would have worked nicely to accomplish this objective. Concept maps should be an integral part of instruction, providing a process for the instructor and students to use to guide learning.

Another short-coming of the unit was failure to analyze in depth the diversity of discourses students brought with them prior to the unit. Ethnic diversity was evident in the students social interactions. As an instructor, I need to become more empathetic to these differences, and to tailor my instruction to these differences. It will be my goal in future units to focus on issues of cultural and social class differences in reasoning. I will make a special effort to help students use their different discourses and language to become scientifically literate.

Overall Evaluation and Conclusion

In conclusion, the energy unit was successful in reaching the goals I set for the unit. Students were enthusiastic learners who constructed their own knowledge of energy. The thematic approach to teaching science breaks up the content necessary for introductory biology students into manageable units with connecting ideas. I am convinced that educators, including this instructor, do need to teach less detailed scientific jargon and to teach connected scientific ideas that students can translate into their own discourses. Meaningful lessons which address everyday natural phenomena must be developed for each theme in biology. This unit is the first unit in a series I will attempt to develop for other themes in biology, i.e., evolution, matter, diversity, etc.

The Michigan State Legislature is proposing to require all students to take three years of science instead of the current requirement of two years. This would facilitate and encourage a thematic approach to teaching science as principles or "big ideas" in the first year, and exploring, in more detail, aspects of these principles in another year. Although this unit took twenty-nine days to complete, it is my understanding that the Michigan State Legislature plans to extend the school year and with carefully planned units all of the objectives proposed by MEGOSE can be taught in an introductory biology course.

BIBLIOGRAPHY

BIBLIOGRAPHY

The American Heritage Dictionary (1992). Boston, MA: Houghton Mifflin Company.

Anderson, C.W. (1995). Teaching content in a multicultural milieu. Paper presented at the Symposium. Didactics and/or Curriculum, Institute fur die Pedagogic der Naturwissenschaften (IPN), Kiel, Germany.

Anderson, C.W.. and Roth, K.J. (1989). Teaching for meaningful and self-regulated learning of science. In J. Brophy, Ed., *Advances in Research on Teaching* (1), Greenwich, CN: JAI Press, 265-310.

Barker, M. (1985). Teaching and Learning about Photosynthesis, Science Education Research Unit, Working Papers, University of Waikato, Hamilton, New Zealand, 220-9.

Biology; Principles, and Explorations. (1996). Holt, Rineholt, and Winston.

Bloom, B.S. (1956). *Taxonomy of Educational Objectives: The classification of Educational Goals, Handbook I; Cognitive Domain*, New York, McKay.

Brumby, M.N. (1982). Student's perception of the concept of life, *Science Education*, 66(4): 613-22.

Driver, R., Squires, A., Rushworth, P., Wood-Robinson, V. (1994). *Making Sense of Secondary Science: Research into Children's Ideas*. London and New York, Rutledge.

Elkana, Y. (1974). *The Discovery of the Conservation of Energy*, Cambridge, MA, Harvard University Press.

Feynman, R. (1975). *Lecture on Physics*, Addison-Wesley.

Gayford, C.G. (1986). Some aspects of the problems of teaching about energy in school biology, *European Journal of Science Education*, 8(4): 443-50.

Gee, J.P. (1991). What is literacy? In C. Mitchell and K. Weeler (eds.), *Rewriting Literacy: Culture and the Discourse of the Other*, New York, Bergin and Garvey, 3-11.

Gellert, E. (1962). Children's conceptions of the content and functions of the human body, *Genetic Psychology Monographs*, 65: 293-405.

Griffiths, A.K. and Grant, B.A.C. (1985). High school students' understanding of food webs: identification of a learning hierarchy and related misconceptions, *Journal of Research in Science Teaching*, 22(5): 421-36.

Hapkiewicz, A. (1992, Winter). Finding a List of Science Misconceptions, *MSTA Journal*..

Hoagland, M. and Dodson, B. (1995).*The Way Life Works*, New York, Times Books, Division of Random House, Inc.

Holman, J. (1986). Teaching about energy-the chemical perspective, In Driver, R. and Millars, R. (eds), *Energy Matters*, Proceedings of an invited conference: Teaching about Energy within the Secondary School Curriculum, Centre for Studies in Science and Mathematics Education, University of Leeds.

Martin, D. (1992). Themes in Science, MSTA Journal.

Michaels,S. and O'Connor, M.C. (1990). Literacy as reasoning within multiple discourses: Implications for policy and educational reform, Paper presented at the Council of Chief State School Officers, Summer Institute.

Michigan Essential Goals and Objectives for Science Education, K-12. (1991). *New Directions For Science Education in Michigan*, Michigan State Board of Education.

Mintzes, J.J. (1984). Naive theories in biology, children's concepts of the human body, *School Science and Mathematics*, 84(7): 548-55.

Novak, J.D. and Gowin, D.B. (1984). *Learning How to Learn*, Ithaca, N.Y., Cornell University Press.

Project 2061. (Summer 1991). *Science For All Americans*, American Association for the Advancement of Science.

Resnick, L.B. (1983). Mathematics and Science Learning: A New Conception, *Science*, 220; 477-78.

Richmond, G. and Striley, J. (1995). Making meaning in classrooms: Social processes in small group discourse and scientific knowledge-building. Submitted to *Journal of Research in Science Teaching*.

Roth, K.J. (1991). Learning to be comfortable in the neighborhood of science: an analysis of three approaches to elementary school teaching. In Wendy Saul and Sybille A. Jagusch (eds), *Vital Connections: Children Science and Books*, Portsmouth, NH, Heinemann.

Roth, K.J. (1992). The role of writing in creating a science learning community (Elementary Subjects Center Series No. 56), E. Lansing, MI: Michigan State University, Elementary subjects Center.

Roth, K.J. and Anderson, C.W. (1985). The Power Plant: Teacher's Guide; Institute for Research on Teaching, Michigan State University, East Lansing, MI.

Simpson, M. (1983). The mole cell rules, O.K.?, Aberdeen College of Education, *Biology Newsletter* 42: 7-11.

Simpson, M. and Arnold, B. (1982). Availability of prerequisite concepts for learning biology at certificate level, *Journal of Biological Education*, 16(1); 65-72.

Smith, E.L. and Anderson, C.W. (1984). Plants as producers: a case study of elementary science teaching, *Journal of Research in Science Teaching*, 21(7): 685-98.

Solomon, J. (1983). Messy, contradictory, and obstinately persistent: a study of children's out of school ideas about energy, *School Science Review*, 65(231): 225-33.

Webb, P. and Boltt, G. (1990). Food chain to food web: a natural progression?, Journal of Biological Education, 24(3): 187-90.

Yager, R.E. (1991).The Constructivist Learning Model: Towards Real Reform in Science Education, *The Science Teacher*, 52-57.

APPENDICES

APPENDIX A

APPENDIX A

DAILY LOG OF ACTIVITIES

DAY 1 Pretest, 57 questions, found in appendix R,
Overview of energy unit,
Writing assessment in journals, found in Appendix G.

DAY 2 Writing assessment in journal, found in Appendix G,
Introduction to energy transformations in mechanical systems, kinds of energy, sources of energy,
Demonstration and worksheet found in Appendix H.

DAY 3 Discussion of the Laws of Thermodynamics, and entropy,
Journal Entry found in Appendix G.

DAY 4 Cooperative activity-groups work to prepare an advertising campaign for the *Laws of Thermodynamics*

DAY 5 Completion of cooperative activity and presentations, small group discussion of presentations.

DAY 6 Introduction to bioenergetics with lecture,
Journal Entry found in appendix G.

DAY 7 Laboratory Activity 1: Thermal Energy From Food (Appendix C),
Discussion of calories found in food, and on food labels.

DAY 8 Discuss Laboratory results and food labels,
Video: "Energy Flow At The Cellular Level".

DAY 9 Discussion of ATP (energy currency of the cell),
Lecture notes found in Appendix G.

DAY 10 Lecture on major nutrients found in food (Notes found in Appendix G),
Preparation for Laboratory Activity 2,
Begin Laboratory 2: Food Testing (Appendix C).

DAY 11 Finish Laboratory and prepare for Formal Laboratory Reports, Discussion of Laboratory Activity 2 results.

DAY 12 Assessment of student understanding with a quiz (Appendix I).

DAY 13 Introduction to the "big ideas", Photosynthesis and Respiration (Appendix G),
Cooperative group activity to create a concept map using pictures and words provided for the "big ideas" (Appendix D).

DAY 14 Presentation of cooperative group's activity concept map from previousday (Appendix J),
Discussion of results

DAY 15 Introduction to photosynthesis and role of chlorophyll,
Photosynthesis Story (found in Appendix M),
Laboratory Activity 3: Chromatography (Appendix C).

DAY 16 Laser Disc Images
Discussion/lecture on characteristics of light,
"Boosting electrons" analogy (Appendix L),
Overlay of photo system (Appendix F),
Laboratory Activity 4: Light and Chlorophyll(Appendix C).

DAY 17 Discuss results of chromatography laboratory
Continue observations of Laboratory 4 for 1-2 weeks.

DAY 18 Video: "Cellular Respiration: Energy For Life",
Preparation for project,
Discuss chemical equations for photosynthesis and respiration.

DAY 19 Build marshmallow models of photosynthesis and respiration (Appendix K).

DAY 20 Laboratory Activity 5: Respiration of Corn/Pea Seeds(Appendix C).

DAY 21 Continue Laboratory 5.

DAY 22 Discuss Results of Laboratory 5,
Discussion/ Lecture on fermentation and microorganisms(Appendix E),Conduct Laboratory Activity 6: Variations in Carbon Dioxide Production Using Instant Blend Dry Yeast (Appendix C).

DAY 23 Conduct Laboratory 7: Yeast Fermentation (Appendix C), Discuss the results of laboratory 6.

DAY 24 Conduct Laboratory 8: Bacteriology of Yogurt (Appendix C). Discuss the results of Laboratory 6 and 7.

DAY 25 Yogurt eating,
Introduction to energy flow through an ecosystem with discussion of food chains and food webs, and energy pyramids,
Notes found in appendix N,
Pyramid of Energy Worksheet (Appendix O).

DAY 26 Writing assessment, found in Appendix G,
Initial planning for self-sufficient ecosystem.

DAY 27 Build Eco-columns (Appendix P),
Discuss energy flow through these ecosystems in the Ecocolumns.

DAY 28 Discuss results of Laboratory 4,
Preparation for Post Test (Appendix S) .

DAY 29 Post Test and exit poll.

APPENDIX B

APPENDIX B

TRANSCRIPT OF INTERVIEW WITH MARY (9th GRADE)

KINDS OF ENERGY

I- What kinds of energy do you know about?
M-My parents tell me I have too much energy and that I am too hyper. I guess not being tired. Kinetic energy,k and that energy is used in everything.
I-Can you name any kinds of energy?
M-Kinetic, Hyper people, nuclear and radioactive, energy to make light bulbs work.

WHERE DOES ENERGY COME FROM?

I-Where do you get your energy?
M-From food and the amount of sleep you get. The body uses the nutrients for energy. You need sleep to rejuvenate-Do you know how that works?
M-I don't know.

HOW DO HUMANS GET ENERGY?

I-Where do you get your energy?
M-From food and the amount of sleep.
I-What do we use energy for?
M-Every movement and everything we do. There are strong forms of energy, but I am not sure what you call this form.
I-How do we get energy from food?
M-Metabolism does this. I am not sure of the connection, but processes the nutrients and gives us energy.

HOW DO PLANTS GET ENERGY?

I-How do plants get energy?
M-photosynthesis. Plants get energy from the sun, water and air.
I-When we eat a plant do we get energy from the plant?
M-We eat the plant and make our own energy. The body processes the energy from the plant.

HOW DOES ENERGY FLOW THROUGH A BIOLOGICAL COMMUNITY?

I-On these cards I have written the name of an organism. All of these organisms live together in a biological community. Arrange these cards to show the flow of energy through this community. Then I will ask you to explain why you put them in the order you did.
I-Mary can you explain why you arranged the cards in that sequence?
M-Well grass is a producer and so is the tree so I put them first. Soil bacteria and mushrooms are not predators so they go here, too. The earthworm gets energy from nutrients in the soil. The bird eats the earthworm. The coyote preys on the bird and gets energy from nutrients in the bird. It processes the energy. Hawk eats sick mouse; it won't get a lot of energy. It will get more energy from a healthy mouse. Not much eats the hawk. Not much energy comes from a small organism. A lot of things get energy from the grass. We eat things that get energy from grass.

HOW DOES AN ECOSYSTEM INVOLVE SUNLIGHT AND HEAT?

I-Include sunlight and heat in your diagram.
M-Sun is at the very beginning before grass. Heat I'm not sure about. It is connected with the deer and coyote because they need it to maintain heat in themselves. They get help from the things they eat. Energy is created from other energies.
I-What other organisms give off heat?
M-Any living organism gives off heat. Everything has heat in it/ It is body temperature which is 98.6 in humans.

WHAT IS ENERGY USED FOR?

I-So Mary what is energy used for?
M-For every movement and everything we do. Strong forms of energy are used from metabolism and a lot of nutrients.
I-Do you have any questions you would like to ask me?
M-No. I don't think so.

APPENDIX B

TRANSCRIPT OF INTERVIEW WITH JUSTIN (9th GRADE)

KINDS OF ENERGY

I-What kinds of energy do you know about?
J-solar, hydro, electric, food energy.
I-Food has energy in it?
J-Yup...carbohydrates.

WHERE DOES ENERGY COME FROM?

I-Does food need the sun for energy?
J-It needs sun to grow so we can eat it and get energy from what's inside food.
I-Does a hamburger get its energy from the sun?
J-No. Hamburger comes from cows, cows eat grass, and grass came from the sun and soil. The cow did not get energy from the sun. The cow had to eat the grass.
I-Where does the energy in the food we eat originally come from?
J-It comes from the sun and goes to grass and the rest of the food chain.

HOW DO HUMANS GET ENERGY?

I-How do we get energy from the hamburger?
J-When we eat it, metabolism separates and turns food into energy we need.
I-Do we use energy when we are sleeping?
J-Probably. The body is burning food that is being digested while you're breathing and stuff while you're sleepin.
I-How does the body turn food into energy?
J-I don't really know. Metabolism has something to do with cells.
I-Do you know what metabolism is?
J-It turns food we eat into energy we can use. Our bodies burn energy.

HOW DO PLANTS GET ENERGY?

I-If we eat to get energy. How do think plants get their energy?
J-They live off nutrients in the soil. They use light, water and air to get energy. Sun, soil, and soil nutrients make plants.

HOW DOES ENERGY FLOW THROUGH A COMMUNITY?

I-I have a stack of cards with living organisms on them. All of these organisms live together in a biological community. I want you to arrange the cards in the sequence you believe they should go to show the flow of energy through this ecosystem. I will ask you to explain why you put the cards in that sequence when you are done.

I-Explain what you have done, please.
J-Well, the soil bacteria are eaten by the mushroom which is eaten by a frog. The earthworm eats soil bacteria. Bird eats earthworm. Hawk eats mouse. Mosquito and insects eat dead organisms. They suck their blood and stuff. The White cedar is living off the nutrients in the grass because soil, light, and water give the energy to the grass.
I-What else can you tell me about food chains?
J-Sun hits grass, other animals eat grass, we eat parts of the animals and when we die our bodies are returned to the soil-soil nutrients and sun make grass so it is like recycling.

HOW DO ECOSYSTEMS INVOLVE SUNLIGHT AND HEAT?

I-Where would you put the sun in your sequence?
J-With the grass and cedar tree because they are plants and need sunlight. White cedar is also used as a home for birds and animals.
I-Where would you put heat? You can use it more than once.
J-By the deer, coyote, hawk. They all need heat to live. Their bodies would freeze.
I-Where do they get heat?
J-They get it from sunlight.
I-What happens when you exercise?
J-We build body heat.
I-Why? Where does this body heat come from?
J-Burning energy. Energy makes the body warm by doing exercise.
I-Where does the heat go?
J-Through he body, sweat, and goes into the air.

WHAT IS ENERGY USED FOR?

I-What do we use energy for?
J-We use energy everyday for everything. We can't live without energy. We need it for strength and to be healthy.
I-do you have any questions about energy?
J-How does solar energy go through those panels and turn into regular energy?
NOTE: I discussed the answer with Justin, but will not include the conversation here.

APPENDIX B

TRANSCRIPT OF INTERVIEW WITH RHONDA (10th GRADE)

KINDS OF ENERGY

I-Name the kinds of energy you know about.
R-Electricity and food I guess.

WHERE DOES ENERGY COME FROM?

I-Rhonda do you know where energy comes from?
R-Food. I don't know.

HOW DO HUMANS GET ENERGY?

I-Where do you get your energy?
R-From sleeping and eating health.
I-Would you get more energy from a hamburger or lettuce?
R-Lettuce I guess.
I-why lettuce?
R-Because it is healthier and better for you.
I-Do you use energy when you are sleeping?
R-Yeh, I guess.

HOW DO PLANTS GET ENERGY?

I-Do plants need energy?
R-Yeh, I guess.
I-How do plants get their energy?
R-I guess through the soil, through their roots.
I-Is water energy for the plant?
R-Yes. It keeps the plant alive.
I-Can water give humans energy?
R-Yeh, You have to drink water to stay healthy and get energy.

HOW DOES ENERGY FLOW THROUGH A COMMUNITY?

I-Rhonda, I have a stack of cards with pictures of living organisms on them. These organisms live together in a community. I would like you to put them in the order you believe they should be in to show how energy flows through this system. I will ask you to explain your answer when you are done.
R-I think they go like this, hawk-mouse. I'm not sure what to do. Is this right?
I-You're doing fine. Keep going.
R-Soil bacteria is eaten by plants I think.

I-Where would the other organisms go?
R-I don't know.

HOW DO ECOSYSTEMS INVOLVE SUNLIGHT AND HEAT?

I-Can you add sunlight to your diagram? Where would the sun go in your sequence?
R-Sun goes in the beginning.
I-Why did you put the sun at the beginning?
R-We need the sun to live. Everything needs the sun to live. We have to have the sun to stay warm.
I-Where would you put heat in your sequence?
R-At the end.
I-Would heat go anywhere else?
R-I don't know.

WHAT IS ENERGY USED FOR?

I-What is energy used for?
R-Everything. So need it for everything.
I-Do plants also need it for everything?
R-Yup, I guess.
I-Do you know anything else about energy?
R-No.
I-Do you have any questions for me? R-No.

THE ORGANISMS FOUND ON THE STACK OF 3X5 CARDS INCLUDED:

GRASS	BAT
EARTHWORM	MOUSE
FROG	HAWK
SOIL BACTERIA	DEER
COYOTE	WHITE CEDAR
MUSHROOM	PURPLE MARTIN
MOSQUITO	

APPENDIX C

APPENDIX C

Laboratory 1

THERMAL ENERGY FROM FOODS

Introduction: You use food as a fuel for your body. Food contains the stored energy you need to run, talk, think and even to sleep. In order to survive, your body must be able to digest the nutrients in food and get energy to keep your body processes going.

You can indirectly measure the energy contained in a sample of food. Most of the thermal energy produced by burning the food can be absorbed by a known mass of water. You must measure the temperature change in the water. It requires 4.184 joules, J, of energy to raise the temperature of each gram of water one Celsius degree. This value is the specific heat of the water. Use the following equation to determine the energy released, Q, when a food sample is burned.

energy released = temperature x mass x specific heat of water

$$Q = (T_f - T_i) \times m \times C_p$$

Purpose: You will calculate a change in thermal energy. You will account for the difference between energy released and energy absorbed.

Materials: (Per Group)

- matches
- wood splints
- ring stand
- thermometer
- watch or clock
- water
- aluminum potpie pan
- balance
- clamp, utility
- flask (100 mL or 250 mL)
- large paper clips or long pins
- graduated cylinder (100 mL)
- food samples
- goggles

Procedure: 1) Straighten a paper clip. Insert the paper clip through the food sample. Position the paper clip on the edges of the aluminum pot pie pan. Use the balance to determine the mass of the pan, paper clip, and food sample. Record this mass in Data Table 1 as m_1.

2) Use a graduated cylinder to add 50 mL of water to the flask. Clamp the flask on the ring stand about 5 cm above the tabletop. Use the thermometer to measure the temperature of the water, (T_i). Record the value in Data Table 1.

3) Ignite the wooden splint with a match. CAUTION: always use care with fire. Use the burning splint to ignite the food sample. Once the food sample is burning, safely extinguish the splint. Position the aluminum pan under the flask. The water in the flask should absorb most of the energy given off by the burning food.

4) Carefully stir the water with the thermometer and closely observe the temperature rise.

5) Blow out the flame of the burning food after about 2 minutes. Record the highest temperature of the water during the 2 minutes in Data Table 1 as T_f.

6) Allow the aluminum pan and its contents to cool. Determine the mass of the pan and contents after the release of energy. Record this value as m_2 in Data Table 1.

Data and Observations:

TABLE 1

	Mass (g)		Temperature (C)	
	m_1	m_2	T_i	T_f
Food Sample				

Calculate the rise in the water's temperature by subtracting T_i from T_f._____________

Use the equation given in the introduction to calculate the energy absorbed by water when your food sample burned for about 2 minutes. For the mass, be sure to use the mass of the water.

Q = ______

Make a class data table using the whole class data , all food samples, and the heat absorbed J/g.

Conclusions: Answer the following questions in complete sentences in a paragraph.

1. Did you measure a temperature change in the water or the food sample?
2. Did you measure the energy released by the food sample or the energy gained by the water?
3. Most of the energy flowing from the burning food is absorbed by the water. What do you think happens to the small amount of energy that is not absorbed by the water.
4. How can you calculate the mass of food burned to form a gas or water?
5. What is the mass of food burned to form a gas or water?
6. Suppose 20.0 g of your food sample burned completely with a temperature rise of 30.0 C. Use a proportion to calculate the value of energy released.

Q = ____________

7. Look at the data table of different food samples you class tested. Which food sample released the most energy?

8. In order to calculate the amount of energy released or absorbed by a substance, what information do you need?

APPENDIX C

Laboratory 2

FOOD TESTS

Notes To Teacher

Recipes for solutions:

Corn Starch Solution (1%)

1 g of cornstarch with small amount of cold water
Mix
Add water to volume of 100 mL
Heat to boiling-boil 1 min. (until starch dissolved)

Sugar Solution (1%)

1 g glucose (dextrose) in small amount of water
Mix
Add water to volume of 100 mL

Gelatin Solution (1%)

1 g unflavored gelatin in small amount of water
Mix
Add water to volume of 100 mL
Heat solution to dissolve gelatin

Iodine solution may be purchased from most chemical supply companies as Lugol's iodine solution or you may obtain tincture of iodine from the local pharmacy. These solutions should be diluted by adding one part of the iodine solution with 5 parts of water. If you wish to make your own, dissolve 2 grams of potassium iodide (KI) in 100 mL of water. Add 1 gram of iodine crystals and stir until dissolved.

Iodine changes to blue-black color in the presence of starch. By comparing the color of the control with the color produced when adding the iodine solution to each of the nutrients, students will discover which of these nutrients changes color with the iodine solution. They will then use this information to test other foods to see if starch is present.

Benedict's solution may be purchased from most chemical supply companies. If you wish to make your own, dissolve 173 grams of sodium (or potassium) citrate ($C_6H_5Na_3O_7$) and 100 grams of anhydrous sodium carbonate (Na_2CO_3),in 800 mL of water. (Note: Instead of anhydrous sodium carbonate, you may use 200 grams of hydrated (crystalline) sodium carbonate. Heat the solution gently to speed dissolving. Filter the solution. Stir constantly while adding to this solution, 7.3 grams copper (II) sulfate pentahydrate ($CuSO_45H_2O$)

which has been 1dissolved in 100 mL of water. Add enough water to bring the total volume to 1 liter.

Some sugars, called reducing sugars, will react when heated with Benedict's solution to produce colors ranging from yellow-green to red-orange.

Biuret solution may be purchased from most chemical supply companies or you make you own. Dissolve 3 grams of copper sulfate ($CuSO_4$ $5H_2O$) and 12 grams of potassium sodium tartrate ($KNaC_4H_4O_6$; also called Rochelle salt) in 1 liter of water. Next prepare a second solution by adding 60 grams of sodium hydroxide pellets (NaOH) very slowly with stirring to 600 mL of water. CAUTION: Use Pyrex glassware as this reaction generates a large amount of heat. Stir constantly while slowly adding the sodium hydroxide solution to the copper sulfate solution.

In the presence of certain proteins, Biuret solution will turn a pink to purple or violet color.

If the food contains only a small amount of fat, it may not be detected in the brown paper test. If no fat has been detected, you may allow the students to investigate further by dissolving a small amount of the food in a few mL of rubbing alcohol. Allow the food to dissolve for about 5 minutes. Then pour the solution onto a piece of brown paper and allow to dry. Then check for a translucent spot on the brown paper.

Brown paper bags work well for this test if you avoid using the parts of the bag with printing on it

The light source works well as a heat source to dry the papers. Place a few inches from the paper after the food has been rubbed very hard into the paper.

Here are some suggested test foods:

oatmeal	apple
banana	cooked egg white
spaghetti noodles	crackers
potato	cheese

Appendix C

Laboratory 1

FOOD TESTS

Introduction: Scientists have ways of telling whether or not carbohydrates , fats or proteins are part of different kinds of food. They use special chemicals that turn color when carbohydrates, fats or proteins make up a certain food. You will do the same tests that scientists use to find out what kinds of substances are a part of the foods you eat.

You will perform four different tests on several different foods. Two of these tests are for carbohydrates (one for sugar, and another for starch), one is for fats, and one is for proteins.

For all of these tests, we will start with four very simple foods, and then use a few more foods that you can bring from home. This will allow you to test some of your favorite foods.

Purpose: Can we determine, in the laboratory, that the food we eat contains carbohydrates, including sugars and starches, fats, or proteins?

Materials:
- goggles
- 5 test tubes
- test tube rack
- a marking pen
- Iodine solution
- Benedict's solution
- biuret solution
- 2" x 2" pieces of brown paper bag
- stirring rod
- light source

Procedure: 1. Using the pen, mark each of the test tubes 1-5. Then mark a line approximately 2 cm from the bottom on each of these.

2. Fill the test tubes to the line with the following substances:
   - TT #1 water (control)
   - TT #2 cornstarch solution (starch)
   - TT #3 glucose solution (sugar)
   - TT# 4 gelatin solution (protein)
   - TT# 5 cooking oil (fat)

3. Create a data table for recording your observations.

STARCH TEST

4. To test starch add a few drops of the Iodine solution to each of the five test tubes. Observe and record the color of each food after the iodine has been added.

(Iodine turns to a blue-black color in the presence of starch.)

5. Keep test tube #1 as a control. Use it to compare colors to see if a reaction occurred in your foods from home.

6. Clean TT #2-5. Repeat the iodine test on the new foods. You should use foods that are mostly white. Record the results in your data table. Wash the test
tubes thoroughly.

SUGAR TEST

7. To test for sugar, set up the experiment like you did for the iodine solution. Number the test tubes 1-5. Make two lines, one 2 cm from the bottom on each and another 4 cm from the bottom.

8. Add the substances in order from the starch test.

9. Add enough Benedict's solution to each of the test tubes to fill them to the second line.

10. Place The tubes in boiling water and boil for 3-5 minutes or until you see a distinct color change. Compare the color to that of the control.

11. Add your observations to your data table.

12. Now perform the Benedict's solution test with the foods from home.

PROTEIN TEST

13. To test for protein, use biuret solution. Set up the experiment as you did before.

14. Add about 5-10 drops of biuret solution to the test tubes.

15. Check for color changes as compared to the control. NOTE: It would be helpful if you use a white piece of paper for a background when comparing the colors of the foods to the color of the control.

16. Record your data in the the table.

17. Test foods from home for protein.

FATS TEST

18. To test for fats, obtain five small pieces of brown paper bag. Label each piece of paper with the name of the food substances tested:

#1: water (control)
#2: corn starch solution
#3: glucose solution
#4: gelatin solution
#5: cooking oil

19. Use a stirring rod or eye dropper to transfer a few drops of each test solution to the appropriate piece of brown paper.

20. Allow the test spots on each sheet of brown paper to dry.

21. Compare the papers with the control. NOTE: The property of light passing through the paper is called translucence. Note whether light passes through the paper.

22. Record your observations in your table.

23. Test foods from home for the presence of fats.

Observations: Data table.

Conclusions: Answers to the following questions should be included in the conclusion.

Did your data support your hypothesis? Why or why not?

The first test tube, which contained water, was used as a control. How did the color change when the iodine, the Benedict's and the biuret solutions were added.

Which test substance turned the iodine color from yellow to blue-black?

Based on your observations, which component of food is the iodine test used to detect?

In test #2 the water was used as a control. What color was it after adding the Benedict's solution?

Which test substances changed the color of the Benedict's?

Based on these observations, what component of food does the Benedict's test for?

What happened to the water in test #3 when the biuret solution was added?

Which test substances changed the color of the biuret solution?

Based on these observations what component of food does the biuret solution test for?

Based on your observations of the way the four test substances and the control reacted with the paper,which of the four components of food can you detect with this test?

On the basis of the tests you have performed in this and the last three activities, which foods brought from home, that you tested, could be a good source of starch? sugar? protein? fat?

Which of the foods from home contained more than one component?

Did any of your foods from home contain all four components?

Based on the evidence you acquired, what foods would you eat for the energy your body needs? Please explain you answer.

Adopted from "Food, Energy, and Growth", New Directions Teaching Materials, Michigan Department of Education, August, 1992.

APPENDIX C

Laboratory 3

THE SEPARATION OF PLANT PIGMENT BY PAPER CHROMATOGRAPHY

Introduction: Chromatography, a technique developed sometime immediately following World War II, is used to separate organic compounds from mixtures on the basis of their solubility in one or more solvents passed through a solid medium. The compounds that are most soluble in the solvent travel the fastest along the medium, and those that are least soluble travel the slowest

Paper chromatography starts with making a stain of the mixture to be analyzed on a piece of absorbent (chromatographic) filter paper. The stain is placed near the bottom edge of the paper and allowed to dry. Once dry, the edge of the paper with the stain is lowered into a solvent in a closed container (If the container is not air tight the solvent will evaporate affecting the outcome. The solvent climbs up through the paper by capillary action. It quickly reaches the stain and passes it .

As a result, the molecules adhere weakly to the paper or dissolve easily. Those molecules are quickly carried away in the advancing solvent "front". Other molecules stick more tightly to the paper, or are less soluble in the solvent, or are large and heavy. Those are carried away at slower rates. This causes the molecules to finally separate into bands in order of those speeds. This series of separate, colored bands on a piece of the absorbent filter paper is known as a chromatogram. In this activity you will use paper chromatography to separate pigments within different types of vegetables.

Purpose: Can more than one colored pigment be found in vegetables?

Materials: 95% ethanol or acetone
3 large test tubes
test tube rack
toothpicks
parafilm
chromatography paper
spinach leaves
carrots
beets

Procedure: 1) Cut chromatography paper in long, thin strips in order to slide them into the test tubes (3 strips). NOTE: The paper should suspend without touching the sides or the bottom of the test tube.

2) Place a toothpick into one end of each of the three paper strips so that they can be suspended into the three large test tubes. (See Diagram)

3) Cut up the vegetables into tiny pieces.

4) Blend each vegetable separately with 5-10 mL of 95% ethanol or acetone in the mortar and pestle.

5) Filter the mixture through 3 layers of cheesecloth or through a double strainer.

6) Place a thick line of the filtrate approximately 2 cm from the bottom on the filter paper (end opposite the toothpick), using another toothpick. Go over and over the line many times letting the extract dry between each application.

7) While the extract is drying, pour some solvent into the test tubes. Add enough so that the end of the paper strip, when placed in the tube will be submerged.

NOTE: Be sure the extract line is not submerged.

8)Suspend the paper in the test tubes and allow about 1/2 cm to touch the solvent.

9) Immediately cover each test tube with the parafilm. NOTE: This allows the environment inside the test tubes to become saturated with the solvent.

10) Do not disturb the test tubes for 10-15 minutes, or until the solvent has risen to a point at the top of the paper strip.

11)Remove the paper strips and allow them to air dry.

12) Record your observations in a data table.

Observations: Data Table

Conclusions: Answer the following questions in a paragraph:

Did your data support your hypothesis? Why or why not?
What color pigments are found in spinach, carrots, beets?
If chlorophyll is green, how do you explain the presence of other pigments?
What pigment is the most soluble? Which is the least soluble?
If only one pigment color can be seen on your chromatogram, what might this suggest?

Going further: When the chromatography is complete, take the distance (from the stating point) moved by a particular substance and divide it by the distance (from the starting point) moved by the solvent. That ratio is referred to as the Rf (rate of flow) value of that substance under certain conditions of temperature and solvent composition. The Rf value of a compound can be used to help identify it.

$$Rf = \frac{\text{distance traveled by compound}}{\text{distance traveled by solvent}}$$

Adopted from NSC 852 Units, Michigan State University, Summer, 1992.

APPENDIX C

Laboratory 4

LIGHT AND CHLOROPHYLL LABORATORY

Introduction: The major light-absorbing pigment in plants is chlorophyll. In green plants, chlorophyll is found in chloroplasts within plant cells.

When atoms in a pigment absorb light, electrons are boosted to higher energy levels. The energy in the photons is transferred to the electrons, causing the move. Boosting an electron requires an exact amount of energy, just as when climbing a ladder you must raise your foot just so far to climb to the next rung. A particular kind of pigment can absorb only photons with the appropriate amount of energy.

In the second stage of photosynthesis, light energy is converted into chemical energy by a series of reactions that is initiated when light is absorbed by the photosystems.

Purpose; How does the color of light affect the development of chlorophyll in seedlings?

Hypothesis:

Materials: paper towels
bean seeds
5 small glass jars with lids (baby food jars work well)
cellophane, red, blue, green, yellow, and clear (colored plastic wrap works well)
masking tape
felt-tip pen

Procedure: 1) Cover the bottom of each jar with a damp paper towel. Place two-three bean seeds on the towel in each jar. Tightly comer the jars with their lids.

2) Completely wrap each jar with one of the pieces of colored cellophane. Use the masking tape to make a label for the lid of each jar.

3) Place the jars in a well-lighted area where they will not be disturbed.

DAYS 2-8..

4) Check the seeds daily. After seven days, remove the cellophane from the jars and observe the color of the seedlings. Do not open the jars.

5) Record your observations.

6) After 24 hours, observe the color of the seedlings.

Observations and Analysis: Record your observations in a data table and answer the following question:

What color were the seedlings in the jar wrapped in clear cellophane?

What color were the seedlings in the jars wrapped in colored cellophane?

What color of light was reflected from each jar wrapped in cellophane?

What colors of light passed through to the seedlings?

Conclusions: Answer the following questions in a paragraph:

Was your hypothesis correct? What were the white seedlings missing?

Why were they missing it?

What color of light is required for photosynthesis to occur?

References: Marson, Ron, *Light: Tops Learning Systems, #17*, 1991.

APPENDIX C

Laboratory 5

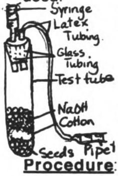
RESPIRATION INVESTIGATION

Introduction: All aerobic organisms take in oxygen and give off carbon dioxide as long as they are alive. This is true for plants as well as animals. some organisms have elaborate structures such as lungs or tracheal tubes for exchanging respiratory gases; others merely use moist membranes. If you place a living organism in a closed system, it is possible to measure its consumption of oxygen. Respiration will be measured in

mL O_2/min./g of organisms

Purpose: Can the respiration rate of germinating seeds be measured?

Materials:
- Respirometer
- large test tube
- 2-hole rubber stopper to fit test tube
- 4-glass tubes to fit snugly into holes of stopper (5-10 cm long)
- syringe, without needle
- latex tubing (45 cm, and 3 cm lengths)
- 1 or 2 mL pipette
- Colored liquid detergent (Add red food coloring to liquid detergent)
- NaOH or KOH pellets (2-5 grams) NOTE: Limewater may also be used.
- Cotton balls
- Cork grease or Vaseline
- Pea or corn seeds (45 pea seeds or 40 corn seeds which are germinating)
- Test tube rack
- Balance
- Eyedropper



Procedure: 1) Set up the respirometer as shown in the diagram.

2) Put about 3 cm CO_2 absorbent (either KOH or NaOH) in the bottom of the test tube. **NOTE**: The KOH of NaOH will absorb the carbon dioxide that the organisms are giving off, which might interfere with your measurement of oxygen uptake. *DO NOT TOUCH THE ABSORBENT.*

3) Find the mass of the germinating seeds by placing them on the balance. Record the mass in a data table.

4) Place the germinating seeds on top of moist cotton in the respirometer. (See diagram)

5) Seal the respirometer joints with a small amount of Vaseline.

NOTE: Make sure the rubber stopper is seated securely in the test tube. *DO NOT PUT TOO MUCH GREASE ON THE JOINTS.*

6) Place a drop of colored liquid detergent into the tip of the pipette with the eyedropper. The drop should be 3-4 mm long. NOTE: Let the respirometer stabilize for 5 minutes.

7) After 5 minutes, adjust the marker drop to the end of the pipette with the syringe. **NOTE**: Pulling quickly on the syringe will break the bubble of dye. Twist or turn the syringe rather that pulling on it.

8) Check the time and record the initial volume in the data table. Every 3 minutes, record the change in volume. Take 10 readings and then disassemble your respirometer.

Observations and Analysis: Data Table Number 1

Calculations: Calculate the average amount of oxygen your specimens used every 3 minutes.

Calculate the average amount of oxygen your germinating seeds used every minute.

Using the above answer, calculate the average respiratory rate of your organisms per gram of organisms. (mL O_2/min./g specimens)

Conclusions: Answer the following questions in a paragraph:
Was your hypothesis correct?
How do you think the respiration rate of insects would compare to the respiration of germinating seeds?
Explain your answer thoroughly.
What were some problems you encountered in this lab?
It is important during this lab to keep the temperature of the environment constant. This experiment was run at room temperature. Do you think that the temperature remained constant?
How might you design this experiment so that you could be sure it was conducted at a constant temperature?
What other experiments could you conduct using your respirometer?

Adopted from NSC 852 Units, Michigan State University, Summer, 1992.

DATA TABLE 1

Name of organisms tested:

Mass of organisms

Number of organisms tested

Time	Initial Volume	Final Volume	△ Volume
0			
3			
6			
9			
12			
15			
18			
21			
24			
27			
30			

APPENDIX C

Laboratory 6

VARIATIONS IN CARBON DIOXIDE PRODUCTION

Using Instant Blend Dry Yeast

Introduction: This experiment illustrates some interesting results when using like amounts of yeast and water with varying amounts of sugar. The production of carbon dioxide begins when the yeast comes in contact with moisture and sugar. The amount of sugar in proportion to yeast is one of the important aspects of carbon dioxide production.

Yeast cells digest food; their favorite foods are sugars. The end products of this fermentation are carbon dioxide and ethyl alcohol. In bread making, the yeast digests the sugars available from flour and added sugars.

After most yeast recipes are mixed and kneaded, the dough is covered and allowed to "proof" of rise to double its size before baking. During the first 10 minutes of baking, another rapid expansion (oven-spring) occurs. The rising in each case is caused by the accumulation or trapping of carbon dioxide gas as bubbles in the soft dough.

Purpose: Will the amount of sugar affect the yeast fermentation?

Hypothesis:

Materials: 4 test tubes
timer or second hand on watch or clock
2 packages Instant Blend Dry Yeast
3 colored pencils
4 100 ml beakers
warm water
thermometer
sugar
felt pen or china marker

Procedure: 1) Label the beakers A,B,C, and D.
2) Into each cup measure 1 teaspoon Instant Blend Dry Yeast. Measure 1 teaspoon sugar into cup A; 2 teaspoons sugar into cup B; 4 teaspoon sugar into cup C and 6 teaspoons sugar into cup D. Stir each to combine.
3) Add 1/2 cup 110 F (43 C) water to each cup. Stir each to dissolve and combine ingredients.
4) Add the ingredients to the test tubes.
5) Set timer and observe changes every five minutes for fifteen minutes.
Record results of observations on Data Sheet.

Observations: See attached data sheet.

Conclusions: Did the increased sugar produce the results you expected? What appears to be different in the results of Cups C and D from Cups A and B? Can you explain what happened in terms of the microorganisms?

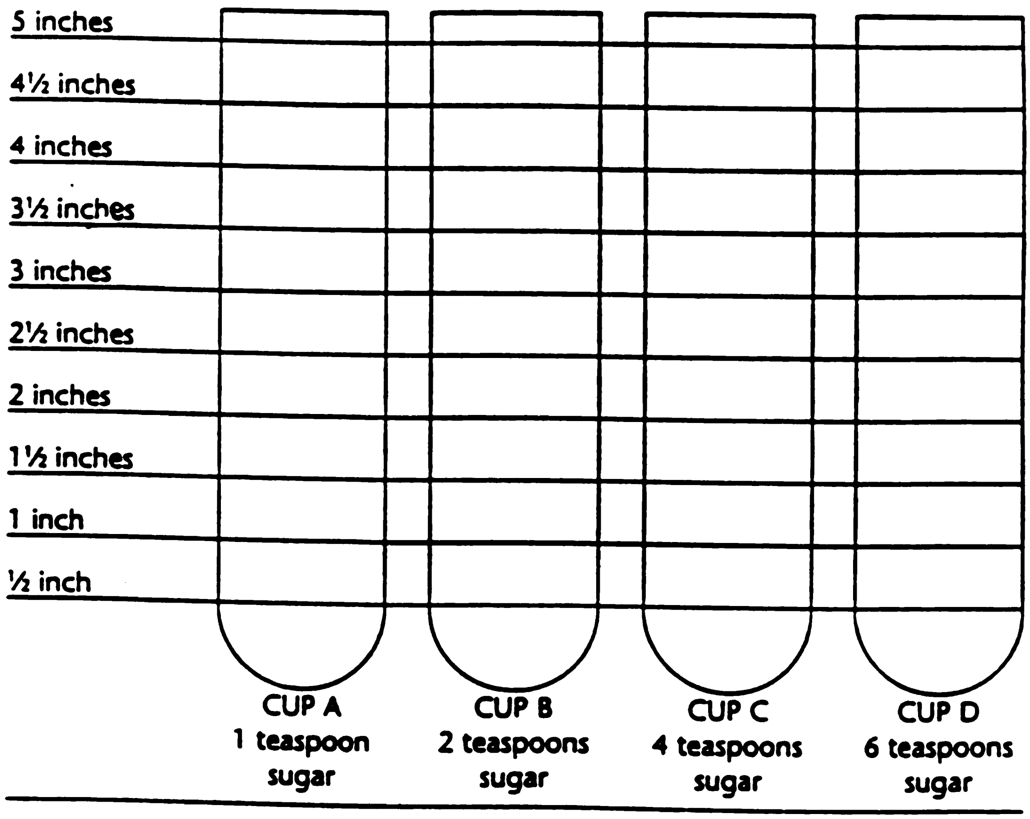
DATA SHEET YEAST EXPERIMENT

Variations in Carbon Dioxide (CO_2) Production Using Instant Blend Dry Yeast

Yeast and water with varying amounts of sugar

Record on the graph below, the inches of carbon dioxide (CO_2) in each test tube at 5 minute intervals by coloring the height with one colored pencil. Use a second color for the next 5 minute measurement, etc.

COLOR KEY: 1st 5 minutes _____ 2nd 5 minutes _____ 3rd 5 minutes _____



CONCLUSIONS:

APPENDIX C

Laboratory 7

YEAST FERMENTATION

Introduction: Yeasts are microorganisms, single-celled fungi, noted particularly for their ability to ferment carbohydrates. The yeast is the oldest domesticated life form on Earth. There are more than 600 species of yeasts. The ability of yeast such as *Saccharomyces cerevisiae* to ferment carbohydrates by breaking down glucose to produce ethanol and carbon dioxide is fundamental to the production of breads and other baked goods, as well as beer, wine, and liquor. Yeast cells use sugars naturally as their energy source. In digesting these sugars, yeast cells produce CO_2 and ethyl alcohol. The rising of bread is caused by the accumulation or trapping of carbon dioxide gas as bubbles in the soft dough. The carbon dioxide is trapped because the dough is elastic and stretchable. It is not possible for the gas to rise up through the dough and escape. The alcohol dissolves in the water and evaporates. In this lab you will use yeasts to make root beer.

Purpose: Does yeast fermentation produce root beer?

Hypothesis:

Materials: Fresh yeast, Champagne yeast if available
Measuring spoons and cups
Small cups to hold water
Gallon Jugs to mix ingredients
Sugar (5 pounds)
Mixing stirrers
Root beer extract
Funnel
Masking tape and marking pencils

Note to teacher: You can purchase the Champagne yeast and root beer extract at a beer/wine-making supply store.

Procedure: 1) Dissolve 1 teaspoon of sugar in 1/2 cup of warm water.
2) Dissolve 1/4 teaspoon Champagne yeast in sugar and water mixture. **NOTE**: If the water is too hot, it will kill the yeasts.
3) Allow the mixture to set for a few minutes.
4) Add 2 cups of sugar to the clean gallon jug.
5) Add 1 Tablespoon of root beer extract to the sugar in the jug.
6) Now add the incredible yeast mixture to the gallon jug.
7) Add enough warm water to make a gallon.
8) Put the top on the gallon jug and shake it gently to mix all the ingredients.

9) Fill the sterilized plastic pop bottles with the mixture. **NOTE:** To sterilize the plastic pop bottles fill the bottles with boiling water. Let stand for 3 minutes and repeat two more times. Boil the bottle caps and reseal immediately after the last hot water sterilization.

10) Make sure to seal the bottles properly or the mixture becomes flat and sour.

11) Lay the bottles on their sides to check for leaks.

12) Age for two to four days.

13) After that time, store in a cool dark place, aging for at least one week, two weeks improves the flavor. **NOTE**: A slight yeast deposit will form on the bottom of the bottle. When serving, pour carefully so as to leave this deposit in the bottle. It is not harmful!

Observations and Analysis: Did you note any visual changes in the mixture?
What did the mixture taste like?

Conclusions: What gave the mixture its flavor?
Was the mixture fizzy? If it was, how can you explain this?
What other food products do we have as a result of microbe fermentations?

Adopted from, The Microcosmos Curriculum Guide to Exploring Microbial Space, Kendall/Hunt, Boston University, 1992.

APPENDIX C

Laboratory 8

BACTERIOLOGY OF YOGURT

Introduction: Yogurt fermentation is brought about by inoculation of boiled milk with two lactic acid bacteria, *Lactobacillus bulgaricus* (adds flavor and aroma) and *Streptococcus thermophilus* (produces acid). The aroma and flavor of yogurt are due primarily to the lactic acid produced by these bacteria. Chemical metabolism of the fermenting bacteria includes changing lactose (milk sugar) into lactic acid. Lactose is the carbohydrate which supports microbial growth and lactic acid is the resultant waste product. Yogurt has a custard-like appearance due to coagulation of milk protein by the lactic acid. In this experiment you will make yogurt. A portion of this product will then be plated to show the two types of bacteria. A gram stain of each organism will also be done to confirm the presence of the two above mentioned bacteria.

Purpose: Can microorganisms change milk into yogurt?

Materials: To make yogurt:

1 quart skim (nonfat) milk

1 Tablespoon plain yogurt with active yogurt cultures (i.e., Dannon or Yoplait)

4 Tablespoons nonfat dry milk (Increases the solids so that the final product will be thicker, more like commercial yogurt) **NOTE**: Make sure the dry milk dissolves.

Non-mercury thermometer (A candy thermometer works well)
1 quart thermos
Mixing spoon
Pan and hot plate or hot pot or yogurt makers

For staining:
Plate Count Agar (For cultivating bacteria)
Microscope slide (For gram stain)
Microscope
Inoculating loop
Methylene blue stain (Gram staining is another option)
Test tube holder (To hold slide)
Bunsen burner or alcohol burner

Procedure: 1) Pour the milk into a clean pot of hot pot.

2) Stir in the 4 Tablespoons of nonfat dry milk

3) Heat the milk on the hot plate or in the hot pot to 82 C. Maintain this temperature for 15-20 minutes. NOTE: stir continuously so that milk does not burn. Heating the milk to just below the boiling point is done to kill any bad

bacteria or microorganisms that might be present.

4) Cool the milk to 43 C. NOTE: You can speed this cooling if you place the pan in ice water. and stir.

5) Stir in 1 Tablespoon of yogurt culture. Mix with a gentle stirring motion. **NOTE**: You want to minimize the addition of air to the yogurt.

6) Immediately pour the yogurt into clean containers (50 mL beakers work well) Cover the containers and incubate (45 C) undisturbed until the product gels or coagulates. **NOTE**: Temperature should not exceed 46 C because temperatures above this will kill the culture. The bacteria will also grow at room temperatures, but at a slower rate. If you decide to make the yogurt at room temperature it will take longer. If you do not have a thermos, you can use warm water in a pan placed near a heat source. An incubator will work or an actual yogurt maker will do a nice job as well.

7) Refrigerate the containers. Eat when desired!

Staining:

8) Place a small amount of yogurt onto a clean slide with an inoculating loop or toothpick. Spread the culture around in a circle to form a thin film. **NOTE**: Do not prepare too heavy of a smear.

9) Allow the slide to air dry, then "fix" the culture by passing it, film side up, quickly three times through a Bunsen flame. **NOTE**: Too much heat will distort the normal shape and structure of the microorganisms to be stained.

10) After preparing a smear, place the slide on a staining bar over one of the lab sinks.

11) Flood the slide with methylene blue. Rinse the slide **gently** with water.

12) Blot dry very gently (Do not rub the culture off) and examine under low power, then high power. If time permits also vies under oil immersion.

13) Make drawings of the various bacterial cultures.

Observations: Drawings of the bacterial cultures on low and high power.

Conclusions: Answer the following questions in a paragraph:

Was your hypothesis correct?
What were the shape and structure of the bacteria you saw?
Were they cocci or bacilli?
Were the bacteria in chains or clusters?
What does "active" cultures mean?
Why must yogurt be kept in a warm place?
What is the effect of refrigeration on the action of the bacteria?
What do the bacteria use as their source of energy?
How did that energy get in the yogurt?
Include a diagram showing where the energy transformations occurred so that yogurt could provide energy for the bacteria.

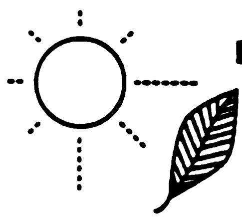
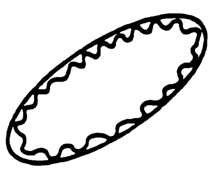
References: Food Science: Food Science, Safety and Nutrition, Teaching Units. National FFA foundation, Madison,WI, The National Council for Agricultural Education, 1993.

Fundamentals of Dairy Chemistry. Wong, N.P., Jenness, R., Keeney, M. Marth, E.H., VanNostrand Reinhold Co. N.Y. 1988.

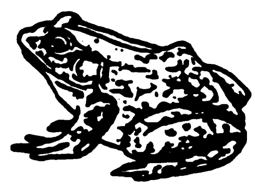
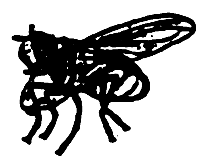
APPENDIX D

APPENDIX D

PICTURES FOR CONCEPT MAPPING

CO_2 Carbon Dioxide	O_2 Oxygen
H_2O Water	$C_6H_{12}O_6$ Glucose
Respiration	Photosynthesis
 Energy Captured	 Energy Released
	Chlorophyll
 Mitochondria	

APPENDIX D

Chlorophyll	Sugar
 Tree	Mushroom
 Plant (or Leaf)	 Frog
Strawberry	 Insect

APPENDIX E

APPENDIX E

THE ROLE OF MICROORGANISMS AND FERMENTATION IN FOOD PRODUCTION

Numerous food products owe their production and characteristics to the activities of microorganisms. Foods such as ripened cheeses, pickles, sauerkraut, and fermented sausages and salami have an extended shelf life over their base raw products. Fermented foods also have aroma and flavor characteristics that result directly or indirectly from the fermenting organisms. Yeasts, bacteria, molds, or combinations of these organisms are responsible for fermentation. Bread, beer, wine and distilled liquors are generally fermented by yeasts. Yeasts and bacteria are involved in the manufacture of vinegar from sugar-bearing materials. Bacteria are responsible primarily in the production of fermented milks and milk products. Molds are important in the preparation of some cheeses and Oriental foods.

Throughout and during the development of human kind, individuals have learned how to utilize and manipulate the growth of microorganisms for food preparation, development and preservation. The bacterial microorganisms and their perspective by-products utilized most by individuals are those that produce lactic acid.

Lactic acid fermentation of foods such as vegetables (cucumbers, cabbage, olives) and dairy products (some cheeses, buttermilk, yogurt) not only helps preserve foods but gives "fermented" foods a distinctive flavor, texture, and aroma. Lactic acid is produced by lactic acid bacteria.

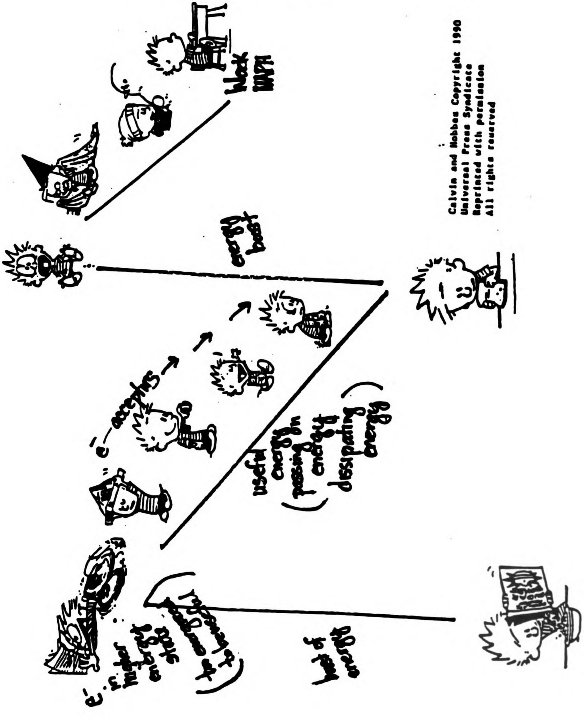
Yeasts are noted for their ability to ferment carbohydrates. "Favorite foods" of yeasts are sugars (sucrose, glucose, fructose, etc.). The results of this fermentation are carbon dioxide and ethyl alcohol . In 1859, Pasteur proved that the result of live activity by tiny yeasts was fermentation. Pasteur's discoveries prompted a new area of research which has since produced volumes of information for medicine, public health, and industry.

Fermentation occurs under anaerobic conditions differently in eukaryotes than in prokaryotes. There are two different products of fermentation among eukaryotes. In the human animal, lactic acid is produced. If you lift a heavy weight up and down rapidly 100 times, for example, your muscle cells get only two molecules of ATP from glycolysis. This situation immediately produces a tired feeling in your muscles. Later, lactic acid in your muscle cells causes your muscles to feel sore. Fungi and plants have a different pathway for fermentation. Ethyl alcohol is produced as a result of these fermentations.

APPENDIX F

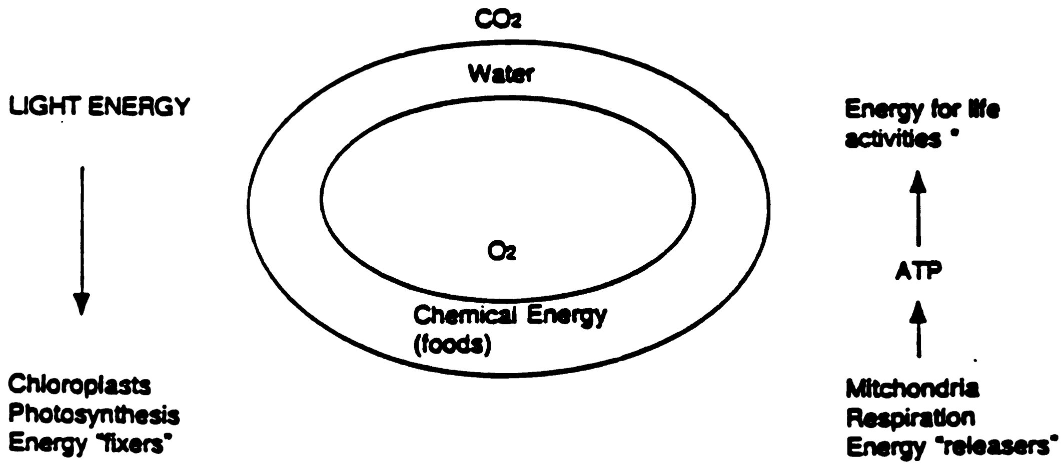
APPENDIX F

PHOTOSYSTEM CAPTURING ENERGY



APPENDIX F

ENERGY FLOWS ONE WAY



* muscle contractions
electrical potentials
active transport
synthetic activities
bioluminescence

APPENDIX G

APPENDIX G

JOURNAL ENTRIES

DAY 1
Write the word energy in ten sentences.

DAY 2
Write your definition of energy in your journals.
Write this scientific definition of energy and compare it to your definition.

Energy is the ability to do work.

Write the definition for kinetic and potential energy:

Kinetic energy is energy due to an object's motion.

Potential energy is energy an object has do to its position or the arrangement of it's parts

Write down these examples:

Kinetic energy-thermal, light, sound, electricity

Potential energy-gravitational , elastic, chemical

If you think of anymore examples tonight write them in your journals for tomorrow.

DAY 3
First Law Of Thermodynamics

Energy cannot be created or destroyed.

Energy can be changed from one form to another, but the total amount of energy never changes.

Second Law of Thermodynamics

Energy does run down in its ability to do work as it is passed from one system to another on its way towards being heat.

Give an example of a system showing the Second Law.

DAY 5
In your journals, draw a diagram or write a story, which represents the *Laws of Thermodynamics.*

DAY 6
Look at your energy sentences and tell whether or not energy and matter are related.

Notes on Energy and Matter

-Plant and animal life on earth is an ordered collection of molecules joined by bonds made of captured energy.

-Bonds are reservoirs of energy , like fuel, that can be put to work in cells to accomplish life's feats of moving, growing, and reproducing.

-Atoms contain kinetic energy as they careen through space. If the kinetic energy of two atoms is great enough, two atoms stick together (chemical reaction) and a molecule is formed.

-The atoms in a molecule can share some electrons. This is called a *covalent bond* which is difficult to break. Covalent bonds hold life's key atoms- carbon, hydrogen, oxygen, nitrogen, phosphorus, etc., together in simple molecules and they join those simple molecules together in chains.

-Cells need to be able to break bonds to rearrange molecules no longer needed. When a bond breaks, the shared electrons fall back into the original orbits around the separated atoms, releasing the energy as heat. (At this time demonstrate with a rubber band how when the band is stretched out, representing the electrons further from the nucleus with greater potential energy, it can cause more damage then when it is not stretched out, representing electrons closer to the nucleus with less potential energy.)

-Cells need to be able to break bonds to rearrange molecules in all sorts of ways and to dispose of molecules no longer needed. When a bond breaks, the shared electrons fall back into the original orbits around the separated atoms, releasing the energy as heat.

-When high energy bonds are broken, the energy is sometimes transferred to other molecules.

-Everything that happens in living cells is the result of various combinations of bond-breaking, bond-making, and bond transfer.

DAY 9

ATP (Adenosine triphosphate)

ATP-the "energy currency" of the cell
TEACHER NOTE:
(20 trillion cells in human body use 1 billion ATP molecules per minute. You recycle 2-3 pounds of ATP everyday. To make that much ATP you must consume 3000 cal/day. The energy consumed by one person each day is equal to energy found in 2.7 kg of dynamite)
Energy is contained in the phosphate bonds.   A-----P P P

When life needs energy, it breaks off one of ATP's phosphates which frees the energy from the bond.

Enzymes are catalysts which work with ATP. They trigger and control particular chemical reactions. (Without enzymes, chemical reactions necessary for life would not occur at a rate sufficient for sustaining life)

Cells use energy to do those things that require work. i.e., movement, changing shape, white blood cell engulfing a bacterium, building new molecules.

DAY 10

FOOD NUTRIENTS

Almost all chemical compounds in living things are made up of combinations of carbon, hydrogen, oxygen, and nitrogen.

These compounds are divided into two groups:
Inorganic-those hat do not contain carbon (exception is CO and CO_2)
Organic-those that do contain carbon

Carbon is unique because of its ability to form strong and stable *covalent bonds.* It can form chains of almost unlimited length.

Organic compounds

1. Carbohydrates=sugars, containing Carbon , Hydrogen, and Oxygen
   Used to provide energy
   - Monosaccharides-simplest sugars
     - glucose, fructose
   - Disaccharides-double sugars
     - sucrose, lactose
   - Polysaccharides-groups of monosaccharides
     - starch, glycogen, cellulose

2. Lipids-waxy or oily compounds
   Used to store energy
   - fatty acids, glycerol, sterols, phospholipids

   Lipids can be saturated or unsaturated.

   Polyunsaturated fats tend to prevent heart disease.

3. Proteins-polymers of amino acids which contain Nitrogen as well as Carbon Hydrogen, Oxygen
   Used to carry out chemical reactions, pump molecules in and out of cells, and
   responsible for cell's ability to move
   Enzymes are proteins.

4. Nucleic Acids-contain Carbon, Oxygen, Nitrogen and Phosphorus
   Used to store and transmit genetic information
   - RNA and DNA

DAY 13

BIG IDEAS

PHOTOSYNTHESIS-is the process by which green plants take energy form sunlight to transform CO_2 and H_2O (along with a few trace elements) through particular chemical reactions into food for the plant along with oxygen gas as a by-product, which is released into the atmosphere.

RESPIRATION-Cells combine complex molecules (made by plants or by other animals which have eaten plants) with oxygen in a chemical reaction which produces CO2, water and energy, along with other by-products. This energy is used by the organism for its life functions.

In photosynthesis, CO_2, H_2O, and energy form sunlight = the plant stuff and O_2, and the plant stuff (food) combine to make H_2O, CO_2, and energy.
Plant and animal like form a kind of cycle each supporting and depending on the other. Energy to make the whole thing work comes from the sun, with plants receiving energy from sunlight and converting it into a form usable by themselves and animals.

$$\text{ENERGY} + \text{CARBON DIOXIDE} + \text{WATER} \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} \text{GLUCOSE} + \text{OXYGEN}$$

$$\text{ENERGY} + CO_2 + H_2O \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + O_2$$

$$\text{GLUCOSE} + \text{OXYGEN} \overset{\text{enzymes}}{\rightleftharpoons} \text{CARBON DIOXIDE} + \text{WATER} + \text{ATP}$$

$$C_6H_{12}O_6 + 6O_2 \overset{\text{enzymes}}{\rightleftharpoons} 6CO_2 + 6H_2O + 36\text{ATP}$$

DAY 22

See typed notes in Appendix E.

DAY 25

In your journals write a story about your life as a photon of light and your travels through an ecosystem as energy that changes form.

DAY 26

You will need to discuss the habitats you have chosen for your Ecocolumns. Include naming the organisms that you have used in your column and how the organisms interact. Where do the living creatures get their energy? What do the organisms need to remain alive? Explain any other interesting ideas you have included in the creating and constructing of your Ecocolumn.

APPENDIX H

APPENDIX H

DEMONSTRATING ENERGY TRANSFORMATIONS

Answer in complete sentences. Explain all of your answers.

PART I KINETIC ENERGY

1. An object contains energy if it has the ability to do work. What does the moving ball do that convinces you it has energy?

2. The energy of moving objects is called kinetic energy. Two factors determine the amount of kinetic energy an object possesses: how fast it is moving (its velocity), and the mass of the object. If a bowling ball and a basketball are moving at the same speed, the more massive bowling ball will have more kinetic energy. When the moving ball hits the stationary ball at the bottom of the tube, there is a transfer of energy. The moving ball has what kind of energy? The stationary ball acquires what form of energy?

3. What energy transformation is taking place in this demonstration?

PART II WORK AND HEAT ENERGY

4. When objects are bent or stretched or rubbed, work is usually being done on them, and they acquire energy. Some of that energy is in what form?

5. When a driver applies the brakes to stop a moving automobile, the brake pad rubs against a metal plate. Would you expect the brake pads to become hotter, colder, or stay the same temperature while the car is slowing down?

APPENDIX H

PART III GRAVITATIONAL POTENTIAL ENERGY

6. Non-moving objects can have the ability to do work: They can have potential energy. Potential energy that is due to an object's position in a gravity field (such as the Earth's) is called gravitational energy. The grapefruit and the brick, when held stationary over the head, have gravitational potential energy. That potential energy is transformed into what form of energy as the object s fall?

7. Catching a grapefruit that falls 1 meter is easy, but your hand would be injured if you dropped a brick on it from a height of 1 meter. (Do not try this!) Which object, the grapefruit or the brick, would transfer more energy to your hand? Which object, therefore, has more potential energy when held 1 meter above your hand?

PART IV ELASTIC POTENTIAL ENERGY

8. Another type of stored energy in non-moving objects is elastic potential energy. This energy is stored in the molecules of objects that are stretched or compressed. The compressed spring of the toy has elastic potential energy. This potential energy is transformed into what form of energy the instant the toy takes off? When the toy stops what form of energy does it have in the spring?

PART V CHEMICAL POTENTIAL ENERGY

9. Work was done on the balloon to stretch it out. Therefore, the balloon required elastic potential energy. That energy must have come from the chemicals that reacted. The energy stored in the chemicals is called chemical potential energy. Some of the chemical potential energy was transformed into what form of energy in the stretched balloon?

10. If you stick a pin into the inflated balloon, the elastic potential energy is transformed into what form(s) of energy?

Reference: Evidence of Energy: An Introduction to Mechanics, Gartrell, Jack E., Jr., Schafer, Larry E., NSTA, 1990.

APPENDIX I

APPENDIX I

BIOLOGY
ENERGY QUIZ

NAME________________
HOUR________________

1. Define energy.

2. Compare *kinetic energy* and *potential energy*.

3. List and describe 3 kinds of *potential energy*.

4. State the *First and Second Laws of Thermodynamics* and explain what they mean. Use explanations in your explanations.

5. Explain how an automobile and the human body are similar and how they are different. In your explanation, include a comparison of the fuel needed, the transferences of energy involved, and the physical or biological make-up of both.

6. Where is the energy stored in and *atom*? In a *molecule*?

7. ATP is called the "energy currency" of the cell. What does this mean?

8. What jobs does ATP have?

9. *Potential energy* is stored in food. Where is this energy found in food?

10. What is the relationship between enzymes and ATP?

BONUS QUESTIONS

11. What is food for plants?

12. Where do plants get their energy to grow, reproduce, etc.?

APPENDIX J

APPENDIX J

MODELS OF THE PROCESSES OF PHOTOSYNTHESIS AND RESPIRATION

KEY:

pink or orange marshmallow=Hydrogen atom
green marshmallow=Carbon atom
yellow marshmallow=Oxygen
toothpick=bond between the atoms

PHOTOSYNTHESIS GROUP

First, build 6 models of CO_2 and H_2O using the marshmallows and toothpicks. From these molecules, build or produce the products, O_2 and $C_6H_{12}O_6$.

Question: What are the possible origins of the oxygen atoms in the carbohydrate product of photosynthesis?

RESPIRATION GROUP

First, build 1 model of $C_6H_{12}O_6$ and 6 molecules of O_2 from the marshmallows and toothpicks. From these, now produce as many H_2O and CO_2 molecules as you can.

Questions: What are the possible origins of the oxygen atoms in the respiration product CO_2?

How many molecules of H_2O and CO_2 did you end up producing?

As a result of your model-building, you should be able to write the chemical equations for both photosynthesis and respiration in the space below. If you cannot, you may look up this information in your textbook or your notes What relationship exists between photosynthesis and respiration?

APPENDIX K

APPENDIX K

"Boosting" Electrons Metaphor

There is an apartment house with several floors. Clumsy bowlers live here and constantly move from one apartment into the next. The upper floor apartments cost more than the lower levels. When residents get raises at their jobs they move to higher floors. When they lose their jobs or get pay cuts, they move down to a lower level. Each time they move they take their bowling balls. Each clumsy bowler drops his/her bowling ball down the stairs when moving, and the ball falls to the bottom of the complex. If the clumsy bowlers who live on a higher level drop their balls, the balls cause a lot of damage because they have a lot of energy. However, if the dwellers drop their balls from a lower level, the balls do less damage because they have less energy.

Questions to consider:

1) Energy added to atoms makes electrons move to different levels in the atom. How is this like the model?

2) Which has more energy an electron in a lower level or an electron in a higher level?

APPENDIX L

APPENDIX L

STORY OF PHOTOSYNTHESIS

As light energy is absorbed by chlorophyll in the living cells of the leaf, the orbiting particles of many atoms become "excited". To understand how the excited particles of chlorophyll do their work, imagine that you go to the circus and meet a team of acrobats. Among the members of the team is a fellow whose name is Electron. As we get to know him better we notice that he has almost peculiar behavior. When the lights go up in the tent and it's time to do his act, Electron gets very excited. His part of the act is very simple. He climbs rapidly to the top of a series of green steps and jumps off, dropping to the end of a springboard. He does the same thing over and over as long as the lights are on.

Other interesting members of the group are Carbon Dioxide and the manager of the group, who is called ATP. The manager always has a box of candy bars handy when the act is about to start. His strong man Carbon Dioxide needs the extra energy in the candy that ATP gives him or Carbon Dioxide cannot complete his part of the act.

Strengthened with the energy from the candy bar, Carbon Dioxide takes his place in the ring. Other members of the team, the Hydrogen twins and Oxygen, climb on one end of the springboard. To keep from falling off the small space, they all clutch hands tightly. Now that everyone is in place, Electron climbs to the top of the steps and without hesitation drops to the opposite end of the springboard. As Electron hits his end of the springboard, the Hydrogen twins and Oxygen fly into the air. But something is wrong. Oxygen was the clown and is no longer part of the performance. But what happened to the Hydrogen twins? What an act. They have landed on the shoulders of Carbon dioxide. The strength from ATP's candy works wonders. He has the Hydrogen twins grasped tightly by the ankles. They stand as one, united in the middle of the ring. Amid thunderous applause, the lights go down and Electron goes to sleep until the lights go up for the next performance.

APPENDIX L

EXPLANATION OF THE PHOTOSYNTHESIS STORY

1. "Electron" is just what his name implies.

2. Light going on in the tent is the light energy that excites the electrons of the chlorophyll molecule. In the analogy the green steps and Electron represent the chlorophyll molecule.

3. Light energy is provided to Electron at each step of the ladder. His potential energy increases with each step he takes up the ladder.

4. The introduction of ATP and its energy-yielding characteristic will serve to give the student some insight into the complexity of photosynthesis.

5. Electron's potential energy becomes active energy as he drops and hits the springboard. Most of the energy that Electron gained in his trip to the top of the steps is converted to another kind of energy in the springboard.

6. Energy is transferred through the springboard to a water molecule, the Hydrogen twins and Oxygen (H_2O).

7. The transferred energy is transformed into another kind of energy, breaking the water molecule apart (H-O-H).

8.Oxygen rolls out of the ring. This represents the release of atmospheric oxygen. (Release of O_2 from plants' activities)

9. Carbon dioxide enters the picture.

10. Emphasize that light energy, by exciting Electron to go up steps, has provided the energy to break the water molecule.

11. At the end of the story we left the Hydrogen twins on Carbon Dioxide's shoulders, locked together in one unit of C, H, and O. Here the student must be made to realize that when atoms are combined into a molecule of glucose, the molecule contains great amounts of stored energy that was transferred to it from Electron and ATP.

Biological Science: Patterns and Processes. Holt, Rinehart and Winston, Inc. 1966.

APPENDIX M

APPENDIX M

From Sugar-making To Sugar-burning

Energy flows into the biological world from the sun. Life exists on Earth because photosynthesis makes it possible to capture some of the light energy from the sun and transform it into the chemical energy of organic molecules. These organic compounds compose what we call food.

Producers-capture the energy from the sun (i.e., plants, some bacteria and algae)
Consumers-obtain energy by consuming other organisms

Trophic level-where an organism is placed dependent on its source of energy
Producers occupy the first trophic level
Herbivores-organisms that consume plants occupy the second level
Carnivores-organsims that consume flesh and **Omnivores**-organisms that consume plants and flesh occupy the remaining levels.
Detritivores-organisms that obtain their energy from dead organisms and organic wastes (i.e., fungus, some bacteria, vultures, and worms)
Decomposers-cause decay (i.e., bacteria and fungi)
Food chain-the path of energy flow in an ecosystem

Every transfer of energy within an ecosystem dissipates energy as heat. Although heat can be harnessed to do work (as in a steam engine), it is generally not a useful source of energy for biological systems. Thus, from a biological point of view, the amount of useful energy available to do work decreases as energy passes through an ecosystem. At each trophic level, the energy stored by the organisms is about one-tenth of that stored by the organisms in the level below.

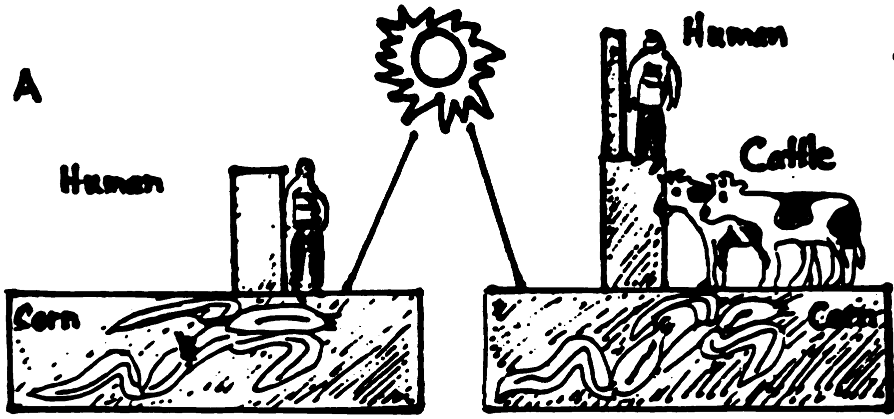
Ecologists often portray the flow of energy through ecosystems by means of a block diagram called a pyramid of energy. In this diagram, each trophic level is represented by a block, and blocks are stacked atop one another, with the lowest trophic level on the bottom. The width of each block is determined by the amount of energy stored in the organisms at that trophic level. Because the energy stored by the organisms at each trophic level is about one-tenth of that stored by the organisms in the level below, the diagram is a pyramid.

APPENDIX N

APPENDIX N

PYRAMID OF ENERGY

Scientists estimate that only 10 percent of the energy present at each level of the food chain is available to the next higher level. Scientists further estimate that 1 percent of the energy from the sun that reaches photosynthetic organisms is converted from light energy to chemical energy during photosynthesis. Based on this information, study the two energy pyramids and answer the questions below.



1. Assume that 1 million kcal of energy from the sun is available to the producers in the food chains above. Determine the amount of energy that will be available at every level of each food chain and fill in the blanks beside each level.

2. What is the total amount of energy available to the human at the top of energy pyramid A? Energy pyramid B?

3. Most terrestrial ecosystems consist of no more than three or four trophic levels. Why do you think this is true?

4. What happens to the energy that does not advance from one level to the next higher one?

5. Earth's population is expanding at a rate that may outpace our ability to produce enough food. Why are some people promoting vegetarianism as an answer to this dilemma?

APPENDIX O

APPENDIX O

ECOCOLUMNS

Think about all the creatures with which you share the Earth. What sorts of insects inhabit your world? What kind of plants grow near your school or home? How do these organisms interact?

With an Ecocolumn you can design bottle habitats for some of the animals and plants with which you live. You can create homes for spiders, snails, fruit flies, fungi, and all sorts of microscopic organisms, and many types of plants. The design possibilities are limited only by your imagination. Before building your Ecocolumn, brainstorm how to create and maintain habitats that will support your living organisms. You will need to consider the energy needs of the organisms, space and shelter needs,and the need for water.

Building the Ecocolumn:

You will need 2 or more two-liter bottles.

Remove the labels from the bottles. NOTE: Soaking the bottles in water helps in removing the labels or soften glue with a blow dryer.

Cut the top off bottle #1 about 1 cm below shoulder. Cut the bottom off 1 cm below the hip.

Cut top off bottle #2 about 1 cm below shoulder.

Slide A down into B. Tape A/B joint. NOTE: Use clear packing tape or similar tape which has a width of about 5 cm. If you need a water-tight seal, use silicone sealant on the joints. Stack chamber A/B on C.

Make as many chambers as you need for your stack of habitats. Connect them by punching holes in the caps and bottle tops. Tape all chambers that will not be opened.

Reference: Bottle Biology, Kendall/Hunt, 1993.

APPENDIX P

APPENDIX P

A LEARNING VS. WORK SETTING

A CONCEPTUAL CHANGE SCIENCE LEARNING COMMUNITY	A WORK-ORIENTED SETTING
Sense-making and learning as the goal	Getting the work done as the goal; getting facts learned or activities and projects completed
Personal, emotional involvement in meaningful and authentic problem situations	Depersonalized, unemotional relationship with work, getting the products made
Ownership and commitment by each person; responsibility shared	Teacher as executive in charge of everything
Active inquiry and question-making are valued and encouraged	Getting the right answer is valued and encouraged
Expertise comes from everyone, is shared; learning is a collaborative process	Expertise comes from the teacher and learning is a private activity
Everyone's ideas are valued and respected as useful in the learning process; diversity is celebrated in a caring environment	Workers need to keep quiet and busy; diversity is a problem for quality control and efficiency
Good learners listen to each other	Good workers listen to the teacher
Public sharing and revising (working out) of ideas	Only complete, polished final products are shared
Evidence, not authority, is used to construct new knowledge and judge merits of ideas	Knowledge comes wrapped in neat packages that are delivered from teacher or text to student; all packages are to be appreciated and not questioned
Each learner starts and finishes in a unique place; learning as a process of conceptual change	All workers create the same product or else are failures; learning as a "you have it or you don't" phenomena

From Kathleen J. Roth, (1992).

APPENDIX Q

APPENDIX Q

9-PATCH QUILT METAPHOR

The Top Layer of the Quilt: has patches that represent for us the various units we teach in our classrooms--the series of interrelated activities we engage in with students over time. Each of these patches may look very colorful and independent, but alone they do not contribute to making a quilt--to helping students construct understanding--unless they are connected in several ways.

The Middle Layer (Batting): Underneath the patches is the batting, which provides the substance, the warmth of the quilt. To us, this batting represents the big ideas and methods of inquiry in the disciplines from which our units are drawn. If our units are not backed by such important ideas, the patches--the units made up of activities--will not have any function, any meaning. But the patches and the depth, the batting, still do not make the quilt.

The Backing and Quilting Stitches: The patches and batting are held together by a backing and by many tiny, intricate "quilting" stitches. The stitches represent the qualities of the learning place. Without this backing and the many tiny, consistent stitches, the quilt would fall apart. It would not only lose its function, it would lose much of its beauty, for the tiny stitches that go through all three layers of the quilt to form the beautiful patterns; they are not random. We think of the backing of the quilt as the learning community in our classrooms and the stitches as the qualities of the learning setting that are created over time as students and teachers engage in learning activities together. People visiting our classrooms need to look for "tiny stitches" to appreciate the qualities of our learning environment: The feedback students receive from their teacher on written work; the encouragement to ask questions and to make sense instead of just finishing work or memorizing facts; the care put into teacher questions and activities to communicate sense-making and meaning; the ways in which student ideas are listened to and brought into the fabric of the classroom; the encouragement and support students are given to forge new connections and patterns.

The Quilters: The teachers and students are the quilters who work together to put these patches together patiently over time using consistent, tiny stitches. We as teachers consistently try to communicate, through our actions and the activities we choose, that this is a collaborative learning setting.

<u>The "Finished" Quilt:</u> In our metaphor, the warm, finished quilt with its patches and intricate stitching patterns represents the quality of understandings that children develop.

<u>The Quilting Process:</u> Like many quilters, we are working on our quilt together, patiently over time. This represents an appreciation of the importance of the quilting (or learning) process--the interaction, reflection, collaboration--as well as the finished product. Also like quilters, we are never sure our quilt is finished completely; we reserve the right to go back and rearrange the patches or restitch an area. This parallels the tentative nature of knowledge and the need to revisit and revise our thinking as members of the classroom learning community.

Reference: Kathleen J. Roth, et. al., *The Role of Writing in Creating a Science Learning Community*, Paper presented at the annual meeting of the National Association for Research in Science Teachers, Lake Geneva, IL, April, 1990.

APPENDIX R

APPENDIX R

ENERGY

Pre-Test and Post Test

MULTIPLE CHOICE Circle the letter of the term of phrase that best completes each statement or best answers each question.

1. Energy is required for a variety of life processes including
   a. growth and reproduction.
   b. movement.
   c. transport of certain materials across cell membranes.
   d. All of the above require energy.

2. Which of the following does not represent a form of energy?
   a. light
   b. heat
   c. water
   d. electricity

3. The statement that "energy can neither be created nor destroyed, but can be changed in form"
   a. is not true for all forms of energy.
   b. is the first law of thermodynamics.
   c. applies only to kinetic energy.
   d. is completely untrue.

4. Which of the following situations is the most stable?
   a. a boulder on top of a hill
   b. a house made out of playing cards stacked on each other
   c. three cheerleaders standing on each other's shoulders
   d. four tennis balls lying on the ground

5. Heterotrophs are organisms that can
   a. produce food from inorganic molecules and sunlight.
   b. survive without energy.
   c. consume other organisms for energy.
   d. carry out either photosynthesis or chemosynthesis.

6. The energy that is stored in food molecules and used by organisms
   a. resides in the nucleus.
   b. is equally distributed among all the atoms' electrons
   c. is held primarily by electrons shared by carbon and hydrogen atoms.
   d. comes from protons orbiting the nucleus.

7. The sun is considered the ultimate source of energy for life on Earth because
   a. all organisms carry out photosynthesis.
   b. all organisms carry out cellular respiration.
   c. either photosynthetic organisms or organisms that have eaten them provide energy for all other organisms on Earth.
   d. the sun heats the Earth's atmosphere.

8. ATP is called a cell's "energy currency" because
   a. it catalyzes all metabolic reactions.
   b. it allows one organelle to be exchanged for another between cells.
   c. all molecules of glucose, a primary source of energy, are made of it.
   d. most of the energy that drives metabolism is supplied by it.

9. Based on the cycle of photosynthesis and cellular respiration, one can say that the ultimate original source of energy for all living things on Earth is
   a. carbohydrates.
   b. water.
   c. the sun.
   d. electrons.

10. All organic molecules contain carbon atoms that ultimately can be traced back in the food chain to
   a. the bodies of heterotrophs.
   b. carbon dioxide from the atmosphere.
   c. water absorbed by plants.
   d. the carbon that comes from the sun.

11. Tiny packets of radiant energy are called
   a. photons.
   b. protons.
   c. eons.
   d. electrons.

12. When photons of light strike an object, the light may be
   a. reflected.
   b. absorbed.
   c. transmitted.
   d. All of the above may occur.

13. What happens when a chlorophyll molecule absorbs a photon of light?
    a. Some of its electrons are raised to a higher energy level.
    b. It disintegrates, giving off huge amounts of heat.
    c. It glows, radiating green light and giving the plant a green appearance.
    d. Red and blue wavelengths are emitted.

14. When electrons of a chlorophyll molecule are raised to a higher energy level
    a. they become a photon of light.
    b. they form a glucose bond.
    c. they enter an electron transport chain.
    d. carotenoids are converted to chlorophyll.

15. The source of oxygen produced during photosynthesis is
    a. carbon dioxide.
    b. water.
    c. the air.
    d. glucose.

16. All organisms that live in a particular place and their physical location make up a(an)
    a. ecosystem.
    b. habitat.
    c. community.
    d. food chain.

17. An ecosystem consists of
    a. a community of organisms.
    b. energy.
    c. the soil, water, and weather.
    d. All of the above.

18. Ecology is the study of the interaction of living organisms
    a. with each other and their habitat.
    b. and their communities.
    c. with each other and their physical environment.
    d. and the food they eat.

19. A relationship between a producer and consumer is best illustrated by
    a. a snake eating a bird.
    b. a fox eating a mouse.
    c. a lion eating a zebra.
    d. a zebra eating grass.

20. In a food web, which type of organism receives energy from every other type?

a. producer
b. carnivore
c. decomposer
d. herbivore

21. In an ecosystem, the producers may include

a. lions, zebras, and bacteria.
b. trees, grass, and shrubs.
c. vultures, deer, and eagles.
d. bacteria, fungi, and algae.

22. The most abundant organisms in a food chain are the

a. producers.
b. herbivores.
c. carnivores.
d. omnivores.

23. Animals that feed on plants are at least in the

a. first trophic level.
b. second trophic level.
c. carnivores.
d. omnivores.

24. The number of trophic levels in an ecological pyramid

a. is limitless.
b. is limited by the amount of energy that is lost at each trophic level.
c. never exceeds four.
d. never exceeds three.

25. Food webs are more commonplace than food chains because

a. the animals that comprise the links in the food chain are mobile, hence the chains become intertwined.
b. organisms almost always eat, and are eaten by, many different organisms.
c. over time food chains always disappear.
d. None of the above.

26. In going from one trophic level to the next higher level

a. the number of organisms increases.
b. the amount of usable energy increases.
c. the amount of usable energy decreases.
d. diversity of organisms increases.

TRUE/FALSE Read each statement. If the statement is true, write T in the space provided. If the statement is false, write F in the space provided.

27. _____ Energy of motion is often referred to as potential energy.
28. _____ When a person uses food as a source of energy to run a race, energy is converted from chemical to mechanical form.
29. _____ The entropy of the universe constantly increases as the energy in the universe becomes more and more organized.
30. _____Without enzymes, chemical reactions necessary for life would not occur at a rate sufficient to sustain life.
31. _____ NAD+ acts as a cell's "energy currency".
32. _____ An autotroph is able to make its own organic molecules from inorganic materials and energy.
33. _____ Energy moves through food chains from heterotrophs to producers to consumers.
34._____ When light hits a plant, all of the wavelengths are absorbed and used to make sugar.
35. _____ Cells that are deprived of oxygen may produce ethyl alcohol and carbon dioxide through fermentation.
36. _____ Carbohydrates are important parts of an organism's diet because they are the only molecules that can yield enough energy to produce ATP during cellular respiration.
37. _____ All organisms in an ecosystem are part of the food web of that ecosystem.
38. _____ The source of energy of an organism determines its trophic level.
39. _____ Decomposers absorb energy from organisms by breaking down living tissue.
40. _____ The lowest trophic level of any ecosystem is occupied by the producers.
41. _____ Producers are at the bottom of ecological pyramids.
42. _____ A food chain is made up of interrelated food webs.
43. _____ Biomass pyramids can point up or down depending on the ecosystem.
44. _____Omnivores feed only on primary producers.
45. _____ The number of organisms in a trophic level is always directly proportional to the amount of energy at that level.

SHORT ANSWER Complete each statement by writing the correct term or phrase in the space provided.

46. ________________ is defined as the ability to cause change, or to do work.

47. Energy that is actively engaged in doing work is called____________ work.

48. ________________ refers to the level of disorder in the universe.

49. Organisms that harvest energy from either sunlight or chemicals in order to make food molecules are called ____________________.

50. Metabolism consists of the capture, transfer, and use of ____________ within the cells of an organism.

51. The ultimate source of energy for all life on Earth is the ______________.

52. The complete range of radiant energy forms is called the

________________________ ______________________________.

53. An ecosystem consists of the living and ____________________ environment.

54. A path of energy through the energy levels of an ecosystem is called a

______________________________.

55. Every time energy is transferred in an ecosystem, potential energy is lost as

______________________________.

56. An energy pyramid shows the amount of energy contained in the bodies of organisms at each ____________________ level.

57. The sequence of one organism feeding upon another is called a food chain. A network of intertwined food chains is called a ________________________.

CONSTRUCTED RESPONSE QUESTIONS

58. The relationship between photosynthesis and respiration is usually described as a cycle. Explain why this is true.

59. Green plants need energy to survive and grow. From the list, below, circle the item(s) which you think are used by green plants as energy for growth and survival. Explain your answer.

water soil sunlight fertilizer bacteria insects in the soil

60. Explain why the leaves of plants appear green to the human eye?

61. In any given community organisms can be classified as producers, consumers, and decomposers. Classify each of the organisms listed below as producers (P), consumers (C), or decomposers (D).

_____grass (blades & seeds)
_____ soil bacteria
_____ mushroom
_____ earth worm
_____ coyote
_____ mosquito
_____ bat
______ hawk
______ mouse
______ deer
______ White Cedar tree
______ frog
______ Purple Martin bird

Assume that the organisms listed above live together in a ecosystem. Show how energy flows through the community in the space below. Tell what kind of energy is flowing in your diagram. Include sunlight and heat in your drawing. Try to include every organism in your diagram.

62. A human needs energy to carry out life functions such as breathing, moving, or growing. Which of the following is (are) source(s) of energy for human life functions (check all correct)?

_____ milk
_____ minerals (e.g., iron in Geritol)
_____hamburger
_____sunlight striking the skin
_____heat
_____water
_____sugar

Select one of the human energy sources above and trace its energy back to its ultimate source, showing all the transitions it may have gone through.

Humans get energy from ______________________________________.
That energy comes from______________________________________,
which comes from ____,
which comes from ______________________________________, etc.
____
____

What was the ultimate source of energy in this food? _________________.

63. Several years ago John Christopher wrote a gripping science fiction book called No Blade of Grass. In it he described the chaos that enveloped the earth when a rapidly spreading virus attacked all forms of grass, including all grains such as wheat, corn, and rice. If we were suddenly faced with destruction of all forms of the grasses, try to predict what would happen to the human food supply. Consider the following foods: eggs, cabbage, rice, pork chops, potatoes, oranges, white bread, cheese, roast beef, tuna. Which of these foods would still be available in substantial quantities? Why would these foods be available? Which of these foods would be scarce or non-existent? Explain why each food that you list would become scarce.

64. Is it good or bad advice to instruct an over-populated country to feed its people beef to supply them with necessary energy? Why or why not?