AN ASTRONOMY/BIOLOGY INTEGRATED SCIENCE CURRICULUM FOR MIDDLE SCHOOL

THESIS

Presented to the Graduate School of

Southwest Texas State University

In Partial Fulfillment

of the Requirements

For the Degree of

MASTER OF SCIENCES

by

Clifford Hamrick, B.S.

San Marcos, Texas

December, 1998

Abstract

This study developed an integrated science curriculum connecting astronomical and biological concepts. It is addressed to middle school teachers. The curriculum consists of four modules organized by themes according to the National Research Council's Standards: energy transfer, properties of various wavelengths of light, origin and distribution of matter in ecosystems, and adaptations useful for living in various types of environments. Each module is developed with a modified Learning Cycle approach that aids in the understanding of the effects of astronomical phenomena on living organisms. Hands-on, investigative activities are used to teach middle school science process skills as well as basic concepts. Common, inexpensive materials are used to facilitate the usefulness of the curriculum for low-income teachers and school districts. Teacher feedback, obtained through presentations at state science teacher conferences, was used to assess the curriculum's success in grade level appropriateness, stimulation of higher order thinking, and evaluation of conceptual understanding.

Background information for this study describes the history of integrated science curricula in the United States, surveys major integrated science programs throughout the world, and discusses the research on the effectiveness of integrated science programs. Also, this study outlines the history of the Learning Cycle teaching method and discusses the research on its effectiveness.

Table of Contents

Acknowledgments

First, I'd like to thank my parents. Without their genetic contribution I would not be here today. I'd also like to thank them for not having anymore children and spending all their time spoiling me as their only son. I also want to thank them for letting me study the subjects that I found interesting as a child.

Second, I'd like to thank Dr. Melanie Lewis for her guidance, patience, and tolerance. She spent much of her time explaining all the ins and outs of educational jargon, listening to my ravings about classes, and tolerating my wardrobe. Though I feel that I was given the talent for teaching from a higher power, she has helped me hone that talent into a precise skill that will last with me forever. In the future, whenever a student compliments me on my teaching, Dr. Lewis will have to take some of the credit. She has been my mentor in the truest sense of the word.

Third, I'd like to thank Dr. Olson and Dr. Barnes, my committee members, for their assistance in writing this curriculum. Their expertise in their respective disciplines of science helped me create the novel activities that make this curriculum interesting and fun.

Fourth, I'd like to thank Dr. Prabhakaran for taking a chance and letting me teach A&P labs for him. During the course of the two years of teaching for him, I have gained valuable experience at teaching a college class. He has demonstrated how to organize and maintain a large class teaching a difficult topic. I will certainly use his techniques in the future.

Finally, I'd like to thank Dr. Terry Maxwell, Professor of Biology at my alma mater. When I indicated to him an interest in entering graduate school, he told me that I not only 'didn't have what it takes' to finish graduate school, but even to get in. Thanks to his harsh words and lack of support, at times when I felt that I could not go on and I was seriously considering throwing in the towel, I pressed on ahead if for no other reason, but to prove him wrong.

Introduction

Science can be defined as a way of understanding the universe. Since the universe can be sub-divided into many parts, a myriad of specific subjects, such geology, biology, and chemistry can be defined. Though all of these specific subjects have their own methods and tools for understanding their respective topics, they are all ways of understanding the universe.

Through the years of study, scientists who have followed one of these subjects have tended to become entrenched into their categories of study. Today, as more and more information is being discovered about each individual subject, this is seen as a necessity. Scientists must become experts in their fields and as more information has been discovered, the fields have become narrower. As a result, many scientists have only a marginal understanding of sciences outside their field of study.

Science education has followed a similar trend. As more information has been discovered, more information is necessary to be learned. Science educators have had to follow suit with scientists and become more specialized in their fields of teaching. Since World War II, science subjects, especially in secondary schools, have become compartmentalized such that students may be given the impression that the world works in discrete areas of life, matter, and energy.

However, today there is a trend to unify knowledge to understand old subjects in a new way. Many scientific organizations such as the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) have recently created new divisions that combine one field of study with another. In the case of NASA, they have created the Astrobiology Division to study the possibility of life outside the Earth. In the case of the USGS, they created the Biological Resources Division to relate the effects of organisms, typically plants, and geology on one another (Eaton, 1997).

Educators have also followed the trend of unification of knowledge. In many states, like Texas, Alabama, and Hawaii, integrated science programs have been developed and implemented. Today, many students do not enter a life science or earth science classroom. They enter a science classroom in which the various science subjects are taught in a seamless continuity or the emphasis is on the relationship between two or more science subjects.

The purpose of this study is to develop a teacher's guide for an integrated science curriculum that connects astronomical and biological concepts for middle school students. The topics were chosen for three reasons: the general lack of such an integrated curriculum (currently only two other programs are known in the United States), the recent discovery of possible fossilized life in a Martian rock, and the interest of the author in both subject areas. Because science integration in Texas only occurs in elementary and middle school grades and both biology and astronomy topics are traditionally taught in the seventh and eighth grade life and earth science curricula, this curriculum targets seventh grade students.

Background and Research

Overview

This is an integrated science curriculum that uses a modified form of the Learning Cycle. Both integrated science and the Learning Cycle have had influential roles in the history of science education. Both have come into and out of favor with educators and researchers. In order to better understand the importance of their roles in education, background research must be studied. The following are literature studies that look at the history and development of integrated science and the Learning Cycle. Both studies list the researchers that have influenced both areas, the influences of the both areas on science education world-wide, and scientific research that supports or does not support the claims of both areas. The literature sources of the studies are listed in the bibliography section of the thesis.

Traditional Classroom Instruction and the Need for the Learning Cycle

In the past there have been many different methods of instruction introduced to science educators. Traditional methods of science instruction center around teaching concepts in a lecture format with occasional lab exercises to reinforce the concepts learned. This method, called the direct method, the teacher often relies on the textbook as the source of most of the concepts taught, the sequence in which they are taught, and how the students will be assessed in their understanding of the concepts (Barnard, 1960; DeRose, et al., 1979). In this method of teaching, most questions asked in the classroom are fact-oriented and not usually pre-planned, instruction is more often verbal rather than related to events or materials, and students usually have few opportunities to manipulate materials or plan activities (Wise and Okey, 1983). This method of teaching allows for an efficient covering of concepts, a sharp focus on a single discipline such as biology, and simple assessment techniques for the teacher to use. This method may be effective for attaining some educational outcomes or objectives and may be effective for some kinds of students (Peterson, 1979).

The impact of the direct method on the views students have about science and science teachers was described by Yager and Penick in 1984. Out of 2500 students, 42% of thirteen year olds and 44% of seventeen year olds feel that they are encouraged to state their own opinions by their science teachers and 48% of thirteen year olds and 46% of seventeen year olds perceive their science teachers as seldom or never admitting that they do not know "everything" about a given subject or concept. Also out of the same study, 57% of thirteen year olds and 53% of seventeen year olds agreed with the statement "science classes make me unhappy". Well over half of the thirteen and seventeen year olds reported that they seldom or never chose which science topics to study or projects to do, chose the way they want to learn science, or selected the order for studying science topics. The irony of this fairly recent research is demonstrated by the Thirty-first Yearbook of the National Society for the Study of Education, A Program for Teaching Science (Craig, 1932), in which the Committee, composed of professors of education, stated, "The present practice of some schools of limiting the work in the seventh, eighth, and ninth grades to mere textbook study and recitation cannot be too strongly condemned as a harmful procedure."

In the early 1960's, a reform movement began to change the instructional methods from the teacher-based lecture format to a more student-based discovery learning approach which allows students to manipulate materials to "discover" how the natural world works. These ideas are supported in the recommendations of the Fifty-ninth Yearbook of the National Society for the Study of Education, Rethinking Science Education (Barnard, 1960). The Committee recommended curricula that provide opportunities for students to learn, practice, and develop critical thinking skills which are paramount to understanding the scientific method. The Committee also stated, "many commonly used teaching procedures offer little promise of realizing such objectives of science-teaching as the development of problem-solving, ability, critical attitudes, and an appreciation of science" and "more attention should be directed to the process or methods of seeking answers in the laboratory rather than putting so much stress on finding exact answers" (Barnard, 1960).

In 1962, J. Myron Atkin, a Professor of Education at the University of Illinois, and Robert Karplus, a Professor of Physics at the University of California at Berkeley, suggested a new method of teaching which combined the strengths of the traditional lecture method with discovery learning (Atkin and Karplus, 1962). This new method of science teaching included basic guidelines. The first guideline is to allow students to observe their world and invent hypotheses about how the world works. If the students are not able to invent their own, then the teacher must introduce the modern scientific theories. However, it is important that the teacher make clear which of the students' observations can be interpreted as a proper example of the theory. Also, the teacher must provide more discovering opportunities for the students to observe examples of the theory at work. Finally, the teacher must not present the theory in a complete, definitive, and authoritative way, for theories are never final. In later publications, Karplus introduced the Learning Cycle, the formalized learning sequence which was originally suggested in his first paper (Karplus, 1974). He structured the sequence with three distinct phases: exploration, concept introduction, and concept application.

In the first phase of the Learning Cycle, exploration, the students are exposed to a concept without any prior introduction of the material. An example of a typical exploration phase is to have students experiment with a light bulb, a D-cell battery, and two copper wires to make the light bulb light up. The students have not been introduced to any concepts or terms at this point. The learning mode in this phase is discovery. The students, by discovering the phenomenon, are more likely to understand the phenomenon. At least, the students will have the opportunity to get the thrill that comes with discovering something new.

In the second phase of the Learning Cycle, concept introduction, the educator explains the concept studied. In the above example, the educator will explain the concept of a circuit and the necessity of all of the components in the circuit. Terms are also introduced in this phase. This phase is necessary as students will often invent their terms and define them in their own ways during the exploration phase. During the concept introduction phase, the educator gives them the same terms that are used in the scientific world to prevent future confusion.

The third phase of the Learning Cycle, concept application, extends the basic concept learned in the exploration phase and applies the concept to the student's everyday life. This is usually accomplished through another activity that is similar to the exploration, but slightly more complex or integrating previously learned concepts. As in the above example, the students will disassemble a flashlight to see how it functions and identify all the parts necessary to make the circuit function. The purpose of this phase is to move the students from a basic, simple concept to a more complicated concept. Also during this phase, the educator should try to show how the basic concept affects the learner in everyday life. By applying the concept to the learner's everyday life, the student gains an appreciation of the importance of the concept. In this example, students learn how a flashlight functions, which can be extended into learning how a simple light switch functions. Learning is no longer a meaningless exercise of memorizing unrelated facts, but a way to gain an understanding of how the world works.

From the concept application phase, new concepts can be introduced. This can lead to new exploration phases. As in the above example, the new exploration phase could be discovering what other materials beside copper wire could or could not be used in the circuit. This will lead into a discussion of the characteristics of an electrical conducting material. Terms such as insulator and conductor could be introduced in the concept introduction phase. And in the concept application, the students could take household items such as forks or knives and build a circuit or take a copper wire apart and examine the parts inside. This idea of one concept naturally leading into the next is the cyclical nature of the Learning Cycle.

In 1962, Karplus developed the Science Curriculum Improvement Study (SCIS) (Karplus and Thier, 1967). SCIS explored the idea of allowing children the time to experiment at their own pace and with their own preconceptions, then introducing the proper scientific explanation and terms. Robert Karplus was joined by Dr. Herbert Thier, Assistant Superintendent of Schools in Falls Church, Virginia, and Doris Hadary, an Assistant Professor of Chemistry at American University. Together, they had the opportunity to implement the new approach in Maryland public schools, where Karplus was a visiting professor. It should be noted that much of the early development of the program involved not only educators, but scientists as well. In 1963, the SCIS project resumed its work at UC Berkeley.

Since the late 1970's, research has been conducted to measure the effectiveness of the Learning Cycle and other "open" methods of instruction versus the traditional, "direct" instruction. Open methods of instruction are defined as allowing flexible use of space, student choice of activity, richness of learning materials, integration of curriculum areas, and more individual or small-group than large-group instruction (Peterson, 1979). The Learning Cycle could be considered a form of open instruction. The direct method of instruction allows an academic focus, teacher-centered focus, little student choice of activity, use of large groups rather than small groups for instruction, and uses factual questions and controlled practice in instruction (DeRose, Lockard, and Paldy, 1979; Peterson, 1979; Rosenshine, 1979). In a review article comparing the effectiveness of open versus direct methods of instruction (Peterson, 1979), 46% of 102 studies showed no difference in the cognitive achievement of students taught by an open method versus those taught by a direct method. Though students taught with an open method may not learn the material any differently that those taught by a direct method, their attitude toward school, curiosity level, and feeling of independence are increased (Peterson, 1979).

The Learning Cycle itself has been the focus of many research studies to explore its effectiveness. The Learning Cycle teaching method leads to greater gains in content-achievement and retention than the direct teaching method (Schneider and Renner, 1980; Renner, Abraham, and Birnie, 1988). All of the phases of the Learning Cycle in the theoretical sequence outlined by Karplus are necessary to produce effective results (Renner, Abraham, and Birnie, 1988). Students taught by the Learning Cycle are more likely to understand a concept correctly and use terms appropriately than those students taught by the direct method (Stephans et al, 1988). The Learning Cycle is a teaching procedure and curriculum construction model which encourages students to move from one intellectual level to another and to develop deeper understandings of the content being taught (Schneider and Renner, 1980; Purser and Renner, 1983; Renner, 1986; Rubin and Norman, 1992). Also, the Learning Cycle teaching method moves students from one intellectual level to the next faster than the direct teaching method (Purser and Renner, 1983). And, the Learning Cycle has also been shown to improve students' achievements in integrated science process skills such as making hypotheses, identifying and controlling variables, interpreting data, and designing experiments (Rubin and Norman, 1992).

In 1986, Anton Lawson categorized the Learning Cycle into three different forms: descriptive, empirical-inductive, hypothetical-deductive. The primary difference between the three categories is the degree to which students either gather data in a purely descriptive fashion or initially set out to test hypotheses in a controlled fashion. Curriculums using descriptive Learning Cycles require the students to discover and describe a pattern within a specific context (exploration), the teacher to give it a name (concept introduction), and the pattern to be identified in other settings (concept application). Curriculums using empirical-inductive Learning Cycles require the students to discover and describe a pattern within a specific context (exploration), but they go further by generating possible causes of that pattern. This requires an understanding of terms and concepts from other settings to apply them to a new situation. The terms may be introduced by the students, teacher, or both (concept introduction). The students then use the data gathered during the exploration phase to determine if the hypothesized causes adequately explain the concept studied (concept application). Curriculums using hypothetical-deductive Learning Cycles are initiated by a causal question to which students are to generate possible answers. The students then devote their time to designing and conducting experiments to test their hypotheses (exploration). The analysis of the experimental results allows for some hypotheses to be rejected, others retained, and terms to be introduced (concept introduction). The hypotheses that are retained can be applied to other situations at a later time (concept application).

The curriculum designed in this study can be labeled as using the empirical-inductive type of Learning Cycle. Students completing the activities in the curriculum are guided by instructions that are designed to explain a concept. The Key Questions that the students answer often ask them to describe what they discovered and to offer possible explanations for the causes of the phenomena they saw. The activity after that will build upon the concept just learned. In this way, the subsequent activity will serve as the concept application for the preceding activity. As an example, the activity Photosynthesis I in Module Two, requires the students to grow plants in boxes with different colors of cellophane covering the plant. After the two weeks, the students are then required to measure the height of the plants. The instructions guide the students to discover a pattern (exploration). The Key Questions ask the students to describe the pattern discovered and give possible explanations for the pattern (concept introduction). The subsequent activity, Photosynthesis II, serves as the concept application by providing an opportunity for the students to use their knowledge in a slightly different context.

At about the same time that the research of the 1970's and 1980's was being conducted, another group, the Biological Sciences Curriculum Study (BSCS), was looking into ways of improving science education, particularly in biology. The main focus of this organization is developing new curricula based upon learning theories and teaching methods with strong research bases. Currently, the main aim of the organization is developing scientific literacy. The BSCS is composed of research scientists, teachers, learning theorists, and science educators. Together they created a modified form of Karplus' Learning Cycle. Their modifications were two additional new phases: engagement and evaluation. The engagement phase is the first phase in their modified instructional model. During this phase, a short activity or demonstration is performed to initiate learning, make connections between past and present learning experiences, and organize the students' thinking towards the current activities. The evaluation phase is the last phase in their modified instructional model and provides an opportunity for the teacher to assess the students' progress toward understanding the concepts taught in the activity. BSCS also renamed the concept introduction and concept application phases to explanation and elaboration, respectively. The entire BSCS instructional model has been nicknamed the 5-E instructional model for the engagement, exploration, explanation, elaboration, and evaluation phases.

Charles Barman, the creator of the instructional model used in the curriculum presented in this thesis, has also modified the original Learning Cycle (Barman, 1997). Though the original idea is still intact, he has added one more phase: the assessment phase. He has placed this new phase at the beginning of the cycle, before the exploration phase. During this phase, the educator asks students probing questions on the concept about to be studied. One purpose of this phase is to get the students thinking about the concept about to be explored. But more importantly, these questions are designed to enable the educator to determine the prior knowledge and prior misconceptions that the students may have about the concept. Students often have some prior experience with the concept studied. However, the students may or may not completely understand the concept. This often leads to misconceptions. The educator must become aware of these misconceptions in order to effectively address them in the lessons ahead. Students will often maintain these misconceptions if they are not dispelled by the educator during the lesson (Osborne and Freyberg, 1985).

Though Barman has retained the other three phases of the original Learning Cycle, he has changed their names. The exploration phase is now called the investigation phase. The concept introduction phase is called the dialogue phase. And, the concept application phase is called the application phase. All of these phases are conducted in the same manner as in the original Learning Cycle model.

Unlike the BSCS model which has a phase dedicated to evaluation, Barman suggests that each of the phases are opportunities for evaluation. At the assessment phase, the teacher can evaluate the amount and type of misconceptions the students hold. Also, in those rare instances when the students do not have any misconceptions, the teacher can evaluate the organization and depth of the students' thinking on the concept discussed. During the investigation phase, the teacher can evaluate student participation, cooperation, and organization, all of which are necessary skills to perform good science. During the dialogue phase, the teacher can evaluate students on their participation and understanding of the discussion of the concept. Finally, the application is the phase where an evaluation of the students' understanding of the concept can be performed. The student must have a good understanding of the concept taught during the exploration phase in order to successfully complete the application phase. By grading the students' completion of the activity in the application phase, the teacher can evaluate the students' understanding of the concept.

Currently, a learning theory called constructivism has become prominent in science education and provides a theoretical underpinning for curriculum development. The original theory came from Jean Piaget's developmental psychology theory in the late 1950's. Though there is no one researcher or paper that has formally laid out the theory of constructivism, the earliest author using the term is George Forman in 1977. However, many authors have redefined the term over the years. Today, constructivism can simply be defined as the dynamic, interactive process by which knowledge is constructed through developing and testing theories based on a foundation of physical experiences (Chaille and

Britain, 1997). Curricula organized around the constructivist learning theory allow students to experiment and build theories by providing materials and experiences. The content and sequence of the activities in the curriculum should also be directed by the students' curiosity of processes rather than an adult's perspective on content. The Learning Cycle is a teaching method that works well with the constructivist learning theory. The structure and sequence of the phases of the Learning Cycle gives an educator and the students some guidance to learn the content of science without overly restricting the important process of discovery and theory building.

A Definition of Integrated Science

Integrated science does not appear to have a single, clear definition. This may be due to the lack of a theoretical basis or a single individual or group with the authority to define it. The term "integrated science" has been used in many ways to describe various methods of organizing science curricula over the years. Though these methods are different in many ways, they all share the basic idea that many scientific disciplines should be organized in a manner that will show the commonalties of the disciplines. However, this simple idea can be accomplished through many means, which is a source of confusion.

Unified science is the most carefully crafted of the programs that could be confused with integrated science. Unified science was invented by Irwin Slesnick and Victor Showalter (Slesnick, 1961) and has definite characteristics. According to them, unified science is the organizing of science curricula so that all of the disciplines of science are taught together in one classroom. There is no distinction between any of the sciences. Unification is accomplished by using themes, concepts, or objectives that are common to all sciences producing a seamless continuation. For instance, one unit of instruction in a unified science classroom would be the "Orderliness of Nature" (Showalter, 1964). In this unit, natural phenomena would be grouped in categories of matter, energy, and life. The basis and usefulness of the periodic table and the electromagnetic spectrum would be emphasized. And, the established phylogenetic classification scheme would be approached as an ordered scheme that reflects evolutionary processes.

Unified science is a revolutionary idea, which might be the reason that the term is used very rarely today. To implement a unified science philosophy, school curricula would have to be completely changed. No longer would individual discipline classes, such as physics or chemistry, be possible. Only one science, unified science, would be used. Also, teacher training would have to be overhauled. Teachers could no longer be considered "biology" or "chemistry" teachers. Their college education would have to be more generalized, and perhaps longer, so that teachers would be prepared for and comfortable with teaching multiple disciplines at once. This would be a very major shift for current secondary teachers who are trained as scientists in a specific discipline with a teaching certification. Many of them may not have the background to teach other disciplines. Integrated science, however, is not as revolutionary as unified science. A teacher, if he/she chooses, may keep the number of disciplines small and closely related to minimize the amount of necessary changes in the curriculum. Also, teachers may feel more comfortable teaching disciplines for which they have had more training, such as their minor area of study.

Another term that has been confused with integrated science is "coordinated science", sometimes referred to as "the teacher of the day" model, which was delineated by Bill Aldridge, the former Executive Director of the National Science Teachers Association (Aldridge, 1992). In this method, the separate disciplines and discipline-based classes are maintained. The students go to various classes such as biology, chemistry, and physics with their respective teachers. However, the classes relate to one another through conceptual themes. For instance, the theme may be pressure. In the physics class, the students would study the effects of volume change of a container on the liquid inside. In the chemistry class, the students would study the effects of temperature change on the pressure of a liquid. And in the biology class, the students would study blood pressure.

Another method of curricula organization often confused with integrated science is "interdisciplinary instruction". In this method, many other branches of knowledge, such as literature, history, math, or art, are brought together with one or more science disciplines. This method requires a team effort from all teachers involved. Because of the complexity of the integration, this method is typically used for a short period of time; usually only a few weeks. Also, integrated science has been used to refer to programs that integrate mathematics into the science class or that integrate technology into the science class. Finally, integrated science is also being confused with unified science. Though the term "unified science" seems to be no longer in use since the early 1980's, today many "integrated science " programs are actually unified science programs. For instance, the new Texas Essential Knowledges and Skills (TEKS) is often referred to as an integrated program. Because the TEKS call for a single science class in which many concepts and skills will be taught to kindergartners to eighth graders, it is actually an unified science program.

Given the information above, certain characteristics of an integrated science program can be determined. First, the scientific disciplines, such as biology, chemistry, and physics, are retained. Second, the program must use a method in which two or more scientific disciplines are taught. Third, these disciplines must be related together by using scientific concepts, themes, or processes that demonstrate the commonalties of the disciplines. And fourth, in most of the other definitions of integrated science, the class is taught in a single classroom by a single teacher.

To prevent confusion, for this curriculum, the definition of **integrated science** will be the method of organizing science curricula in which two or more scientific disciplines are taught in one classroom by one teacher demonstrating the common concepts to all of the disciplines or the effects of one discipline on another.

Methods of Integration

One method of integrating science is that suggested by the National Science Education Standards (NRC, 1996) in which broad themes are used as the integrating force. Themes are defined as "conceptual and procedural schemes that unify science disciplines" and "provide students with productive and insightful way of thinking about and integrating a range of ideas that explain the natural and designed world". Some themes suggested by the Standards are systems, order, and organization; evidence, models, and explanation; and form and function. Curricula using this method of integration often have a variety of activities that all relate to the integrating theme. For instance, in the theme "Systems", activities could include the proper functioning of the parts of a circuit, labeling the parts of the circulatory system and tracing the path of blood, and demonstrating the trophic levels of an ecosystem in an aquarium. Because the themes are so broad, many disciplines can be integrated into them.

Another method of integrating science is using topics which are often used to organize information in science textbooks (Bianchini, 1998). Topics typically covered in an elementary classroom might include the properties of matter, the solar system, and the human body (Bianchini, 1998). Topics are used as the focus of the curriculum or a part of the curriculum. For instance, using the topic "The Human Body", activities in a curriculum would all relate to the human body. Activities might include labeling the parts of the digestive system, investigating the amount of energy contained in different foods, and examining how the eye functions. Using many activities, the students should gain a basic understanding of the various disciplines used in the topic and an in-depth understanding of the topic itself. Though topics are broad enough to allow integration of many disciplines, they are not quite as broad as themes.

Another method of integrating science disciplines is by using concepts which can be defined as groups of facts or ideas that are logically related. Curricula using concepts to integrate often use a series of activities to develop the concept or to show how the same concept can be understood in many different contexts. For instance, using the concept "warmer air rises as cooler air falls", a curriculum could include activities demonstrating convection cells, the cause of thunderstorms, and the flight patterns of vultures. Because concepts are often narrow and specific, integrations of many disciplines may be difficult or limited. However, using a series of activities in different contexts to develop a single concept should provide the student with a good understanding of the concept.

The curriculum in this study uses the latter method of integration. The curriculum is broken into four modules, each of which represents a major concept in science. The individual activities use that concept in a more specific context to develop the student's understanding of the concept and it's importance and relevance in the natural world.

A Brief History of Integrated Science

The idea of teaching all sciences together has had a long and convoluted history and is recorded in the literature during the 1920's and 1930's. This idea grew out of dissatisfaction with the major mode of curriculum design, called nature study, in which the science was organized by specialists in science who lacked the experience and skills of teachers (Smith, 1975). Also, the prime motivation of nature study was to improve agriculture and the content of the science courses reflected this motivation. In the seventh through ninth grade classrooms where general science was practiced, the students learned concepts and performed activities in one classroom that related to all sciences in a balanced way. Students did not go to a separate classroom for various specialized sciences. This method of curriculum design was supported in the Thirty-first Yearbook of the Society for the Study of Education, A Program for Teaching Science (Craig, 1932), in which the Committee stated, "The introduction of such 'general science' courses represents an outstanding educational experiment of the last twenty years." The Committee also sanctioned integrated programs of science study for grades one to nine. The Committee suggested that these courses should not be organized around any special science or sciences, but on the basis of large topics, problems, or units that relate to real-life situations.

Looking back, Chisman (1973) notes that the sciences in the general science classrooms were not truly integrated, but a co-ordinated survey of physics, chemistry, and biology. Also, the courses were regarded as too superficial and were allocated too little time by school authorities. Finally, teachers were not prepared to teach science in an integrated fashion. The movement lost momentum in the late 1930's.

The idea of combining the sciences re-emerged in 1964 when Victor Showalter published his paper "Unified Science: An Alternative to Tradition" (Showalter, 1964). He stated that the traditional sequence of science courses in high school is based on the untested assumption that the objectives of science education can be best attained in the course structures of biology, chemistry, and physics. He then suggested a "unified science" approach, which does not rely on that assumption, but on the assumption that science education can best be served by a course structure based around an interdisciplinary theme. He gave the following justifications for his new assumption: natural phenomena have no inherent properties that make them the exclusive property of any one discipline of science, the scientific disciplines are intellectual conveniences that facilitate specialized study, a general rather than a specialized science education is needed to create a scientifically literate citizenry, and scientific inquiry has evolved processes and theoretical concepts that are used in all disciplines.

He then goes on to describe his unified curriculum model in which generalized scientific concepts, such as entropy or equilibrium, are taught in study-teaching units. The theme of these units may be an expansion of one big idea or it may be a natural phenomenon that has interdisciplinary aspects, such as "The Sun". The sequence of the study-teaching units is designed so that no unit is repeated, but a given concept can be revisited at a more sophisticated level in a later unit. The curriculum model is very open-ended as many different units could be used and a great number of ways could be used to sequence them.

Showalter supported his curriculum model with one research study which showed that unified science students had a more "rational image of the universe", high school students that had gone on to college had not reported any difficulties due to their science education background, unified science graduates had entered college with the intention of studying rarely chosen fields such as psychology, geology, and anthropology, and unified science students showed a more positive view of science.

However, Showalter did list a few problems with the unified curriculum model. One problem was that due to time constraints and a large amount of subject-matter content, not all the subject matter relevant to the main theme may be used. Also, there was a lack of textbooks which depicted science in a unified manner. Standard biology, chemistry, and physics textbooks were made available to the students. However, Showalter also stated that a single text for a whole year would result in an undesirable degree of crystallization of subject-matter content. He also warned that it was necessary to be prepared to remove or add the scientific concepts taught as scientific thought progresses.

In 1966, with NSF funding, Victor Showalter set up the Federation for Unified Science Education (FUSE) at Ohio State University. FUSE endorsed the idea that a liberal or general education in science for all students should be the goal of all science programs in kindergarten until the second year of college (Showalter, 1973). Basically, FUSE set to carry out the ideas Showalter suggested in his earlier paper by publishing various unified science modules for use in classrooms, suggesting ways in which educators could develop their own unified science programs, and serving as a clearinghouse for information concerning unified science. Though the Federation is now defunct, Victor Showalter and FUSE served as the champions of the integrated science crusade.

Soon after Showalter's first paper, other opinion papers were published supporting the idea of some form of integrated science education. The journals School Science and Mathematics (1973) and Science Teacher (1975) dedicated whole issues to the subject of integrated science. One opinion was that integrated science would help improve the students' scientific literacy, the proper understanding of the purpose, methods, and terms of science (DeRose, 1965; Chisman, 1973; Fertitta, 1975; Yager, 1994). Many authors stated that an integrated science program is more logical because the universe and the problems it presents are not broken down into neatly defined categories such as "biology" or "physics" (Showalter, 1964, 1971; Hayward, 1973; Yager, 1994). Another reason suggested that integrated science curricula make science more accessible, understandable, and interesting to students who will not necessarily become scientists (Craig, 1932; Hurd, 1975; Showalter, 1971, 1975; Yager, 1994). Other authors felt that using integrated science as a way to help students solve real life problems in their home, school, or community would greatly increase students' problem solving skills (Hayward, 1973; Hurd, 1975; Lomon, Becky, & Arbetter, 1975; Yager, 1994). One of the major obstacles to good integrated science programs is the education of teachers which leads them to become highly discipline oriented and uncomfortable with the idea of teaching integrated science (Craig, 1932; Hawkins, 1973; Ost, 1975; Yager, 1994). However, this may be overcome through college preparation of teachers in a number of science areas, teacher training that includes the history and philosophy of science, and educating teachers in the processes of science and inquiry-oriented strategies (Meyer, 1973).

During the 1970's and 1980's, integrated science programs have sprung up all over the world. In 1969, there were 30 curriculum projects in the United States that could be defined as integrated (Adams, 1971). In 1972, the Eighth Report of the International Clearinghouse of Science and Mathematics Curriculum Development listed 65 integrated science programs in the United States plus nearly 30 outside the United States (Lockard, 1972). By 1974, the Ninth Report of the Clearinghouse listed 122 integrated science projects in the US and a similar increase was reported worldwide (Lockard, 1974). And in 1975, there were approximately 170 integrated science programs (Showalter, 1975).

As can be seen, integrated science is not only gaining popularity in America, but in other countries as well. Various organizations throughout the world have been promoting integrated science programs. One of the strongest proponents of integrated science has been the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (Fiasca, 1973). Due to its concern for developing countries, UNESCO promotes integrated science programs by publishing source books, conducting conferences and workshops throughout the world, and maintaining a collection of integrated science materials in Paris (Fiasca, 1973). Due to the fact that in developing countries very few students go on to secondary school or university, the only science that students learn is taught in elementary school. The idea of integration is carried on into high school, because many of these schools cannot afford to hire a separate teacher for physics, chemistry, and biology. UNESCO, still in operation, has well developed programs in Kenya, Nigeria, Malaysia, New Guinea, Ghana, Israel, and the Philippines (Fiasca, 1973; Gardner, 1975). A successful and notable integrated program is the British Open University, which began in 1971 (Munn, 1973) and is still operating. In this program, the Science Foundation Course, which is integrated and multidisciplinary in nature, serves as an introduction to science for persons who will continue in some branch of science and for those that will not. The topics, chosen from physics, chemistry, biology, and geology, are introduced to show how these disciplines are related and mutually interdependent and to show what is common in method, technique, and philosophy, and what is specific to each (Munn, 1973). Other international organizations promoting integrated science are the Regional Centre for Education in Science and Mathematics (RECSAM) which operates in Southeast Asia and the Caribbean Regional Science Project (CRSP) which has programs in Trinidad, Barbados, and Jamaica. RECSAM ended operations in the late 1980's; the current status of CRSP is unknown. National integrated science curriculums have also been developed in Japan, Australia, and Russia.

Despite all of the promises of integrated science, there is currently little scientific research on the effectiveness of integrated science curricula. Those few studies investigating this topic have shown greater increases in positive attitude and likelihood for taking more science courses in the future for students that are enrolled in integrated science courses compared to students enrolled in discipline-oriented courses (Supinski, 1974; Garafalo, 1988; Keating, 1996). It was shown that schools with unified science programs have a 50% chance that they will see a 20% increase in twelfth grade science enrollment (Supinski, 1974). Also, students in integrated science courses have greater increases in group problem solving ability, have more frequent use and comfort level in applying group tasks, and higher average grades than in previous science courses (Keating, 1996). Students in integrated science programs also better understand how one can find out about the physical world (Klopfer, 1969). One look at integrated science and traditional physics courses showed that integrated science courses can have as much or more physics concepts as the traditional classes (Supinski, 1974). A study of the grades of students with and without integrated science backgrounds taking college level science classes showed that students with integrated science had the same or slightly better grades in biology and physics than the students without integrated science (Skinner, 1988). And, a careful coordination and cross-referencing of topics in physical and life science should enhance the understanding of both areas (Garafalo, 1988). No research could be found that dealt with integrated science's effectiveness at increasing students' scientific literacy. However, all of this research shows that while students may not learn science any better or worse through an integrated rather than a discipline oriented curriculum, they will enjoy science more and have a better chance of seeing science as an important part of their lives.

In recent years, integrated science has again become influential in curriculum across the country. In 1989, Project 2061, an organization of teachers, administrators, and scientists gathered by the American Association for the Advancement of Science (AAAS), published *Science for All Americans* (Project 2061, 1989). In this book, the project describes its scientific literacy goals for all high school graduates. Project 2061 defines scientific literacy to include knowledge of natural and social sciences, mathematics, technology, and the connections among them. The project also covers the nature of the scientific enterprise and the themes that cut across science, mathematics, and technology, thereby softening the boundaries between traditional subject-matter categories and emphasizing links between them. These can certainly be considered concepts of integrated science. In 1993, Project 2061 published *Benchmarks for Scientific Literacy*. In the development of this book, the project created alternative curriculum models for all grades in science, mathematics, and technology and tested them in school districts, four of which were in San Antonio, TX. The book is a report of the results of the test curricula and is to be used as a tool that districts, school, and educators can follow to design useful curricula.

In 1989, the National Science Teacher's Association (NSTA) with funding from the US Department of Education and National Science Foundation (NSF) began the Scope, Sequence, and Coordination of Secondary Science (SS&C). 'Scope' indicates a coherent science curriculum that covers all of the secondary years with 'less is more' as a guide in teaching and curriculum development. 'Sequence' is the idea that science education must not only appropriately sequence instruction, but also take into account the ways different students learn. 'Coordination' is the idea that because sciences share topics and processes, their integration must be made clear. One of the main tenets of the organization is for all students to study science every year for six years beginning at the sixth grade and not ending until graduation. The SS&C advocated that the number of topics be greatly reduced to produce in-depth student learning and greater student retention, students experience hands-on activities prior to theories in order understand science, and activities should sequenced so that they begin with practical applications of science that have a personal impact on the student and then move into more global applications. The SS&C tested their ideas in six pilot centers around the US including one in Houston, TX, which involved the Baylor College of Medicine, NSTA, Houston Independent School District (ISD), Conroe ISD, Rice University, and the University of Houston. Though the SS&C and Project 2061 differ in their approaches and their time frames for implementation, both projects contend that less content taught more effectively over successive years will result in greater scientific literacy of the general public. It should also be noted that when carefully analyzing the principles of Project 2061 and SS&C, they both utilize a Learning Cycle teaching method to implement an integrated science curriculum, though neither use those terms to describe themselves.

Due to declining numbers of students enrolling in science classes and numbers of science teaching certificates awarded, the Texas State Board of Education adopted a restructured elementary science curriculum in 1989. Changes in the elementary science essential elements, which became effective in 1991, included integrating the life, earth, and physical sciences at each grade level in a spiral curriculum that focuses on life science at Grades 1 and 4, earth science at Grades 2 and 5, and physical science at Grades 3 and 6. The elementary science program also includes all of the processes of science in Grades 1-6 and provides rigorous science content through the textbooks. In 1991, the State Board of Education offered districts the option of using the traditional life science curriculum and textbook or using Science I, which is based on coordinated thematic science, which was first presented at a Texas Education Agency curriculum meeting and was based on the work of Project 2061 and SS&C. The purpose of coordinated thematic science is to develop the students' understanding of facts and concepts, as well as the connections that make scientific information manageable and useful. This is accomplished using space learning, coordinated content, the idea of 'less is more', and a thematic approach. Spaced learning is the concept that content in any one discipline is spread out over two to four years. The coordinated content is organized to illustrate the common elements among the science disciplines. The sequence of instruction is organized around four themes: environmental interactions, energy, systems and structures, and changes over time. Also considered is the developmental appropriateness of the material. In subsequent years, the State Board of Education also offered Science II in lieu of eighth grade earth science, Science III in lieu of ninth grade biology, and Science IV in lieu of tenth grade chemistry. Though coordinated thematic science emphasized teaching science process skills such as making and testing a hypothesis, classifying organisms, and predicting outcomes, it did not indicate what content should be taught at each grade level.

In 1996, the National Research Council published the *National Science Education Standards*. Similar to Project 2061 and SS&C, the *Standards* defined what the scientifically literate person should know after thirteen years of school science. The *Standards* agrees with SS&C and Project 2061 in that it states that science curricula should be developmentally appropriate, interesting, relevant to student's lives, organized around inquiry, and connected with other school subjects. The *Standards* also list unifying concepts and processes in science in order to show links between the various disciplines of science. Unlike Project 2061 and SS&C, the *Standards* also listed the exact content that should be taught at each grade level for each science subject.

Based in part on the *Standards*, the Texas State Board of Education adopted the Texas Essential Knowledge and Skills (TEKS) in 1996. The TEKS not only describe methods of instruction, but also the content required for each grade level for each discipline of science. Also, for grades K-8, the TEKS have removed any distinctions between the disciplines of science. Instead, science processes and content are taught using themes such as scientific inquiry, critical thinking and problem solving, systems, and properties and patterns. At the ninth grade, the TEKS describes an integrated physics and chemistry course in which the students follow themes such as waves, energy transformations, and changes in matter. No sciences are listed specifically for other high school grades, but the content for the traditional sciences, biology, chemistry, and physics, are listed, as well as astronomy, environmental systems, and aquatic science. No integrations for the upper high school grades are suggested. From this literature review, it can be stated that the TEKS have adopted an unified science program for grades K-8, an integrated program for ninth grade, and a traditional, discipline-based program for the upper high school grades.

Textbook companies have produced integrated texts to go along with state-mandated integrated science courses. For example, the publisher, Holt Rinehart Winston, published a series of integrated science textbooks for middle school. Also, in 1992, the University of Alabama's Center for Communication and Educational Technology (CCET) created and introduced an integrated science curriculum combining biology, chemistry, physics, and earth/space science for sixth through eighth grades. In the past six years, the project has grown from 90 enrolled teachers in Alabama to over 1400 teachers in 15 states and Quebec, Canada. In 1994, with funding from IBM and NSF, the Biological Sciences Curriculum Study (BSCS) published a series of integrated science textbooks, which utilize the 5 E's instructional model, for middle school.

The University of Hawaii has produced an integrated curriculum, which includes one of the few biology/astronomy integrated curriculums in the country, called the Foundational Approaches in Science Teaching (FAST). However, because the program does not wish to give away it's information for free, and the exact nature of the integration and the topics covered are unknown.

The October 1998 edition of the journal, School Science and Mathematics, is a special issue entitled "Integrated, Interdisciplinary, or Thematic Instruction: Implications for Learning in Science and Mathematics". The issue contains articles relating to subjects such as the definitions, implications, and research on the effectiveness of the various approaches. Also, another group, American Renaissance in Science Education (ARISE), has suggested a three-year integrated science curriculum for high school students that would replace the traditional sequence of biology, chemistry, and then physics (Bardeen and Lederman, 1998).

Definitions

This curriculum uses many terms which may be unfamiliar to readers who have not studied education. Also, many of the terms have different definitions assigned to them by various authors. To prevent confusion, terms are defined as used for this curriculum.

The **concept** for each activity briefly states the scientific ideas taught in the activity. Usually the ideas are rather simple and succinct. After completing the activity, the students should have a good understanding of the idea presented in the concept. It is recommended that if student copies of the activity are produced that the concept be listed.

The **objectives** for each activity are the skills that the students will have learned after completing the activity. These skills can be as simple as measuring temperature with a thermometer or as complex as using a chart showing the amount of protein fat, and carbohydrates to determine an unknown food source. The objective is explained by stating what the student will do and what the student will use to do it. It is recommended that if student copies of the activity are produced that the objectives be listed.

The **materials** for each activity are a list of the objects needed for each group of students. In an activity where the materials state that one protractor, one meter stick, and one flashlight are needed, one of each is needed per group. Only in a few cases, such as the activity Seasonal Environments, are the students to work together as a class. In those cases, only one set of each item is needed. It is recommended that if student copies of the activity are produced that the materials be listed.

The ***assessment*** for each activity relates back to the Barman method of the Learning Cycle. In this phase, the teacher gives a short demonstration of the concept that will be investigated. The teacher engages the students' interest by asking probing questions that require the students to think about the concept. During this phase, the teacher is able to gain an insight into the students' understanding of the concept and any misconceptions they may have. This phase is what distinguishes it from Robert Karplus' original design of the Learning Phase. It is recommended that if student copies of the activity are produced that the assessment not be listed.

The ***investigation*** for each activity also relates back to the Barman method of the Learning Cycle. In this phase, the students follow the instructions written, using the material provided, to discover the concept of the activity. At the beginning of each investigation, a recommended size for students groups is suggested. Usually, the student group size is listed a two or three, however, in some cases the students are suggested to work alone. It is recommended that if student copies of the activity are produced that the investigation be listed.

The **key questions** for each activity are activities used to evaluate the students' understanding of the concept of the activity. Due to the inquiry nature of the activities, few fact recall questions are used. In order to answer most of the questions, the student must use skills learned in the activity or analyze information from the activity. The questions have been designed to stimulate higher order thinking in the students. It is recommended that if student copies of the activity are produced that the key questions be listed.

The **what's going on** section for each activity is an explanation of the concept taught. This is meant to serve as a background reading for the teacher. In this way, the teacher is able to fully understand the concept and anticipate any questions or misconceptions the students may have. The information has been compiled from various textbooks, scientific papers, and interviews with scientists. The background reading can also provide ideas for new activities or means by which the concept can be expanded upon. It is recommended that if student copies of the activity are produced that the what's going on not be listed.

Integrated science is the method of organizing science curricula in which two or more scientific disciplines are taught in one classroom by one teacher demonstrating the common concepts to all of the disciplines or the effects of one discipline on another.

The **direct method** of instruction involves reliance on the textbook as the source of most of the concepts taught, the sequence in which they are taught, and how the students will be assessed in their understanding of the concepts. Also, most questions asked in the classroom are fact-oriented and not usually pre-planned, instruction is more often verbal rather than related to events or materials, and students usually have few opportunities to manipulate materials or plan activities.

Trial Tests and Feedback

To insure the usefulness of the curriculum to teachers, two methods of evaluation were used. The first method involved presenting the curriculum to educators in order to evaluate the usefulness of the curriculum in science classes. The second method involved using some of the activities from the curriculum in a classroom setting to evaluate the ability of the students to understand the instructions. The curriculum was evaluated using two groups: university students in Earth Science and educators at the Conference for the Association of Science Teachers (CAST), which is sponsored by the Science Teachers Association of Texas (STAT).

Two groups of 16 and 12 university students experienced the curriculum much in the same manner as middle school students. Each student was given a copy of a few of the activities and placed in groups of two or three. The author of the curriculum presented the material in the same manner as what is suggested to middle school teachers. The assessment phase was presented and discussed with the students. Using the materials provided and following the instructions, the students completed the activities and answered the key questions. The author then discussed the concepts learned in each activity. The author evaluated each activity by noting any difficulty in the student's understanding of the instructions, shortage of supplies, or misconceptions that the students may have developed due to the activity. The most common result of the experience was that some students found the language used in the curriculum to be difficult to understand. Also, in some steps of certain activities, details were omitted that presented difficulties in completing the activity. Where necessary, the activities were re-written in and details were added to clarify any confusion. Changes made from the experiences with the first group of students seemed to correct the problem as the second group did not have as much difficulty understanding the instructions.

The educators at CAST were presented with the theoretical basis of the curriculum as well as some sample activities. The curriculum was presented at two workshops in which the author presented the basic concepts and a short history of the Learning Cycle and integrated science to thirty educators, which included elementary, middle school and high school science teachers. Also discussed was the rationale of the organization and structure of the curriculum. The author then presented a few of the activities in the same manner as suggested to middle school teachers. The assessment phase was presented and discussed with the educators. Using the materials provided and following the instructions, the educators completed the activities and answered the key questions. The author then discussed the important points of each part of the activity such as the possible misconceptions that students may have during the assessment phase, variations of the investigation to suit special circumstances presented by the educators, and extension activities that teachers could do to expand on the concept of the activity. The educators were encouraged to make comments and suggestions on the curriculum and share any previous experiences they may have had with integrated science or discovery learning.

At the end of the presentation, the educators were asked to complete an evaluation form in which the educators were asked to evaluate the curriculum on it's development on the concepts presented, simplicity of instructions, the suitability of the concepts and language for seventh and eighth grade students, the effectiveness of the key questions as evaluators of conceptual understanding and stimulators of higher order thinking, and the logic of the sequence of topics and activities for each module. Statements were made about the curriculum and the participants were asked if they agreed, disagreed, or were neutral about the statements. Nineteen evaluation forms were returned. The scores for statements relating to the curriculum's organization, clarity, appropriateness for grade level, and effectiveness of developing concepts were averaged. A table of the evaluation sheet and the raw data pertaining to the curriculum is provided below. Concerning the curriculum's organization, 95 % of the evaluations agreed with the statements, 5 % were neutral, and no evaluations disagreed with the statements. Concerning the curriculum's clarity, 91 % of the evaluations agreed with the statements, 7 % were neutral, and 2 % disagreed with the statements. Concerning the curriculum's appropriateness, 84 % of the evaluations agreed with the statements, 14 % were neutral, and 2 % disagreed with the statements. Concerning the curriculum's effectiveness, 92 % of the evaluations agreed with the statements, 7 % were neutral, and 1 % disagreed with the statements. Overall, the area of the curriculum in which the educators gave the lowest marks was in language. For 21% of the evaluations, the statement "The language of each activity is appropriate for 7th-8th grade level" received the lowest score. Many of the educators felt that the activities were written at a level that would be too difficult for the students to understand. Also, the educators felt that some of the instructions in some of the activities were not clear enough for students to follow. As a result, the author rewrote the instructions in shorter, simpler sentences. The instructions were also rewritten to include all details of each step to prevent any confusion. During the writing process, clarity of language became a primary concern.

Table 1. Raw Data of Responses

Statement	Strongly Agree	Agree	Neutral	Disagree
Organization				
The activities were well organized.	16	11	1	0
The activity sheets were well organized.	22	6	0	0
The sequence of topics and activities for each module is logical.	18	7	3	0
Clarity				
The objectives of each activity are stated clearly.	25	2	1	0
The directions in each activity are simple and easy to follow.	14	10	3	1
Appropriateness				
The language of each activity is appropriate for 7th-8th grade level.	14	7	6	1
Each activity is appropriate for 7th-8th grade level.	15	11	2	0
Effectiveness				
Each activity is successful in developing the concept of the activity.	18	10	0	0

The materials of each activity are simple to use, inexpensive, and easy to obtain.	22	2	3	1
The Key Questions are good evaluators of a learner's conceptual understanding.	15	13	0	0
The Key Questions require higher order thinking.	15	10	3	0
The sequence of topics and activities for each module facilitates learning.	16	10	2	0
The implementation of Barman's Modified Learning Cycle is effective in developing the concepts of the modules.	14	10	4	0
Total	224	109	28	3

Summary and Conclusions

A history of the development and research on the Learning Cycle and integrated science was compiled. The majority of the research listed compared the Learning Cycle to traditional teaching methods pertaining to students' concept understanding, improvements in students' attitudes toward science, and the encouragement of student's for higher order thinking. The overall results of the research on the Learning Cycle has shown that it effectively increases student's integrated science process skills, deepens the understanding of science content, and moves the students from one intellectual level to the next. The literature search also showed that the Learning Cycle has also been used and developed by nationally-funded programs such as the Biological Sciences Curriculum Study (BSCS).

The overall results of the review of integrated science have shown that it has a lengthy history, wide support from educators, and has been used by many programs around the world. Research has shown that students' attitudes about science is improved more when using integrated science as opposed to the traditional methods of instruction. As of yet, few studies have compared the effectiveness of integrated science to develop conceptual understanding when compared to traditional curricula. However, those studies have shown that there is no significant difference between the conceptual understanding of students after completing an integrated science curriculum and those completing a more traditional method of teaching. Therefore, it is likely that integrated science will neither improve nor hinder student's understanding of science, but will improve their attitudes toward science. Considering the effectiveness of the Learning Cycle in the development of conceptual understanding and of integrated science in the improvement of students' attitudes, the combination used in this curriculum could be quite effective.

Various methods of organizing an integrated science curricula, such as using themes, topics, or concepts, were discussed and defined. Also, other methods of combining content in science curricula, such as coordinated science and unified science, which are often confused with integrated science, were discussed and defined. What can be concluded from the research on opinions of integrated science is that there are as many definitions for integrated science as there are authors writing on the subject. Many authors call their programs 'integrated science', but may have very little in common with other programs that are also called 'integrated science'. Because there is no single authority to provide a coherent definition, a definition of integrated science was given as it relates to this curriculum.

Finally, the methods of measuring this curriculum's organization, clarity, appropriateness, and effectiveness were described and the results were listed. Results of the evaluation by educators at CAST indicated that most agreed that the curriculum achieved it's goals.

Module One Summary (Varying Amounts of Energy)

Activity Title	Astronomical Concept	Biological Concept
Changing Light Area *Investigation*	Inclination angle at which light strikes a surface is inversely related to the area.	None
Changing Temp due to angle *Application*	Surface temp is directly related to the inclination angle of light.	None
Latitudinal Variations *Application*	Amount of energy entering Earth varies over latitudes.	Amount of energy at latitude determines vegetation.
Daytime Temperature *Application*	Height of Sun each day determines temperature.	Plant and animal activity levels change during day.
Sun Tracking *Application*	Sun moves across daytime sky.	Some plants move leaves to optimize light gathering.
The Seasons *Application*	Due to change in the direction of the Earth's axis, we have seasons.	None
Seasonal Environment *Application*	Seasons can be measured by shadow's length.	Plants and animals respond to varying amount of energy in environment caused by seasons.

Changing Light Area

Concept: The inclination angle at which light strikes a surface is inversely related to the area that that light strikes.

Objectives: Measuring angles with a protractor, measuring distance with a meter stick, determining proportions.

Materials: Meter stick (1), flashlight (1), masking tape, grid sheet (1), protractor (1), paper clip (1).

***Assessment*:** Draw a picture of light hitting a surface at different angles. Ask the students what they think the light will look like when it hits the surface. Will it be a small beam? A large beam? Will there be a difference between light coming from a steep angle and a low angle? Write the students' answers on the board and leave them there as they complete the investigation.

***Investigation*:** The students should work in groups of two or three.

1. Straighten out the paper clip and run it through the hole of the protractor and the hole of the meter stick. Bend the paper clip in such a way as to hold the two together.
2. Using the masking tape, fasten the flashlight onto the meter stick so that the bulb is at the 0.5 m mark and pointing towards the end with the protractor.
3. Lay the grid paper (supplied for you on the next page) onto a flat level surface.
4. Put the end of the meter stick with the protractor in the center of the grid paper and turn on the flashlight.
5. Adjust the meter stick in such a way as the center of the stick is along the 90^{o} mark.
6. Draw a circle around the edge of the light on the paper. Count how many grids are within the circle and record that number in your notebook.
7. Adjust the meter stick in such a way as the center of the stick is along the 45^{o} mark.
8. Draw a circle around the edge of the light on the paper. Count how many grids are within the circle and record that number in your notebook.

Key Questions:

1. Were there more grids hit by the light at 90^{o} or 45^{o}?
2. Were there less grids hit by the light at 90^{o} or 45^{o}?
3. Was the light on the paper brighter at 90^{o} or 45^{o}?
4. Why do you think that you got the results that you did?
5. How many grids do you think would be in the light if it was at 30^{o}? Why?

What's Going On:

As light strikes a surface at an angle less than perpendicular (90^{o}), the area of the surface struck by the light increases. The less the angle, the more the area. At 90^{o}, the light beam is concentrated onto the surface. At less than 90^{o}, the light beam is more diffuse, meaning that the same amount of light is spread over a larger area. A good analogy is jelly. If you took a teaspoon of jelly and spread it onto a cracker, then the jelly would be very thick and taste very sweet. But, if you took that same amount of jelly and spread it out on a large piece of bread, then the jelly would have to be very thin and would have little or no taste at all.

Changing Temperature Due to Inclination Angle

Concept: The temperature of a surface relates to the inclination angle of the light striking that surface.

Objectives: Measuring temperature with a thermometer, measuring angles with a protractor, determining proportions, relating the temperature of surface with angle of the light striking the surface.

Materials: Adjustable lamps with reflector shield (1), 60W bulbs for lamps (1), black construction paper (2), thermometers (2), protractor (1), clock or timer, 4" Styrofoam ball (1), knitting needle (1), different colored pins (3), 2 cm^2 pieces of paper (3), Styrofoam block (1).

Investigation: The students should work in groups of two or three.

A. Measuring the surface temperature.

1. Lay the pieces of construction paper on a flat level surface with the thermometers lying on top of them. Write down the temperatures of the thermometers in your notebook.
2. Using the protractor, tilt the thermometer and the paper until they are 30^o above the level surface. Use a book to hold it at that angle.
3. Place the lamp on the ring stand so that the bulb is pointing straight down at the two thermometers. Be certain that nothing is blocking the light from hitting the thermometers.
4. Turn on the lamp and let it sit for 10 minutes to heat up the surfaces.

B. Building the globe apparatus.

5. While you are waiting for #4, take the knitting needle and push it through the ball and put the pointed end into the Styrofoam block to hold the needle up straight.
6. Take one of the 2 cm^2 pieces of paper and put it at the top of the ball and hold it in place with a blue pin. Take another one of the pieces of paper and put it at the bottom

of the ball and hold it in place with a black pin. Take the last piece of paper and put in the middle of the ball and hold it in place with a green pin. Make certain that all the pins are in a line from top to bottom. (See Figure 1)

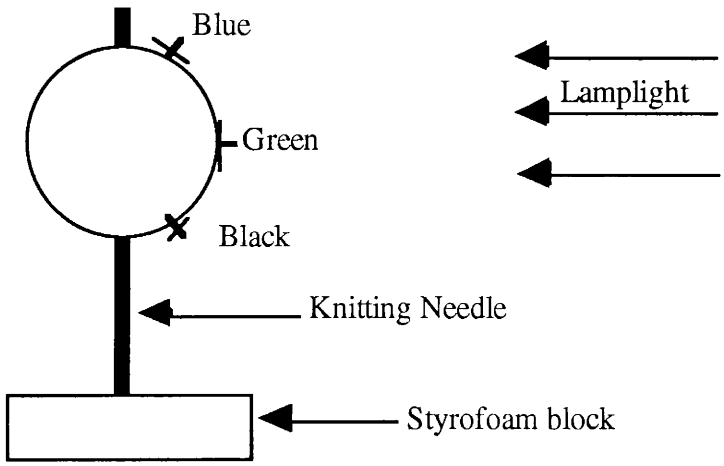

Figure 1. The Styrofoam Globe Model

7. Returning to the construction paper, write down the temperatures of both of the thermometers in your notebook.
8. Using the lamp from the first part of the investigation, shine the light onto the ball in a way that the light is 90^{o} to the knitting needle.
9. Answer the Key Questions below.

C. <u>Alternate Investigation.</u>

If it is possible, the following investigation can be used in place of or along with the lamp investigation from above. The advantage of this investigation is that it will allow the students to see that this phenomenon happens in the natural world and not just in a classroom.

1. Tape a thermometer to the center of each of the pieces of construction paper. Write down the initial temperatures of both of the thermometers in your notebook.
2. Take the papers outside on a clear, sunny day.
3. Lay one of the papers on a flat level surface.
4. For the other paper, angle it in such a way that the thermometer's face is perpendicular to the sun's rays. You may need to use books to support the paper.
5. Let them sit for 10-15 minutes and begin on the Styrofoam ball investigation.
6. Write down the final temperatures of the thermometers in your notebook and answer Key Questions 1-2.

Key Questions:

1. For the first part of the activity, did you see any differences in the temperatures of the surfaces? What were they?
2. What could be causing these differences?
3. What temperature would you predict if the thermometer was placed over a surface at 60^{o} above the surface?
4. Was your first guess from the beginning of class correct?
5. Taking what you discovered in the first part of the activity, which colored pin on the ball do you think will be the hottest? The coldest? Why do you think so?
6. How do you think the ball relates to the Earth?

What's Going On:

According to Lambert's Cosine Law, the angle at which light strikes an area relates directly to the amount the of energy entering the area; which in turn, relates directly to the temperature of the area. Light with a higher inclination angle to a given surface area hits that area in a more concentrated form; therefore, the amount of energy entering the area is also more concentrated which leads to a higher temperature. Light with a lower inclination angle to a given surface area hits that area in a more diffuse form; therefore, the amount of energy entering that area is also more diffuse which leads to a lower temperature.

Latitudinal Variations

Concept: The amount of energy entering the Earth changes with respect to latitude which changes the type and amount of vegetation at those latitudes.

Objectives: Reading maps with isolines, relating maps to globes, relating temperature and precipitation with vegetation.

Materials: Maps with isolines showing temperature, precipitation, and photosynthesis rate, globe (1).

***Assessment*:** Ask the students what parts of the Earth have the most plants. The fewest? Why do they think so? Write their answers on the board and leave them there as they complete the activity. Now, let's do an experiment that will answer these questions.

***Investigation*:** The students should work in groups of two or three.

1. Using the globe, write the latitude at which you would expect to find the highest temperature, the lowest temperature, the most amount of vegetation, and least amount of vegetation.
2. Look at the map showing temperature. What are the latitudes where the temperatures are highest? The lowest? Write your answers in your notebook.
3. Look at the map showing rainfall. At which latitude is the rainfall highest? The lowest? Write your answers in your notebook.
4. Look at the map showing vegetation. At which latitude is there the most vegetation? The least? Write your answers in your notebook.

Key Questions:

1. At the latitude with the most amount of vegetation, is the temperature high or low?
2. At the latitude with the most amount of vegetation, is the rainfall high or low?
3. At the latitude with the most amount of vegetation, would you expect to find many or few animals? What about at the latitude with the least amount of vegetation? Why do you think so?

4. Why are the numbers of plants not evenly distributed over the Earth?

What's Going On:

As the amount of energy entering the Earth changes with respect to latitude, the type and amount of vegetation changes at those latitudes. At the poles, where the inclination angle of sunlight is very low, it is very cold and dry. The low temperature and rainfall prevent large plants, which require higher temperatures, from growing. Therefore, only short grasses, mosses, and lichens exist at the poles. At the equator, where the inclination angle of sunlight is very high, it is very hot and humid. The higher temperature and precipitation allows a large number of plants, some which can be over a hundred feet tall, to grow. Deserts exist in areas where the inclination angle of sunlight is high, but precipitation is low. This allows only a few, specialized to plants to exist. The type and numbers of vegetation affects the type and numbers of animals which can exist at that latitude. At the poles, there are very few animals that can exist due to the few plants that serve as the animal's food. However, at the equator, a large variety of animals can live due to the tremendous numbers of plants.

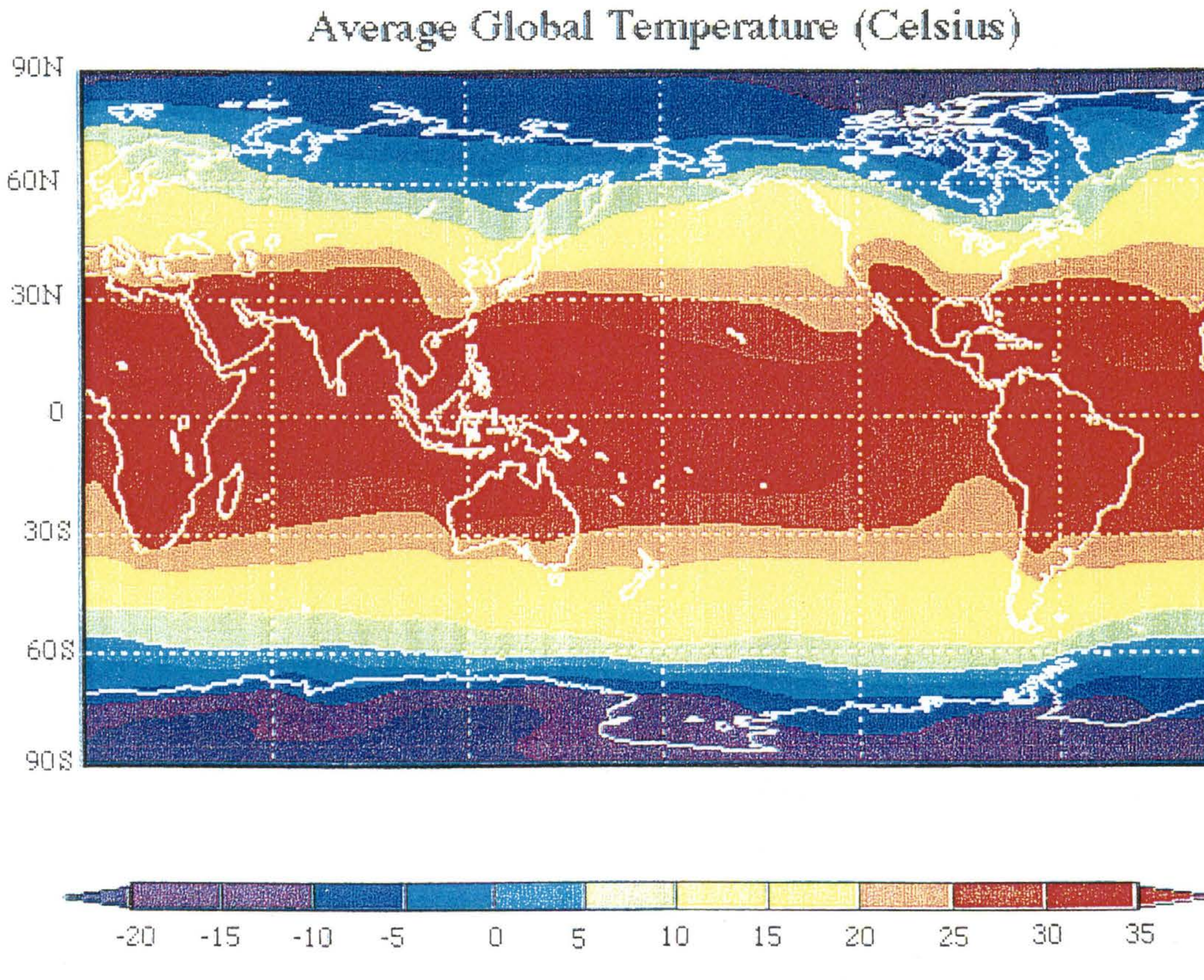

Figure 2. Average Global Temperature

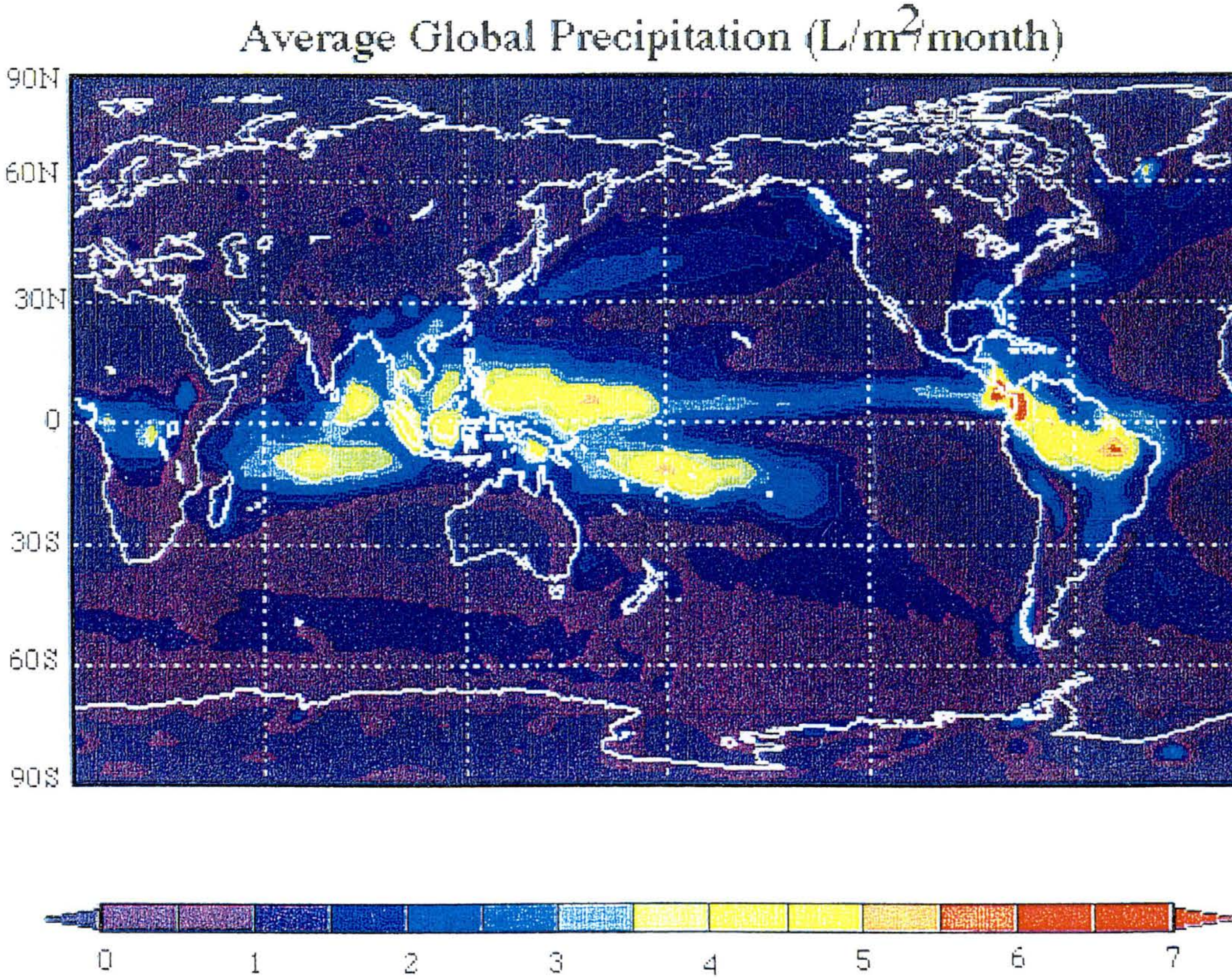

Figure 3. Average Global Precipitation

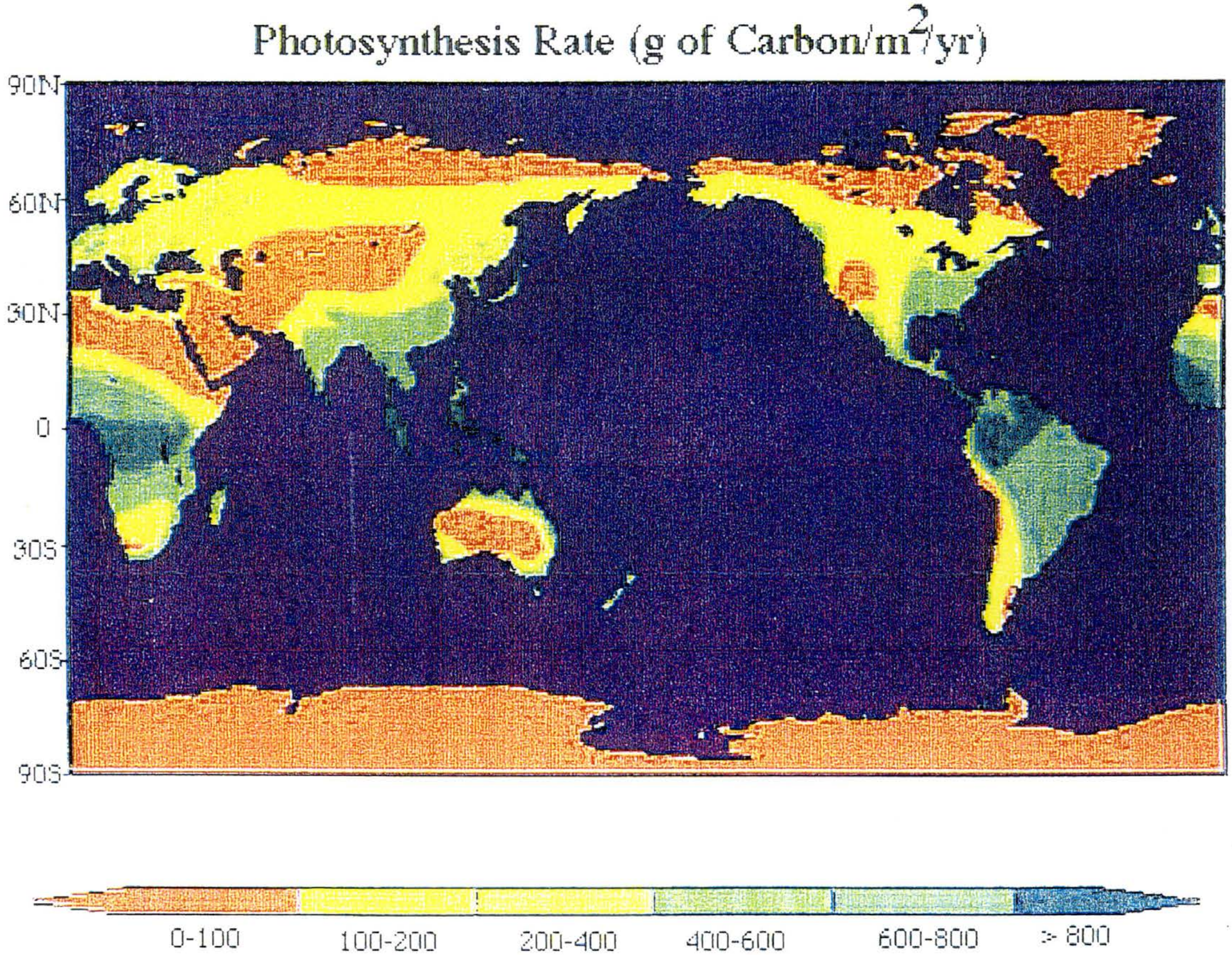

Figure 4. Global Photosynthesis Rate

Daytime Temperature

Concept: Because the Earth rotates on its axis, the Sun's height above the horizon changes; thereby, changing the incident angle of the sunlight.

Objectives: Three dimensional visualization, relating moving planes.

Materials: Styrofoam ball model, lamp (1), 2 cm^2 paper (4), multicolored pins (4).

***Assessment*:** Ask the students why they think the Sun seems to rise in the morning, travel across the sky, and set in the evening. Ask them why does it get cold at night and hot at noon. Write their answers on the board and leave them there as they complete the activity.

***Investigation*:**

1. Using your Styrofoam ball model with the pencil pointing straight up, turn the lamp on and aim the light so that it is at 90^o to the pencil.
2. Take one of the 2 cm^2 pieces of paper and pin it with a red pin in the middle of the ball pointing directly at the light.
3. Take another one of the 2 cm^2 pieces of paper and pin it with a blue pin in the middle of the ball on the right side of the red pin where the light and shadow meet.
4. Take another one of the 2 cm^2 pieces of paper and pin it with a green pin in the middle of the ball on the left side of the red pin where the light and shadow meet.
5. Take the last 1 cm^2 piece of paper and pin it with a black pin in the middle of the ball on the exact opposite side away from the light. Make certain that your model looks like Figure 2.

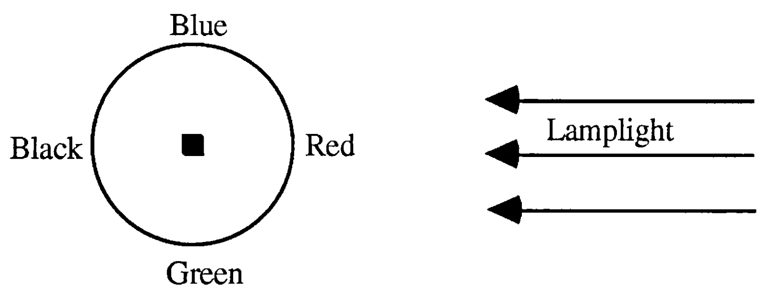

Figure 5. Styrofoam ball model as seen from above.

6. Answer Key Questions 1-2.
7. To simulate the rotation of the Earth, turn the pencil counterclockwise until the green pin is pointing directly at the lamp and answer Key Questions 3-6.

Key Questions:

1. Do you think that it is hot or cold at the red pin? At the blue pin? At the black pin?
2. Imagine yourself standing where the red pin is. How do you think the lamp would look from your perspective? What if you were standing at the green pin?
3. Imagine yourself still standing at the red pin, now how would the lamp appear? What about the green pin?
4. Knowing that the Earth rotates on its axis, how could you use this model to explain why it is cool in the mornings and evenings and warm in the afternoon?
5. At what time of day do you think most animals are active? Why?
6. Knowing that plants need light to make their food, at what time of day do you think that they will be the most active? The least active?

What's Going On:

Because the Earth rotates on its axis, the Sun appears to travel across the daytime sky. This changes the height of the Sun above the horizon. This, in turn, changes the incident angle of the sunlight which, as we have seen, changes the amount of energy entering the Earth. This is the cause of changing daytime temperatures. When the Sun is low in the morning, the amount of energy entering the Earth at that time and place is low and so are the temperatures. At noon, the Sun is at its highest point during the day and the greatest amount of energy is entering the Earth at that time and place. However, the highest temperatures of the day will be afternoon, because it takes some time for the energy to be absorbed into the environment. In the evening, the temperatures begin to decrease as the amount of energy entering the environment is reduced. The energy that was put into the environment at noon is radiated out into space and without more energy coming in, the temperatures begin to fall.

Sun Tracking

Concept: Because the Earth rotates on its axis, the Sun's height above the horizon changes; thereby, changing the incident angle of the sunlight. Some plants have pigments which allow them to track the Sun as it travels across the sky.

Objectives: Performing long term studies, relating moving planes, determining direction with a compass.

Materials: Sun tracking plant (clover), popsicle sticks (15), compass (1), protractor (1).

***Assessment*:** Ask the students if they think that the Sun is important to plants and why. Ask them if they think that it would be important to plants to be able to sense where the Sun is in the sky. Ask them if they think that plants have a way of sensing where the Sun is. Write their answers on the board and have them copy them down in their notebooks. This investigation will take two days to complete.

***Investigation*:** This will be a two day investigation. The first day will be performing the investigation and the second day will be analyzing the data. The day before performing the investigation, put the Sun tracking plant in the full sunlight of a south facing window to allow the plant to acclimate to the sunlight. The whole class should be involved in this investigation on the first day and should work in groups of 2-3 on the second day.

1. Using the compass, determine which way is directly north (0^{o}) and south (180^{o}). Put a stick at both ends of the pot in such a way that the stem of the plant and the sticks form a line pointing from north to south with the stem in the middle. Label the sticks as the northern and southern points.
2. Looking at the 'face' (flowers/leaves) of the plant, determine in which direction is it facing.
3. Place a stick at the end of the pot where the plant is facing. Label the stick with the time of making the observation.
4. Repeat steps 2 & 3 every thirty minutes over the whole day.

5. On the next day, you should have a semi-circle of sticks with their times on them.

6. Using the protractor, measure the position of each of the sticks in degrees. Align the protractor along the north and south sticks with the stem at the center of the flat edge. Starting from north (0^{o}), count the number of degrees to the first stick. That is the direction that the plant was 'facing' at that time. Copy these data into your notebook.

7. Repeat step 6 for all of the other sticks.

8. Copy the data onto the polar graph paper. Consider that the plant is at the center of the graph. North (0^{o}) is at the top and south (180^{o}) is at the bottom of the graph.

Key Questions:

1. Using the compass, which direction, in degrees, was the plant 'facing' at your first measurement? The last measurement?
2. At what time was the plant facing due South?
3. How many degrees did the plant move in thirty minutes?
4. With this data, would you say that it is important for plants to sense where the sun is located in the sky? Why?
5. How do you think that the plant is able to sense where the sun is located?
6. Was your first guess correct?

What's Going On:

Some plants are able to sense the intensity of sunlight through the use of special pigments. These plants will then 'track' the sun as it moves across the sky. After sunset, these plants will then orient themselves to face towards the east where they somehow 'know' the sun will rise a few hours later. Plants do this for various reasons. The most common reason is for photosynthesis. By maintaining their leaves at a perpendicular angle to the sunlight, plants are able to maximize the efficiency of their energy uptake for photosynthesis. Another plant, called the Arctic rose (*Drias*), flowers in the summer months in the tundra. Its white petals form a parabolic dish which focuses sunlight at the very tip of the reproductive parts of the flower. This causes the temperature of that area to be up to ten degrees higher than the air temperature. To maintain this temperature, the flower tracks the sun like a miniature satellite dish. The plant does this to attract insects which land on the flower to get warm. In the process, the insect is covered with pollen and will unwittingly deposit that pollen on the next Arctic rose it lands on.

The Seasons

Concept: The tilt of the Earth's axis causes energy from sunlight to be more concentrated or diffuse on the Earth's surface which causes the seasons.

Objectives: Relating planes of different orientation, measuring angles with a protractor, measuring diameters with a ruler.

Materials: 4" Styrofoam ball (1), knitting needle (1), protractor (1), Styrofoam block (1), adjustable lamp with reflector shield (1), 60W bulb for lamp, different colored pins (3), 2 cm^2 pieces of paper (3).

***Assessment*:** Ask the students to name the seasons and give characteristics of some of the seasons. Ask them what causes the seasons. Many of the students may suggest that during summer, the Earth moves closer to the Sun and during winter, the Earth moves farther away from the Sun. Put their answers on the board and leave them there as the students complete the investigation. Now, lets do an experiment that will answer these questions.

***Investigation*:** The students should work in groups of 2-3.

A. Determining if the seasons are caused by the Earth moving closer to the Sun.

1. Using Figure 6 below, measure the diameter of the Sun as it appears in the sky at different times of the year. Write your measurements in your notebook and answer Key Questions 1-3.

Figure 6. The apparent size of the Sun at different times of the year.

B. <u>Building the Styrofoam globe apparatus.</u>

2. Take the knitting needle and run it through the center of the Styrofoam ball. If you still have your model from the previous experiments, then you may use that.

3. Put the point of the knitting needle into the Styrofoam block. Put the flat edge of the protractor on the block and position the center of the needle so that it is at the 90^o mark.

4. Run a blue pin through the center of one of the 2 cm^2 pieces of paper and put it at the top part of the ball. Run a red pin through the center of the one of the 2 cm^2 pieces of paper and put it at the center of the ball. Run a black pin through the center of the last piece of paper and put it at the bottom of the ball. Be certain that all of these pins are in a straight line from the top of the ball to the bottom.

5. To simulate the tilt of the Earth, you will need to tilt the needle 24^o. Actually, the Earth is tilted at an angle of 23 $1/2^o$, but for this investigation, we will round up to 24^o. To do this, subtract 24^o from 90^o. Calculate the answer and put it in your notebook. Then, put the edge of the protractor on the block and move the center of the needle to the mark of the answer that you calculated.

6. Compare your model to Figure 7.

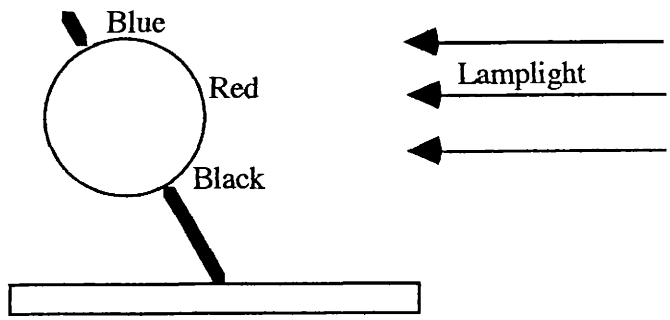

Figure 7. The finished Styrofoam globe model.

C. Determining if the seasons are caused by the tilt of the Earth.

7. Turn on the lamp and position the model about 1 meter away from it with the top of the ball pointing towards the lamp. You may have to turn the ball to be certain that the pins are facing towards the lamp. Answer Key Questions 4-6.

8. Now position the model about 1 meter away from the lamp with the top of the ball point away from the lamp. You may have to turn the ball to be certain that the pins are facing towards the lamp. Answer Key Questions 7-9.

9. Now position the model about 1 meter away from the lamp with top of the ball pointing towards the side, neither towards nor away from the lamp. You may have to turn the ball to be certain that the pins are facing towards the lamp. Answer Key Questions 10-15.

Key Questions:

1. Did you notice any differences in how the Sun appears in January than in July? What were they?

2. Considering that things appear larger as they get closer, how can you explain these differences?

3. Do you think these differences have any effect on the Seasons?

4. Which do you think will be the hottest pin? The coolest?
5. Which do you think would be warmer, the blue pin or the black pin? Why?
6. If you were at the blue pin, which season do you think it would be? Why?
7. Which do you think will be the hottest pin? The coolest?
8. Which do you think will be the warmer, the blue pin or black pin? Why?
9. If you were at the blue pin, which season do you think it would be? Why?
10. Which do you think will be the hottest pin? The coolest?
11. Which do you think will be warmer, the blue pin or the black pin? Why?
12. If you were at the blue pin, which season do you think it would be? Why?
13. Remembering that the Earth revolves around the Sun, draw a picture in your notebook showing how the Earth must look from space at all four of the seasons.
14. Try to explain in your own words why we have seasons.

What's Going On:

The change in the seasons is caused by two things: the revolution of the Earth around the Sun and the tilt of the Earth's axis. The tilt of the Earth's axis causes sunlight to be distributed unevenly over the Earth's surface. For instance, when the northern pole of the axis is pointing towards the Sun, the energy from the Sun is more concentrated. From the earlier activities we can know that this higher concentration of energy causes the temperature of the surface to increase. This is Summer in the Northern hemisphere. When the northern pole of the axis is pointing away from the Sun, the energy is more diffuse which causes the temperature of the surface to decrease. This is Winter in the Northern Hemisphere. Fall and Spring occur when the poles are pointing neither towards nor away from the Sun. As you have probably already figured out, the seasons will be exactly opposite in the Southern Hemisphere.

Many people (including some Harvard graduates) mistakenly believe that Summer occurs when the Earth moves closer to the Sun and Winter occurs when the Earth moves away from the Sun. On the surface, this would seem a likely explanation. We know that the Earth does revolve around the Sun and, at a certain point, it is closer to the Sun. We can see this by measuring the apparent size of the Sun at different times of the year. As the Sun appears larger, the closer we must be to it. We have discovered that the Earth is actually closest to the Sun in January. And, of course, January is in the middle of Winter for the Northern Hemisphere. This would certainly show that Summer is not caused by moving closer to the Sun.

The Seasonal Environment

Concept: The changing seasons affect the amount of energy entering the environment which changes the weather, which changes the physiology of plants and the behavior of animals.

Objectives: Measuring length with a meter stick, measuring temperature with a thermometer, making detailed observations.

Materials: Pole of known height fixed to an open area (1), measuring tape or meter stick (1), thermometer (1).

***Assessment*:** Ask the students to name the seasons. Ask them to list changes in the environment associated with the seasons. Try to be specific. Instead of saying that the birds fly south for the winter, ask them which birds fly south and when. Ask them exactly what changes in the environment cause which change in the plants and animals in the environment. Have them copy this in their notebooks.

***Investigation*:** This will be a long term study. At the end of this study, the students should write a report in the form of a scientific paper.

1. A permanent post must be erected for this activity. The post should be mounted in a level, open area. There can be no trees or buildings nearby that will block the Sun or distort the post's shadow. There can be no grass or gravel around in the area around the post as they will prevent accurate measurement of the post's shadow. You must be certain that the post is perpendicular to the ground. Once it is mounted, measure the height of the post to the nearest centimeter. The post can be mounted in one of three ways:

   A. Mount a metal fence post in cement. The benefit of this type is that it will be permanent fixture to the school which will be suitable as other astronomical tools such as a sundial.

B. Mount a wooden post into a sandy area. The benefit of this type is that it will not be permanent. So, when school is not in session it may be removed. However, as long as the study is continuing, the post cannot be moved and it should be measured weekly to ensure that it is still perpendicular to the ground and the height is the same.

C. Use a fence post that is already mounted in a level, open area in the school yard. Of course, this post should be checked to be certain that it is perpendicular to the ground. Be certain that the fence itself will not interfere with the measurement of the shadow. Also be certain to mark the post somehow so that there will be no confusion as to which post will be used in the activity.

2. At the same time (preferably noon) on the same day of every week, measure the length of the shadow cast by the post to the nearest centimeter. Write this in you notebook. (If there are any changes in the time, such as Daylight Savings or Standard Time, then you will need to change the time of day at which you measure the shadow by adding or subtracting an hour.)

3. After measuring the shadow, measure the temperature of the air in ^{0}C. To measure the temperature be certain to hold the thermometer in the shade about 1 meter above the ground. Write this in your notebook.

4. After measuring the air temperature, make observations on the weather. Is the sky clear or cloudy? Is it windy? Is it raining or snowing? Write this in your notebook.

5. Then, make observations of the plants and animals in the environment. Are there leaves on the trees? What color are the leaves? Is the grass dead or alive? Are there flowers? Are there any new species of plants that weren't there at the last measurement? Are there many insects? What types? Do you see or hear birds? What types? What other animals can you see? What are they doing? Write this in your notebook.

6. When writing your report, be certain to answer the Key Questions.

Key Questions:

1. Did you notice any changes in the length of the shadow? What were they (be specific).
2. On what day was the length of the shadow the longest? The shortest?
3. What was the temperature and the weather conditions on the day with the longest shadow? The shortest?
4. What was going on with the plants when the shadow's length was longer than the post's height? When it was shorter?
5. What was going on with the animals (including insects) when the shadow's length was longer than the post's height? When it was shorter?
6. Why do you think you see changes in the environment throughout the year?

What's Going On:

As the Earth rotates around the Sun and the North pole points towards or away from the Sun, the concentration of sunlight striking the Earth's surface changes. This sunlight is the main source of energy for almost every living organism on Earth. As the concentration of light changes, they must respond to meet these changes.

The main effect that the changing light concentration has is to change the availability of food for most organisms. During the winter, usually the most stressful time of the year for most organisms, the concentration of light is very low which is why temperatures are also usually at their lowest during this time.

For plants, which require light for photosynthesis, the availability of their 'food' has been reduced in winter. Plants have a wide variety of strategies of dealing with this problem. Some plants, such as the maple tree and other deciduous plants, shed their leaves, the organs of photosynthesis, and enter a period of dormancy until the light concentration is high enough to permit growth. Other plants, such as annuals, simply die when the light concentrations are too low. Their whole life span is often only a few months long.

Animals are also greatly affected by the concentration of light. The severe lack of plants, the main food source of herbivores, is a very stressful situation. Some animals avoid this situation by hibernating. This period of dormancy allows animals to 'wait it out' until the environment becomes less stressful for them. During the winter, many species of insects also die during the first cold spell because they aren't able to keep their body temperatures high enough to maintain life. This, of course, affects animals such as birds which often have insects as their main food source. Some birds have other food sources which allow them to cope with the lack of insects. Other birds do not have these coping strategies and will then move on (i.e., migrate) to better environments.

Of course, as light concentrations and temperatures increase, plants have more light available for photosynthesis and the environment is warmer for more animals to survive. This is why during the spring and early summer months, there are more green plants, more insects, and more species of migrating birds.

Module Two Summary (Varying Types of Energy)

Activity Title	Astronomical Concept	Biological Concept
Electromagnetic Spectrum *Investigation*	Light is composed of various wavelengths with different properties.	None
Light Reactivity *Application*	Substances react differently when exposed to different wavelengths.	None
Photosynthesis I *Investigation*	Filters can be used to isolate certain wavelength.	Plant growth changes depending on removal of certain wavelengths.
Photosynthesis II *Application*	Filters can be used to isolate certain wavelengths.	Plant starch production changes depending on removal of certain wavelengths.
Distance Vision *Application*	Objects appear smaller at farther distances.	Different animals are able to resolve images differently.

Electromagnetic Spectrum

Concept: Light is composed of many types of wavelengths. This collection of wavelengths is called the electromagnetic spectrum. These wavelengths have their own properties and effects on the biosphere.

Objectives: Using a prism to see colors in white light, determining the effects of colored filters on light.

Materials: Prism (1), flashlight (1), red cellophane, blue cellophane, white cardboard, aluminum foil, tape, scissors, razor blade.

Assessment: Ask the students if they think that white is a color. Ask them if they feel that white light may be composed of different types of light. What could those types be? Ask the students where colors come from. Write their answers on the board and leave them there as they complete the Investigation.

Investigation:

1. Cut the aluminum foil so that it will cover the flashlight except for a slit over the flashlight bulb. Make the slit 1 cm long an as wide as the razor blade. Tape the aluminum in place.
2. In a darkened room, shine the flashlight through the prism in such a way as to allow the light to hit the white cardboard screen. The light will not be in a straight line so you may have to put the screen at an angle. It may take a little time to get it, but you eventually see faint rainbow on the screen. Answer Key Questions 1-2 in your notebook.
3. Place the red cellophane between the prism and the screen and shine the light through the prism onto the screen. Answer Key Questions 3-4 in your notebook.
4. Remove the red cellophane and replace it with the blue cellophane and shine the light through the prism onto the screen. Answer Key Questions 5-6 in your notebook.

Key Questions:

1. When you shone the light through the prism, what did you see? What could be causing this?
2. List what you saw from left to right as it appears on the screen.
3. How is what you see with the red cellophane different than what you saw without it? What could be causing this?
4. List what you saw from left to right as it appears on the screen.
5. How is what you see with the blue cellophane different than what you saw with the red cellophane? What could be causing this?
6. List what you saw from left to right as it appears on the screen.

What's Going On:

Light is composed of many parts called wavelengths, which all have properties that are unique to them. All of the wavelengths combined are called the electromagnetic spectrum. The Sun emits all wavelengths of light to some degree. Most of these wavelengths, especially the ones most harmful to living creatures, are filtered out by the Earth's atmosphere. The three wavebands of light most important to living creatures are the visible, infrared, and ultraviolet wavelengths.

The light that we can see is called the visible wavelengths, which is only a very small portion of the electromagnetic spectrum. Most creatures that are able to see, also see the visible spectrum. We usually see visible light as white. In reality, white light is composed of many other wavelengths. These are red, orange, yellow, green, blue, indigo, and violet; the colors of a rainbow. We can see these wavelengths when we pass white light through a prism. Our eyes have structures that are designed to receive these wavelengths of light; therefore, allowing us to see colors. Not all creatures are able to perceive colors. The Sun produces much of its visible light in the yellow wavelengths. This is why the Sun appears yellow to us.

Another wavelength of light is infrared. We cannot see infrared light, but we can perceive this light mainly in the form of heat. We cannot see heat with our eyes, but we are able to feel it through our skin. The Sun produces a vast amount of infrared radiation which is why it feels so hot. In many ways, infrared is more important to living creatures than visible light. Life cannot exist without a certain amount of heat, however life can exist without light to see. Many types of creatures live at the bottom of the ocean where sunlight cannot penetrate. These creatures live off of the heat from small thermal vents on the ocean floor. They have heat and do not need light. Some creatures are better at perceiving infrared light than we are. Pit vipers, rattlesnakes for instance, have structures on the front part of their skulls that allow them to detect the faintest traces of infrared light. They use this to track their warm prey, rodents, against the cool, nighttime desert.

The last important wavelength of light important to living creatures is ultraviolet. The media has given much attention to ultraviolet light in the past few years. Ultraviolet light is actually composed of many wavelengths, similar to visible light. One type of ultraviolet light-B (UV-B) is harmful to living things. UV-B is able to cause cancer. Normally, this form of ultraviolet light is filtered by a layer in our atmosphere called the ozone layer. However, scientists have found that the ozone layer is getting very thin, which means more UV-B is reaching living creatures. This increase of UV-B could be the cause of the rise of cases of skin cancer in humans, as well as deformities in amphibians all over the world. Some creatures, such as insects are able to see ultraviolet light instead of visible light. The world looks very different to these creatures. A flower that may appear red to you could look bright blue to an insect.

Other wavelengths of light that you may be familiar with are microwaves, which we use for cooking, x-rays, which are very useful in medicine, and radio waves, which humans use to talk to each other over vast distances.

Light Reactivity

Concept: Different substances respond differently to various wavelengths.

Objectives: Measuring time with a timer, measuring temperature with a thermometer, determining the wavelength range to which an substance will react.

Materials: Meter stick (1), lamp with adjustable reflector and 100W bulb, fluorescent lamp, hot air blow dryer, thermometers (4), timer (1), small pan (1), cold tap water, sheets of Sun Sensitive Paper (4), keys (4), permanent marker, paper towels.

***Assessment*:** Ask the students if they think that light can cause changes in things. Ask them to give an example if they say yes. Ask them how they think light causes changes. Ask them if they think that different colors can cause different changes. Have them write their answers in their notebooks.

***Investigation*:** The students should work in groups of two or three.

1. On the white side of one of the Sun Sensitive Papers, write '100W' with the permanent marker. Put this paper, blue side up, with a key on top of it and a thermometer lying next to it under the lamp with the 100W bulb. Use the meter stick to be certain that the bulb is 20 cm above the paper.
2. On the white side of one of the Sun Sensitive Papers, write 'Fluorescent' with the permanent marker. Put this paper, blue side up, with a key on top of it and a thermometer lying next to it under the fluorescent lamp. Use the meter stick to be certain that the bulbs are 20 cm above the paper.
3. On the white side of one of the Sun Sensitive Papers, write 'Dryer' with the permanent marker. Put this paper, blue side up, with a key on top of it and a thermometer lying next to it under the blow dryer. Use the meter stick to be certain that the end of the dryer is 20 cm above the paper.

4. On the white side of one of the Sun Sensitive Papers, write 'Sun' with the permanent marker. Put this paper, blue side up, with a key on top of it and a thermometer lying next to it in open, unshaded sunlight.

5. Turn on all of the lamps and the dryer and let them sit for 5 minutes. While you are waiting, put cold tap water in the bottom of the pan until the bottom 1 inch is covered.

6. When the time is up, write down the temperatures of all four sheets of paper in your notebook. Then, put all four sheets in the pan with the cold tap water. Let them sit for 2 minutes. While you are waiting, turn off all of the equipment and put them away.

7. At the end of two minutes, pull out the sheets of paper and put them on the paper towels to dry.

8. Answer the Key Questions in your notebook.

Key Questions:

1. Describe what appears on the paper with 'Sun' written on the back of it.
2. Describe what appears on the paper with '100W' written on the back of it.
3. Describe what appears on the paper with 'Fluorescent' written on the back of it.
4. Describe what appears on the paper with 'Dryer' written on the back of it.
5. How were these appearances similar? How were they different?
6. Which paper had the strongest reaction? What was the temperature of that paper?
7. Which paper had the weakest reaction? What was the temperature of that paper?
8. Knowing that infrared light is perceived as heat, which paper do you think was exposed to the most amount of infrared light? The least amount of infrared light? Why do you think so?
9. Knowing that fluorescent lamps produce mainly visible and ultraviolet light, how reactive do you think the Sun Sensitive Paper is to those types of light? Why do you think so?

10. Knowing that the 100W lamp produces mainly visible light with some infrared, how reactive do you think the Sun Sensitive Paper is to those types of light? Why do you think so?

11. Knowing that the Sun produces visible, ultraviolet, and infrared light, why do you think the paper did or did not respond to the sunlight?

What's Going On:

As we discovered in the previous activity, light is composed of various wavelengths. These wavelengths also have different properties. These properties are caused by the various energy levels in the different wavelengths. Shorter wavelengths, such a the color blue, have higher energy than longer wavelengths, such as the color red.

Also, various substances react at specific energy levels. Many chemical reactions will only happen at certain specific energy levels. If the energy level is too low, then the reaction will not occur. If the energy level is too high, then the reaction may not happen or it may happen, but not in the same way as at the correct energy level.

The Sun Sensitive Paper is an example of a chemical reaction that will only happen under certain energy levels. At the correct energy level, the chemicals will react in such a way to produce a dark blue color. The energy level needed corresponds with the color yellow. This is why the fluorescent lamp, which produces mainly blue and ultraviolet light, did not work. This is also why the hair dryer, which produces only infrared light, did not work. This is also why the 100W lamp, which produces a weak color yellow, worked slightly. However, the Sun, which is a yellow star, produces a massive amount of yellow light. The best results should have occurred with the paper that was exposed with the Sun.

Photosynthesis I (Inquiry Activity)

Concept: Plants use certain wavelengths, colors, of visible light for photosynthesis.

Objectives: Making long term observations, drawing comparisons, taking detailed notes, measuring temperature with a thermometer, writing scientific paper, determining the important colors of light for photosynthesis.

Materials: 4" plastic pots (4), potting soil, sunflower seeds (4), thermometers (4), red cellophane, blue cellophane, green cellophane, clear cellophane, shoe boxes (4), masking tape, water.

***Assessment*:** Ask the students if they think that plants can tell the difference between different colors. Ask them if they think that plants can use any type of light for photosynthesis or are certain types of light more important than others. Have them write their answers in their notebooks. Now, let's do an experiment that will answer these questions.

***Investigation*:** This will be a long-term study in which the class must make detailed observations of the growth of plants in different environments. The length of the study should be no longer than two weeks. Be certain that every student is a part of the study. At the end of the study, the students will be required to write a scientific paper giving the results of their experiment. Please refer to Appendix 1 for more information on scientific papers as they relate to this curriculum.

A. Building the growing station.

1. Fill each of the plastic pots with potting soil until it reaches about 3 cm below the edge of the pot.
2. Put one sunflower seed in the center of each of the pots approximately 1 cm beneath the soil surface.
3. Add an equal amount of water to each of the pots until the soil is saturated.

4. Cut one of the short ends of each of the shoe boxes so that it can be opened and closed. Do not cut the end completely off.

5. Wrap the red cellophane over the large open portion of the shoe box so that no light except red light can get through. Hold the cellophane in place with masking tape. You may wish to wrap one or two more layers over that one if you are not satisfied that no light other than red can get through. It is very important that no other light hit the plant as it will ruin the experiment.

6. Repeat this process for the green, blue, and clear cellophane with the other three boxes.

7. Place one of the plants in each of the boxes so that the colored light of the cellophane will strike the pot.

8. Place a thermometer in each of the pots so that the numbers can still be read.

B. Collecting the data.

9. In your notebook, write the temperatures of each of the pots and the date that you started the experiment.

10. Every day add equal amounts of water to each of the pots. Also, write in your notebook the date, the temperature of each of the pots, the height of the plants in centimeters, and what color the leaves are.

11. After two weeks of collecting your data, begin to write your scientific paper. Be certain to answer the Key Questions in the Conclusions section of you paper.

Key Questions:

1. What was the color of light of the plant that grew the tallest? The shortest?

2. Did any of the plants not grow at all? Explain why you think this might have happened.

3. Was there a significant difference in the temperatures? Do you think that this would have any affect on the plant's growth? Why or why not?

4. Why was it important to use the same amount of water for each of the plants?

5. From the data that you collected, do you believe that plants can sense different colors of light?
6. Which color or colors do you think are most important to plants?

What's Going On:

Plants actually use only certain wavelengths of light for photosynthesis. The wavelengths at the red and blue ends of the visible spectrum are used for photosynthesis and the green portion of light is reflected. Actually, plants appear green because they are reflecting the portion of the spectrum that is useless to them.

Photosynthesis II (Inquiry Activity)

Concept: Plants require not only sunlight, but certain wavelengths of sunlight to produce food through photosynthesis.

Objectives: Analyzing plant tissues to determine the presence or absence of starch.

Materials: Geranium plant (1), 2 pieces of cardboard (2 cm^2), 2 pieces of red cellophane (2 cm^2), 2 pieces of green cellophane (2 cm^2), 2 pieces of blue cellophane (2 cm^2), 2 pieces of clear cellophane (2 cm^2), one large beaker, one small beaker, water, methanol, iodine solution, one eye dropper, small straight pins, hot plate, oven mitts, safety goggles, lab apron, forceps, latex gloves, 6 sheets of white paper.

***Assessment*:** Ask the students if they think that plants can tell the difference between different colors. From the Photosynthesis I Investigation, they should say yes. Ask them if they can think of another experiment that will show how different colors affect photosynthesis. You may wish to review exactly what the process of photosynthesis (see **What's Going On**) is with the students. You may also give them hints that we can cover just portions of the leaves rather than the whole plant. Have them write their answers in their notebooks. Now, let's do an experiment that will answer these questions.

***Investigation*:**

A. <u>Preparing the plant.</u>

1. First, we will affect the leaves by changing the amount and type of light that hits them. On one of the leaves of the geranium plant, place the two pieces of cardboard. Put one on top of the leaf and one on the bottom. Stick a straight pin through one corner of the top piece of cardboard, through the leaf, and through the bottom piece of cardboard. Do this so that the pieces of cardboard are held tightly against the leaf. Repeat this step for each of the other corners of the pieces of cardboard.

2. On one of the leaves of the geranium plant, place the two pieces of red cellophane. Put one on top of the leaf and one on the bottom. Stick a straight pin through one corner of the top piece of cellophane, through the leaf, and through the bottom piece of cellophane. Do this so that the pieces of cellophane are held tightly against the leaf. Repeat this step for each of the other corners of the pieces of cellophane.

3. Repeat Step 2 using blue, green, and clear cellophane on different leaves.

4. Place the plant in a window that has full sunlight and leave it there for two days.

5. After the days have gone by, remove the plant from the window.

B. <u>Removing the Chlorophyll to See the Starch.</u>

6. Next we will remove the chlorophyll from the leaves so that we can see any evidence of starch, the product of photosynthesis. Fill one-third of the large beaker with water. Place the small beaker inside the large beaker. Place them on the hot plate and turn it on.

7. Clip off a leaf that was untreated in the investigation. Write what it looks like in your notebook

8. Place the leaf inside the small beaker. Put on your lab apron, gloves, and safety goggles. Pour enough methanol into the small beaker that it covers the leaf. Let the beakers sit on the hot plate until the methanol begins to boil. **Warning:** Methanol is a dangerous liquid. The fumes and the liquid can catch on fire very easily. When not using the bottle of methanol, keep the lid on it.

9. Once the methanol boils, turn off the hot plate and remove the beakers using a pair of oven mitts to protect your hand.

10. Use the forceps to take the leaf out of the methanol. Rinse the leaf with water and place it on a piece of white paper. Add five or six drops of the iodine solution to the leaf. Write down what you see in you lab notebook.

11. Rinse out the small beaker and dry it. Remove the pins, cellophane, and cardboard from the leaves that were treated in the experiment. Repeat steps 10 through 12 for each of the leaves.

12. Write your results in a scientific paper. Be certain to include the answers to the Key Questions in your paper.

Key Questions:

1. Did you see a difference between the untreated leaf and the leaf with cardboard on it? What was it? Why do you think there was a difference?

2. Did you see a difference between the untreated leaf and the leaf with the clear cellophane on it? What was it? Why do you think there was a difference?

3. Did you see a difference between the leaf with the cardboard and the leaf with the clear cellophane on it? What was it? Why do you think there was a difference?

4. Did you see a difference between the untreated leaf and the leaf with the green cellophane on it? What was it? Why do you think there was a difference?

5. Did you see a difference between the untreated leaf and the leaves with the red or blue cellophane on it? What was it? Why do you think there was a difference?

6. Did you see a difference between the leaf with the red cellophane and the leaf with the blue cellophane on it? What was it? Why do you think there was a difference?

7. From your observations, do you believe that plants can sense different colors of light?

8. Which color or colors of light do you think is most important to plants?

What's Going On:

Photosynthesis is the conversion of light energy into chemical energy. Most of the processes of photosynthesis occur in the mesophyll of green leaves. However, in any green part of the plant, such as the stem, photosynthesis could be occurring. In the mesophyll are cells packed with chloroplasts, the cellular organelles of photosynthesis. Inside the chloroplasts are structures that resemble stacks of green coins called the thylakoids. The thylakoids are folded in such a way as to allow the photochemical processes of photosynthesis to occur. It is in the thylakoids that ATP and NADPH, the energy storing molecules that drive the chemical reactions, are produced.

Photosynthesis occurs in two phases, the light dependent phase (also called the light phase) and the light independent phase (also called the dark phase). Simply, during the light dependent phase, wavelengths of blue and red light stimulate chemical reactions with water and electron receptors which converts $NADP^+$ and ADP to NADPH and ATP. In a sense, the light raises the energy level in the leaf. During the light independent phase, so called because no light is necessary for the reaction, the NADPH and ATP react with the carbon dioxide, in a process called the Calvin Cycle, to produce glucose. Glucose, though at a lower energy level than NADPH and ATP, has enough chemical energy stored inside of it.

Plants use the glucose produced by photosynthesis in many ways. One of the ways is to break the chemical bonds to produce more ATP for more energy. Animals do this same reaction which is why eating sugar can give you a short burst of energy. Plants can also use glucose to produce cellulose in the cell walls. Cellulose is a strong, long chain molecule that gives plants the support they need to stand up against gravity. Also, plants can store their glucose in the form of starches. Potatoes, for example, store large amounts of starches in swollen underground roots called tubers. Plants also store glucose in the fruits they produce to make them taste good so that animals will eat them and the seeds inside. The animals then excrete out the seeds at another location, thereby dispersing the plant's offspring.

Photosynthesis is simply the most important chemical reaction on the planet. Without it, energy from the Sun could not be converted into chemical energy usable by living organisms. Without plants to convert this energy, there would be no food for animals to eat. As the poem says, "Roses are red, violets are blue. If the green plants go, then so do you."

Animal Receptors

Concept: Animals use their eyes to see light from objects far away. Some animals are able to resolve, see more detail, better at farther distances than other animals.

Objectives: Measuring distance in meters with a tape measure, make comparisons on measurements.

Materials: Two wooden pencils, one sheet of black construction paper, tape measure with metric units.

***Assessment*:** Ask the students how far do they think they can see. Write even the most outlandish answers on the board. (Some knowledgeable students may know that we can see stars trillions of miles away.) Then ask them how much detail or how well can they see from these distances. Ask them if they think that all animals can see as well as we do. Have them write their answers in their note book.

***Investigation*:** For this investigation, you will need to be able to measure at long distances. This investigation may have to be done in a gymnasium or on a football field.

1. Lay out the length of the measuring tape. Have one student with the construction paper and pencils stand at the zero mark.
2. Have the student at the zero mark hold the pencils 2 cm (about 1 inch) apart in front of the black construction paper.
3. Have the other students move along the tape measure until they see the pencils appear as one pencil instead of two. Have them write their results in their notebooks. (Students wearing glasses or contacts should keep them on for this investigation.)
4. Return to the classroom and have the students write their results on the blackboard. Then, have the students copy the results of the all of the other students in the class.
5. Have them answer the Key Questions in their notebooks.

Key Questions:

1. Which student was able to see the farthest? The shortest?
2. What was the distance of the student that could see the farthest? The shortest?
3. What was the difference between the two distances? (Subtract the shortest distance from the farthest.) Do you think this is a big difference? Why or why not?
4. How does your distance compare to the farthest or shortest distance?
5. Take the farthest measurement and multiply it by 3. The result is how far a hawk could see. Why do you think they are able to see so much farther than us?
6. What other animals do you think could see much farther than humans? Check in the library and see if you are correct.

What's Going On:

Various animals are able to resolve images at various distances. Hawks and eagles are able to resolve images at great distances due to structures in their eyes. They need to do this because they often search for small prey at great distances. Other animals, such as snakes, are not able to resolve images well. Even at close distances, the prey often times must move before the snake can see it. This trait is common in creatures that are primarily nocturnal.

Module Three Summary (Conservation of Matter)

Activity Title	Astronomical Concept	Biological Concept
Ecosystems Matter I *Investigation*	None.	The largest percentage of matter in an ecosystem is found in plants.
Ecosystems Matter II *Application*	None.	Very little of the matter in plants is eaten, but almost all of the matter in herbivores is eaten.
Food Stuff *Investigation*	None.	Various foods contain different amounts of protein, fat, and carbohydrates, which are needed for life.
What's the Matter *Application*	None.	Carbohydrates, proteins, and fats contain different atoms in different amounts.
Origin of Matter *Application*	Stellar evolution is the ultimate source of all matter in the solar system.	None.

Ecosystems Matter I

Concept: Most of the matter in ecosystems is in plants, then herbivores, then carnivores.

Objectives: Determining percentages, determining the relative biomass of plants, herbivores, and carnivores.

Materials: 2 cm^2 green construction paper (100), 2 cm^2 brown construction paper (1), 2 cm^2 red construction paper (1), paper bag (1).

Assessment: Ask the students if they think there is more plants or herbivores or carnivores. Then ask them by how much is there more of each. (Ten times as many plants as herbivores, for instance.) Write their predictions on the board. Now let's do an exercise that will help us find out.

***Investigation*:** The students should work in groups of two or three.

A. Teacher's Work

1. Put all of the squares of construction paper into a paper bag labeled 'Ecosystem', then pass out the bag to the students.

B. Student's Investigation

1. Open the bag labeled 'Ecosystem' and take out the squares that are inside. Each of the green squares represent a hundred grams of plants in the ecosystem. Each of the brown squares represents a hundred grams of herbivores (plant eaters) in the ecosystem. And, each of the red squares represents a hundred grams of carnivores (meat eaters) in the ecosystem.
2. Count all of the squares in the ecosystem. Write your results in your notebook. (Plants + Herbivores + Carnivores = Ecosystem).
3. Count all of the squares for each individual group. (Just the plants, then just the herbivores, then just the carnivores.)
4. Find the percentage of each group that makes up the ecosystem. Start by finding the percentage of plants in the ecosystem. Do this by dividing the total plant squares by

the total ecosystem squares, then multiply by 100. Do the same for the herbivores and, then, the carnivores. Write your results in your notebook.

(Plants / Ecosystem X 100 = percent Plants)

Key Questions:

1. What percentage of the ecosystem is made up of plants? Herbivores? Carnivores?
2. Which group (plants, herbivores, or carnivores) is the largest? The smallest?
3. Were any of the groups equal? Which ones?
4. How close were your predictions?

What's Going On:

In all ecosystems, plants comprise the largest amount of living or dead material. Not only are plants the most massive of organisms (imagine how many mice it would take to equal the weight of one oak tree), but they are also the most numerous. Plants are often called 'producers' as they use sunlight to convert nutrients from the soil and air into organic compounds that can be used for growth, reproduction, or maintaining their health. Plants 'produce' food. Herbivores are often called primary consumers as they are the first animals to 'consume' the food produced by the plants and convert it into organic compounds usable to animals (plants and animals have slightly different nutritional need.). Carnivores are called secondary consumers as they eat the primary consumers and gain organic compounds that are readily usable by the animal. However, this means that they are indirectly consuming plant material.

So, the simple cycle of matter goes like this: the matter in the soil and air is taken in by the plants, the matter in the plants is taken by the herbivores, the matter in the herbivores is taken in by the predators, and the matter in all of the plants and animals is returned to the soil and air when they die and decompose.

Ecosystems Matter II

Concept: Though plants have the most matter in ecosystems, very little of it is consumed by herbivores. However, almost all of the matter in herbivores is consumed by carnivores.

Objectives: Determining percentages, determining what fraction of each group is consumed by the higher group.

Materials: 2 cm^2 green construction paper (100), 2 cm^2 brown construction paper (1), 2 cm^2 red construction paper (1), paper bag (1).

Assessment: Ask the students if they think there is more plants or herbivores or carnivores. They should remember the correct answer from the previous activity. Now ask them how much of the plants do they think herbivores eat. Then ask them how many herbivores do they think are eaten by carnivores. Write their predictions on the board. Now let's do an exercise that will help us find out.

***Investigation*:** The students should work in groups of two or three.

A. Teacher's Work

1. The paper squares con be the same ones used in the previous experiment.
2. On five of the green squares, write 'Herbivore'. On the back of the brown square, write 'predator'.
3. Put all of the squares of construction paper into a paper bag labeled 'Ecosystem', then pass out the bag to the students.

B. Student's Investigation

1. Open the bag labeled 'Ecosystem' and take out the squares that are inside. Each of the green squares represent one hundred grams of plants in the ecosystem. Each of the brown squares represents a hundred grams of herbivores (plant eaters) in the ecosystem. And, each of the red squares represents a hundred grams of carnivores (meat eaters) in the ecosystem. This is just like the last activity.

2. Count all of the squares for each individual group. (Just the plants, then just the herbivores, then just the carnivores.) Write your answers in your notebook.
3. On some of the plant squares, you will find 'Herbivore' written on them. These represent the plants that are eaten by herbivores. Count all of those plant squares and write your answer in your notebook.
4. Check to see if any of your herbivore squares have 'Predator' written on them. Those represent the herbivores that are eaten by carnivores. Count all of those herbivore squares and write your answer in your notebook.
5. Find the percentage of plants that are eaten by herbivores. Do this by dividing the total number of plant squares by the plant squares that have 'Herbivore' written on them, then multiply by 100. Write your answer in your notebook.
   (Plants eaten by herbivores / Plants X 100 = percent of plants eaten by herbivores)
6. Find the percentage of herbivores that are eaten by predators. Do this in the same way as in Step 5. Write your answer in your notebook.
7. Answer the Key Questions in you notebook.

Key Questions:

1. What was the percentage of plants eaten by herbivores?
2. Was this higher or lower than your prediction?
3. What was the percentage of herbivores eaten by carnivores?
4. Was this higher or lower than your prediction?
5. On the carnivore squares, there is nothing to show that carnivores are eaten by anything, why do you think this is so?
6. Where do you think carnivores get the matter they use to grow (where does their food come from)?
7. Where do you think herbivores get the matter they use to grow (where does their food come from)?

8. Where do you think plants get the matter they use to grow (where does their food come from)?

What's Going On:

In most ecosystems, only a small percentage of plants are actually eaten by herbivores. In a tallgrass prairie, such as the ones found in the Great Plains, only 2-7% of plants are eaten by herbivores aboveground (the leaves and stems). The percentage goes up to 25% eaten by herbivores belowground. Though we tend to think of herbivory in situations that we can see, such as a cow grazing in a field, the greatest amount of herbivory happens in the soil. Very small worms called nematodes fill the soil and eat a large amount of plant material, both dead and alive. This still means that at least 75% of plants are untouched by herbivores. This has led ecologists to believe that plant populations are not limited in their size or range by herbivores. The most limiting factor to a plant may be the amount of nutrients, particularly nitrogen and phosphorous, and water available to the plant.

Herbivores, however, are another story. Almost all herbivores are eaten by carnivores. Though a young, healthy rabbit may be able to outrun a coyote, the rabbit will eventually get older or sick and become coyote food. Those few herbivores that are not eaten by carnivores have either died due to illness, starvation, or injury.

Carnivores are not eaten by anything, except in cases where small carnivores are eaten by larger carnivores; such as, a snake eaten by a hawk. Generally, carnivores die due to illness, starvation, injury, or, in very rare cases, old age.

All of these dead organisms are processed back into the ecosystem by decomposers, which digest the organic material back into basic inorganic compounds. These, in turn, will be taken in by plants to start the whole cycle over again. The most effective decomposers are bacteria which can convert the large organic molecules into the simple inorganic ones. However, larger decomposers, such as flies, vultures, and fungi, can also do this.

Food Stuff

Concept: Food contains varying amounts of protein, fat, and carbohydrates, which are needed to promote growth and maintain health.

Objectives: Using a chart showing the amount of protein, fat, and carbohydrates, determine an unknown food source.

Materials: Food chart (1), list of unknown food sources (1).

***Assessment*:** Ask the students why do they think we eat food. They will probably give answers such as "It tastes good" or "To keep our stomachs from growling" or "So we won't die". Ask if there is anything in the food that our bodies use. List these on the board. Ask the students if these things can be found in all types of food. Then do an activity to answer a few of these questions.

***Investigation*:** The students should work in groups of two or three.

A. Chart Explanation

1. Look a the Food Chart. Notice how the different types of food have different amounts of fat, carbohydrates, and protein.
2. Read this information about fat, carbohydrates, and protein.

Fat, carbohydrates, and protein are types of food components. This means that they are a part of the food that we eat. Our bodies take these food components and use them to help us grow and maintain our health. Not all food has all of these components. Some food may have little or none of a certain type of component. Fruits, for instance, have almost no fat in them. Typically, fat and protein are highest in food that comes from animals and carbohydrates are highest in food that comes from plants.

Fat is used by the body for high energy that lasts a long time. If fat is not used, then it is stored in fat cells. Meat and cheese are high in fat.

Carbohydrates, sometimes called sugars, are also used by the body for energy. But, this energy is not so high and only lasts for a short time. Carbohydrates are usually not stored in the body. Beans, potatoes, and candy are high in carbohydrates.

Proteins are used to build more cells. Protein is important for growth. Athletes eat a lot of protein to make their muscles bigger and stronger. Meat is high in protein.

B. Determining an Unknown Food Source

3. Using the Food Chart, determine the unknown food sources by comparing the amount of grams of fat, carbohydrates, and proteins in each unknown food source to each of the foods in the Food Chart. The first one has been done as an example:

Food Source A has 33.1 g of fat, which is High. Only beef and cheese are High in fat, so Food Source A must be one of these. Food Source A also has 1.3 g of carbohydrates, which is Low. Both beef and cheese are Low in carbohydrates, so we still can't be certain what type of food it is, yet. Food Source A has 23.9 g of protein, which is Medium. Only cheese is High in fat, Low in carbohydrates, and Medium in protein, so Food Source A must be cheese.

Write Cheese as your answer for Food Source A on the Answer Sheet.

4. Continue this process for the other Unknown Food Sources.
5. Answer the Key Questions in your lab notebook.

Key Questions:

1. Which food would you eat if you wanted to get bigger muscles?

2. Which three foods would you eat to get the highest amount of fat, carbohydrates, and protein?
3. Which food do you think is the least nutritious?
4. Is a meal of beef and potatoes very nutritious? Why do you think so?

What's Going On:

The food that we eat is very important to providing the matter necessary for our growth and health. This matter comes in the form of organic compounds. Some of these compounds are fat, protein, and carbohydrates. Other food components include vitamins, minerals, and other elements. These components enter our bodies as large molecules, which are too big to enter our cells for use. Through chemical digestion, the large components are broken down into smaller components that our bodies can use.

Fats provide our bodies with high energy. The chemical bonds in fats are broken through a process called glycolysis, which releases the enormous amount of energy contained in the bonds. Our bodies can use this energy to build other molecules or move muscles for strenuous physical labor. However, because fats are so rich in energy, our bodies will store them if they are not immediately used. The reason why obesity is such a problem in our modern society is that we still eat foods high in fat, but do not use the energy in the chemical bonds. Our bodies are simply storing the energy for a rainy day.

Proteins provide our bodies with building blocks to build other proteins. Our bodies take in protein, which are often very large molecules and therefore useless to our cells, and breaks them down into amino acids, which can be used by our cells. These amino acids are then used by our cells to build other protein that our bodies need. Some of these proteins are in our muscles. By lifting weights, we increase the muscle cells' demand for more protein. As we give these cells the proteins they demand, they get bigger and stronger. This is why many weight lifters eat a large amount of meat on a daily basis.

Carbohydrates provide our bodies with short term energy. The chemical bonds in carbohydrates are not as energy rich as in fats. However, the process of breaking the bonds in carbohydrates is simpler and faster, so our bodies can utilize them almost immediately. Sugar is a type of carbohydrate. Many people will eat a candy bar or drink a soda, both contain high levels of sugar, for a quick burst of energy. However, this burst of energy usually only lasts for 20-30 minutes. Rice, which is high in carbohydrates, is the main food in most countries. People in those countries often eat several meals a day as they quickly use up the energy in the rice.

Other compounds, such as vitamins, are also important. Vitamins are often found in highest concentrations in fruits in vegetables. Though they are lowest in fats, protein, and carbohydrates, vegetables are highest in vitamins. There are many types of vitamins which our bodies use in very different and important ways to maintain our health.

What's the Matter

Concept: Carbohydrates, fat, and protein are composed of different elements and in varying quantity.

Objectives: Determining the amounts and types of elements in various organic molecules.

Materials: Peanut (1), marshmallow (1), small piece of bacon (1), cigarette lighter (1), three envelopes, one envelope should be labeled as 'Protein', another as 'Fat', and the last as 'Carbohydrate', 2 cm^2 pieces of construction paper that follow the specifications below:

Amount	Color	Element
30	White	Hydrogen
14	Orange	Carbon
12	Blue	Oxygen
2	Red	Nitrogen

Write the element name on one side of the construction paper. Into the envelope labeled 'Fat', put 20 Hydrogens, 2 Oxygens, and 9 Carbons. Into the envelope labeled 'Carbohydrate', put 12 Hydrogens, 6 Oxygens, and 6 Carbons. Into the envelope labeled 'Protein', put 10 Hydrogens, 3 Oxygens, 5 Carbons, and 2 Nitrogens.

***Assessment*:** As a demonstration, use the cigarette lighter to burn the marshmellow, peanut, and bacon. Be certain to allow each one to burn completely so that there is black ash. Let the students look at the ash of each one and ask them what do they think the ash could be. Ask them why do they think that such different types of food would all produce the same ash when they are burned. Now let's do an activity that will explain this.

Investigation: The students should work in groups of two or three.

1. Open the envelope labeled 'Carbohydrate' and take out the squares inside. Count the total number of squares in the envelope. Write this in your lab notebook.
2. Put all of the carbons in one group, the oxygens in another group, hydrogens in another, and nitrogens in the last group. Count to see how many squares are in each group. Write the results in your lab notebook.
3. Do the same thing for the envelopes labeled 'Fat' and 'Protein'.
4. Answer the Key Questions in you lab notebook.

Key Questions:

1. Which group had the most amount of elements? The least?
2. Which group had the most amount of carbons? Oxygens? Hydrogens?
3. Which group had an element that wasn't in any of the other groups? What element was it?
4. Using this information, how could you determine if a substance was a fat, carbohydrate, or protein.

What's Going On:

Fats, carbohydrates, and proteins are all organic molecules, which means they all have carbon. Also, other common elements in organic molecules are oxygen, nitrogen, and the ever present hydrogen. These four elements make up the vast majority of all of the molecules in all living things from bacteria to humans. As we have seen in previous activities, these molecules were produced in other plants and animals and enter our bodies when we eat them for food.

The main differences between the three molecules are the types of elements, the numbers of elements, and how they are connected to each other. Actually, the types of elements have very little to do with the molecules, because both carbohydrates and fats are composed of just carbon, oxygen, and hydrogen. Proteins are distinguished by being the only molecule with nitrogen in it.

Fats are very large molecules with the two oxygens at one end and a long chain of carbons and hydrogens at the other. There are two types of fats, saturated and unsaturated, which differ by the amount of hydrogen in the molecule. Saturated fats, such as those found in butter and lard, have the maximum amount of hydrogens and are quite unhealthy to eat. Unsaturated fats, such as those found in vegetable oil, have less hydrogens and are more healthy to eat.

Carbohydrates include starch and sugar. Much of the food that we think of as sweet is high in carbohydrates. Glucose, a simple sugar, is a quick source of energy for cells. Plants, such as potatoes, beets, and carrots, store carbohydrates in the form of starch for later energy. Plants also use carbohydrates as a food source for their embryos in seeds. Also, carbohydrates are used to surround seeds in fruits to make them more appealing to animals that will eat them and disperse the seeds. Finally, all plants use a carbohydrate called cellulose to construct the cell wall which gives plants their support.

Proteins are long chained molecules composed of amino acids, which are built by ribosomes in cells. Proteins also make up most of the muscle tissue in vertebrates and are therefore found in highest concentrations in meat. Though the protein used in this activity is rather small (only two amino acids), most proteins are composed of hundreds or thousands of amino acids and are often the largest molecule in a cell.

Origin and Distribution of Matter

Concept: All matter in the solar system originated from the Sun and is distributed in the solar system by the element's mass.

Objectives: Relating the atomic weight of one element to another.

Materials: Six boxes, one box should be labeled as the Sun and the other boxes labeled as 'Planet 1', 'Planet 2', etc., 2 cm^2 pieces of construction paper that follow the specifications below:

Amount	Color	Element	Atomic Wt.
55	white	hydrogen	1
25	yellow	helium	2
10	orange	carbon	12
7	red	nitrogen	14
2	blue	oxygen	16
1	purple	iron	56

Write the element name on one side of the construction paper and the atomic weight on the other.

***Assessment*:** Ask the students to name one of the planets close to the Sun. If they do not mention it, you may wish to point out to them that the Earth is a planet close to the Sun. Ask the students to name one of the planets that are far from the Sun. Jupiter or Saturn are good examples. Have the students give some of the basic characteristics of the two planets. Ask them why they think that there are so many differences between the two types of planets. Write their ideas on the board and begin the investigation.

***Investigation*:**

1. Put all of the pieces of construction paper in the box labeled as the Sun.
2. Have six students come to the front of the classroom. Give each of them a box. Have them stand in order from the Sun to Planet 5 from left to right.

3. Have each of the students reach into their box and randomly pull out a handful of papers. (The students should quickly note that only the box with the Sun has any paper in it.)
4. Then have the students put the papers in their hands into the box on their left. (Moving away from the Sun.) However, the papers do not move equally. Hydrogen and helium move out two boxes at one time. Carbon, nitrogen, and oxygen move out one box at one time. Iron only moves one box at a time.
5. Have the students repeat this procedure four more times.
6. When they have finished. Write each of the names of the boxes on the board. Under those names, write the name and amount of each element that was found in that box. Have the students copy this information in their notebooks and answer the Key Questions.

Key Questions:

1. In the beginning, where were all the elements located?
2. Over time, what happened to the elements?
3. Why do you suppose we had hydrogen and helium move faster than oxygen, nitrogen, or carbon? (Hint: consider the atomic weights of the elements)
4. Which planet had the highest percentage of hydrogen and helium?
5. Which planet had the highest percentage of carbon, nitrogen, and oxygen?
6. How is the model we used similar to our own solar system?
7. Did the iron show up in your model? Which planet was it located? How likely do you think it is that Planet 5 will get the iron atom before the time is up?

What's Going On:

The current theory to the origin of the solar system is that it started as a nebula, a giant cloud of interstellar gas and dust, which slowly condensed into our solar system. This nebula began to spin into a flat rotating disk. At the center of the disk, a large pocket of gas, mainly hydrogen and helium, began to form. This pocket eventually condensed into the Sun. However, inside this pocket were other trace elements. These elements composed only a small percentage of the elements found in the pocket, but were extremely important to the development of the planets. Some of these trace elements were life-giving atoms such as carbon, nitrogen, oxygen. However, more exotic elements such as iron, gold, and uranium could also be found.

As this disk continued to spin, the elements moved from the central pocket to the outer reaches of the disk, much like a weight attached to the end of a string. As you know, the heavier the weight, the more energy it takes to move the weight. So, the lighter elements moved out the fastest and the heavier elements barely moved out at all. Eventually, other pockets formed inside the disk itself. These pockets condensed into the planets.

However, as the composition of the pockets were different from each other, the current planets also appear different from each other. Towards the center of the solar, where heavier elements condensed, we see small planets composed of rocks with heavy elements like iron, nickel, and zinc. Also, elements such as oxygen, carbon, and nitrogen can be found in abundance. The outer planets, where the lighter elements condensed, we see giant planets composed of gases such as hydrogen and helium. Some of the heavier elements can also be found in these gas giants, but only in a small percentage. The only exception to this rule is Pluto. Though it is farthest planet from the Sun, it appears to be composed of a rocky or, at least, an icy material. So far, scientists are unable to explain this.

Module Four Summary (Biosphere)

Activity Title	Astronomical Concept	Biological Concept
Definition of Life *Investigation*	None.	All living things grow, reproduce, require food, air, and water, and respond to their environment.
Is It Alive? *Application*	None.	Using one of the definitions of life, test a substance to determine if it could be alive.
Three Spheres *Investigation*	None	The three spheres, litho, hydro, and atmo, have varying amounts of organisms with different adaptations.
Extraterrestrial Biospheres *Application*	Varying planets have very different environments according to their distance from the sun.	The different planets have different possibilities for life based on their environments.
Draw an Alien *Application*	Extraterrestrial planets can have environments very different from Earth's.	Living things have adaptations to help them survive in their environment.
Extinctions *Application*	Asteroid collisions, sun spots, and lunar phases are all possible causes of extinctions.	There are two types of extinctions. The organisms that survive will dictate how organisms appear in the future.

Defining Life

Concept: Living organisms all show the characteristics of growth, reproduction, response to environmental stimulus, and require food, air, and water for energy. Dead and non-living things may show some, but not all, of the characteristics of life.

Objectives: Using an operational definition and a chart, determine if various objects are alive.

Materials: Lit candle (1), crystal (1), bowl of water (1), dried leaf, bone or shell of some animal (1), small potted plant (1), living animal (fish, insects, or some reptiles are suggested) (1), tray to carry objects (1).

Assessment: Show a short video or film of an animal, preferably a baby and its parent. (Because the students only need to see the animal, you can turn the sound down and leave the room lights on.) While the video is playing ask the students to name ways that they can tell that the animal is alive. Write their answers on the board.

Investigation: Students should work in groups of 2-3.

1. Read the following characteristics of life.
   a. Growth is the process by which things get bigger and, often, more complex. Plants start their lives as tiny seeds, but can later become huge trees. Animals are small when they are born and then become much larger.
   b. Reproduction is the process by which all living things make offspring (seeds, eggs, babies). If living things did not reproduce, then there would be no more living organisms to replace the dead ones.
   c. Response to stimulus from the environment means that living things are aware of changes in their environment (temperature rises or falls, rainfall increases or decreases, day or night). Once they are aware of the changes, then their bodies or behavior can change (grow more fur, grow deeper roots, hide underground). Some responses are immediate, like a person being cut and running away, and

others take a long time, like a plant living in an area going through a drought and growing deeper roots.

d. All living things require energy in the form of food, air, and water, though the exact requirements for each organism may be different. Animals, for instance, require oxygen to breathe and eat either meat and/or plants. Plants require carbon dioxide and take in nutrients from the soil. However, all living things require water to live.

2. Using the Life? Chart and the objects on the tray, observe each listed object. As a group, decide if the object is alive or not and write 'yes' if you think it meets the characteristic for life and 'no' if you do not think so. For instance, the bowl of water does not grow so write' no in the column for 'Grow?'. Continue this process for all of the objects and all of the columns.
3. Answer the Key Questions in your lab notebook.

Key Questions:

1. Knowing that an object must have all four of the characteristics to be considered alive, which of the objects that you looked at are alive? Not alive?
2. Which objects have all but one of the characteristics but are still not considered alive? Which characteristic are they lacking?
3. Were there any things that you knew were alive, but didn't show all the signs of life? Which things? How do you think you could show that they were really alive?
4. Were there any things that you knew were not alive, but showed all the signs of life? Which things? How do you think you could show that they were not really alive?

What's Going On:

'Biology' is a Greek word that means the study of life. However, this is not as straightforward as it may seem. Throughout history many scholars have had difficulty in defining exactly what a living organism is. A few hundred years ago, many scholars believed in spontaneous generation, the idea that life could instantly arise from dead things. Scholars believed that dead leaves falling into a stream would eventually become fish and rotted meat grew maggots which became flies. Louis Pasteur disproved spontaneous generation by placing a piece of rotten meat in the open air and another piece under glass. According to spontaneous generation, both pieces should grow maggots. However, only the meat in the open grew maggots. He showed that flies must go to the meat and lay eggs which becomes maggots and that only life begets life.

Today, we have designed a better definition of what a living organism is. The most important of these characteristics are growth, reproduction, response to stimulus, and a necessity for food, air, and water. Living creatures show all of these traits. Growth is basic to all living things. Every organism begins it's life at a very small size and then grows to become larger. Even bacteria, which are microscopic, arise through the division of one large into two smaller ones, which then grow to become large cells and repeat the process. Humans grow from infants which weigh about seven and half pounds into adults which can weigh two hundred pounds. However, growth alone does not mean that something is alive. Fire can spread and seem to grow, but it is not alive. Crystals also grow at about the same pace as a plant, but they are not alive.

Reproduction is the driving force of all living things. Many biologists would argue that an individual organism exists to reproduce. In some animals, such as many insects, this certainly seems the case. Many species of mosquitoes only enter their adult stage to breed, lay eggs, and then die. Also, in many insect species, the male dies immediately after breeding with a female. However, fire can also appear to reproduce. One could argue that the sparks rising from a fire are spore-like particles that land and start a new fire. However, fire is not alive.

Living things all have ways of detecting and responding to changes in their environment. Most animals have senses such as sight, hearing, touch, or smell that inform them of things occurring around them. They can then make adjustments according to the information. Even plants respond to their environment. Most plants close the tiny openings in their leaves during dry weather as a way to prevent water loss. Again, one could argue that fire is alive because when one blows on a flame, it moves. But, fire is not alive.

Also necessary for all living things are food, air, and water. Animals must eat food, either plants, other animals, or decaying organic matter. Even plants must absorb inorganic compounds from the soil. Animals must also breathe in oxygen to maintain life. Plants also need carbon dioxide from the air for photosynthesis. And all living creatures need water to live. One could argue that fire needs food and air. Fire must have some combustible materials to burn and oxygen. However, water douses fire, therefore fire is not alive.

Is It Alive?

Concept: Using the definitions of life given in the previous lesson, **Definition of Life**, tests can be performed to determine if a substance is really a living organism or not.

Objectives: Measuring volume with a beaker, measuring temperature with a thermometer, measuring mass with a balance, experimenting and using an operational definition to determine if a substance meets the standards of the operational definition.

Materials: Marker (1), small plastic baggies (2), hot plates (2), 1L beakers (2), 50 ml graduated cylinder (1), balance, clock or stopwatch, thermometers (2), water, powdered sugar, Mystery Powder (yeast).

Assessment: Write the definitions of life on the board. Then, pass around a beaker of the Mystery Powder (yeast). Tell the students that NASA has collected this powder from a rock from Mars and they need to know if it is a living organism. Tell the students that you will need their help. Ask the students what would be some of the signs of life. Ask them if they can think of a way that they could test for some of these signs. Now let's try an experiment that may tell us if this powder is really a living organism.

Investigation:

1. Read the following information:

   One of the signs of life is the need for food, air, and water. When organisms eat food and digest it, they produce a gas, usually carbon dioxide. This is the reason humans exhale carbon dioxide. Most organisms require sugar as one form of food. If the Mystery Powder produces a gas when combined with sugar and water, then it may be alive. If it produces a gas, then we should see evidence of a gas in the bag containing the Mystery Powder even though we make certain to remove the no air in there before the experiment. Warm surroundings will help speed up the process.

A. Prepare Baggies and a Warm Waterbath

2. Heat the water for the water baths. Do this by filling both of the 1L beakers with water up to the 300 ml line. Put one thermometer in each beaker. Then, put each of them on one hot plate, plug in the hot plate, and turn the hot plate on 'Low'. Put the thermometers in the water. When the temperature of the water gets between 35-45 ^{O}C, then turn off the hot plate.

3. Label the baggies. On one of the baggies, write 'A' and on the other 'B'. Bag B will contain the Mystery Powder, sugar and water. Bag A will contain only sugar and water.

4. Measure equal amounts of sugar to add to each of the baggies. Using the balance, measure out 5g of powdered sugar and add it to bag 'A'. Do the same thing for bag 'B'.

5. Measure equal amounts of cool tap water to add to each of the baggies. Using the graduated cylinder, measure out 40 ml of water and add it to bag 'A'. Do the same thing for bag 'B'. Seal up both bags and shake them until the sugar is dissolved in the water.

6. Add the Mystery Powder to only one of the baggies. Using the balance, measure out 5g of the Mystery Powder and add it to bag 'B'.

7. Flatten the bags to squeeze out all of the air and then seal them up so that no air can enter or leave. When the water in the beakers is between 35-45 ^{O}C, then put both of the bags in the water and let them sit for 10 minutes.

8. After the ten minutes is over, remove both of the bags from the water and lay them flat on a table. Write your observations on both of the bags in your lab notebook. Be certain to describe differences between the two bags.

9. Answer the Key Questions in lab notebook.

Key Questions:

1. What differences did you see between the two bags?

2. From this experiment, can you be certain that the Mystery Powder is alive or not? Why or why not?
3. What other signs of life would we need to check for?
4. Why do you think it was important to put the bags in warm water?
5. Why do you think we used one bag with just sugar and water?

What's Going On:

The Mystery Powder, yeast, is a living organism. Yeast is a type of fungus and like all living things it requires food to live. In this case, the yeast is 'eating' the sugar and metabolizing it for energy. This is the same process human go through, but at a cellular, and simpler, level. Just as with humans, when the yeast metabolizes the sugar, it produces carbon dioxide as a waste gas. However, humans build this gas up in our blood and carry it to our lungs to be exhaled. Yeast simply lets the gas diffuse out of their cells. When the yeast was put into the warm, the heat of the water gave the organisms enough energy to carry out the metabolism of the sugar and produce carbon dioxide gas. If the water was too cold, there would not have been enough energy for the reaction to take place and no gas could be detected. If the water was too hot, then the living organism would have been killed and no gas could be detected. By the way, yeast in dough is what makes bread rise. As the yeast in the dough eats the ingredients and metabolizes them using the energy in the oven, the dough rises from the build up of carbon dioxide gases. Unleavened bread, such as the kind eaten by Jewish people during Passover, is bread without yeast added.

The reason why we used one bag with only sugar and water is to provide a control for the experiment. In this way, students can be certain that the production of gas was not caused by a reaction of the sugar and water. However, this one experiment cannot certainly determine that the Mystery Powder is alive. Baking soda added to vinegar also produces a gas. However, we know that baking soda is not alive. Other tests would have to be conducted to see if the Mystery Powder also grows, reproduces, and responds to its environment. If it is positive in all those tests, then we could safely argue that it is alive.

Life? Chart

For each object listed, write 'yes' or 'no' in the space of each characteristic of life that object shows. For instance, the bowl of water does not grow, so write 'no' in that space.

Object	Grows?	Reproduces?	Responds to environment?	Needs food, air, and water?
Bowl of water	___________	___________	___________	___________
Candle flame	___________	___________	___________	___________
Crystal	___________	___________	___________	___________
Plant	___________	___________	___________	___________
Animal	___________	___________	___________	___________
Dried leaf	___________	___________	___________	___________

The Three Spheres

Concept: The lithosphere, hydrosphere, and atmosphere are composed of different phases of matter and have different properties. The properties of each sphere have an effect on the number of organisms and their adaptations found in each sphere.

Objectives: Measuring with a ruler, classifying organisms by their adaptations to survive in common environments.

Materials: Sand, gravel, rock salt, water, clear plastic tub, ruler, plastic beaker, Organism List.

Assessment: Ask the students to name an environment on Earth in which organisms can't live. Then, ask the students to name all the different types of environment that organisms can live in. Write their answers on the board. Then write on the board 'Land', 'Water', and 'Air'. Then ask the students to group the types of environment together in each of the categories, such as the rain forest, desert, and caves could all be put in the 'Land' group. Ask the students to name a characteristic that is true for each environment in each category. Ask them how they think that characteristic might affect the plants and animals living in those environments. Let's do an activity investigating how environmental characteristics affect animals living there.

Investigation: Students should work in groups of two or three.

1. Read the following:

   The earth is composed of three spheres: lithosphere, hydrosphere, and atmosphere. The lithosphere, the largest of the spheres, is composed of all the rocks, soil, and lava on the earth. The hydrosphere, the next largest of the spheres, is composed of all the salt water, fresh water, and ice on the earth. The atmosphere is composed of all the gases on the earth.

A. Making a Model of the Three Spheres

2. Make a model of the lithosphere. Fill three quarters of the plastic beaker with sand and one quarter with gravel. Mix the sand and gravel together. Pour the sand/gravel mixture into the plastic tub on the right side. Fill it on the right side until it is about 5 cm deep. Throw away any extra mixture that you have left in the beaker.

3. Make a model of the ocean floor. Fill three quarters of the plastic beaker with sand and one quarter with rock salt. Mix the sand and rock salt together. Pour the sand/salt mixture into the plastic tub on the left side. Fill it on the left side until it is about 1.5 cm deep. Throw away any extra mixture that you have left in the beaker.

4. Add the ocean. Pour in water on the left side until it is about 1.5 cm over the sand/salt mixture. When you have finished, you should have a mound of sand/gravel mixture on the right side that is about 2 cm higher than the water level.

5. The atmosphere is the air above the hydrosphere and lithosphere.

6. Answer Key Questions 1-3 in your notebook.

B. Where Are All the Organisms?

7. Look at the Organism List. For each organism, write in your notebook in which sphere you think that organism lives. Thinking about the requirements for living, write what special adaptations do you think each organism has to help it live in that sphere.

8. Answer Key Questions 4-6.

Key Questions:

1. Write observations on the lithosphere. How is it different from the hydrosphere and atmosphere? How is it similar?

2. Do you see in any way where the lithosphere mixes with the other two spheres? In what way?

3. Answer questions 1 and 2 in relation to the hydrosphere and then the atmosphere.

4. How many of the organisms are found in the lithosphere? The hydrosphere? The atmosphere?
5. Which sphere has the most amount of organisms? The least? Why do you think this is so?
6. In general, what is one adaptation that all organisms in the lithosphere have in common? The hydrosphere? The atmosphere?

What's Going On:

The three spheres are all quite different from each other and have a great influence on each other. Each of the three spheres help create and shape the other two.

The lithosphere is composed of rocks, minerals, and soil, which are all solids. This is called the crust of the earth and is the most familiar to us. However, the lithosphere is also the molten rock, called magma. It is found in the upper part of the mantle and inside the crust. When the magma comes to the surface through volcanic vents, gas and dust also escapes through volcanic vents, goes out into the atmosphere, and can affect weather patterns such as rainfall and temperature. Also, the ocean floor is a part of the lithosphere. The reason why sea water is salty is because of the dissolved minerals from the lithosphere in the water.

Organisms that live on or in the lithosphere, which are the majority of organisms, have common problems. Most organisms that live underground are often microscopic, like fungi and bacteria. These organisms do not have the same physiological requirements as animals, so they may not need to get as much air as animals. For animals that live underground, such as gophers, burrowing insects, and worms, getting oxygen is the most important problem they have. There are microscopic pores in the soil where air collects, which smaller, invertebrate animals like the worms and insects can use. However, for larger, burrowing mammals, like gophers and moles, these microscopic pores are insufficient, their bodies require less oxygen than other non-burrowing mammals.

For organisms living on the lithosphere, which are most of the organisms that we think of, getting air is rarely a problem. However, the main problem for these organisms is getting and keeping water. Animals like birds, mammals, reptiles, and insects have special skin, scales, or exoskeletons that waterproofs their bodies. This is not meant to keep water out, but to prevent water from leaving the body through evaporation. Animals that lack this special skin, like amphibians, must stay in moist environments or their bodies will dry out. Plants living on land also have this same problem. They use tiny pores in their leaves, called stomata, to let carbon dioxide in for photosynthesis. However, as they leave their stomata open, they lose water through evaporation. Many plants that live in extremely dry climates open their stomata only open at night when it is cooler and water loss will be at its lowest.

The hydrosphere is composed of liquid and frozen water. The vast majority of the hydrosphere is found in the ocean. However, much water is contained in the polar ice caps, rivers, lakes, and underground aquifers. The hydrosphere loses water through evaporation to the atmosphere. This water stays as gas in the atmosphere and forms clouds which affect weather patterns like rainfall and temperature. The hydrosphere also helps reshape the lithosphere. Many of the land formations we see, such as canyons, rolling hills, and deltas, are caused by water flowing over the land and carrying away parts of the soil. Also, rocks are often broken, shattered, or eroded into sand, silt, and clay by the actions of ice and water. If it were not for the slow and constant actions of the hydrosphere, the earth would be one giant rock unable to support life.

Organisms that live in the hydrosphere have similar problems as those that live in the lithosphere. For animals, getting oxygen is even more difficult than for those living underground. Most animals have low metabolisms and usually use gills to help them extract what little oxygen there is dissolved in the water. Creatures like whales and dolphins that do not have gills must come up to the water surface for air. Plants, which require carbon dioxide, do not have such problems. Carbon dioxide dissolves easily in water and is usually found in abundance. However, water does not let light pass through it easily. Plants can live no deeper than 70m below water. Light used for photosynthesis cannot penetrate any deeper. Also, water, unlike soil, has very little nutrients in it. Plants must also be able to extract nutrients from the water or have roots in the ground at the bottom of the water.

The atmosphere is composed of gases that lie above the other two spheres. The atmosphere is about 70% nitrogen and 20% oxygen with trace amounts of carbon dioxide, water vapor, and other gases. The atmosphere greatly affects the other two spheres. The water vapor in the air, which comes down as rain, can help reshape the lithosphere. Also, rocks are broken down into soil by rain. This rain eventually runs down into rivers, lakes, or oceans and replenishes the hydrosphere. Also, winds, which is just the atmosphere flowing much like water, help to reshape the lithosphere and evaporate the hydrosphere.

There are no know truly atmospheric organisms. Though many organisms fly in the atmosphere, they must, at least, land to rest and reproduce. There are simply not enough nutrients in the atmosphere to allow an organism to live in the sky indefinitely. Also, because temperatures in the upper atmosphere are below freezing, water is frozen, which is unusable to living creatures.

Common Names of Organism List

Euplectella (Venus' Flower Basket)	*Tubularia crocea* (Hydra)
Clonorchis sinesis (Human Liver Fluke)	*Polinices lewisii* (Moon Snail)
Ascaris lumbricoides (Intestinal Roundworm)	*Lumbricus terrestris* (Earthworm)
Limulus limus (Horseshoe Crab)	*Latrodectus mactans* (Black Widow Spider)
Rhynchocinetes rigens (Red Night Shrimp)	*Squalus acanthias* (Dogfish Shark)
Schistocerca gregaria (African Desert Locust)	*Perca flavescens* (Yellow Perch)
Eurycea longicauda (Long-tailed Salamander)	*Chelydra serpentina* (Snapping Turtle)
Mimus polyglottis (Northern Mockingbird)	*Ursus horribilis* (Grizzly Bear)

Organism List

Euplectella

Does not move.

Uses tiny pores to filter out food.

Food and oxygen carried to it by water.

Body wastes carried away by water.

Tubularia crocea

Does not move.

Uses special stinging cells to catch prey.

Absorbs oxygen from water.

Body wastes carried away by water.

Clonorchis sinesis

Moves by sliding over surfaces.

Must stay moist to live.

Removes body wastes through body canals.

Absorbs oxygen from environment.

Ascaris lumbricoides

Excretes body wastes through gland cells.

Must stay moist to live.

Absorbs oxygen from environment.

Polinices lewisii

Must stay moist to live.

Absorbs oxygen through lungs.

Has a muscular foot to slide over surfaces.

Lumbricus terrestris

Has hairs to help it move through soil.

Eats dead vegetation.

Must stay moist to live.

Limulus limus

Has a hard shell and spiny tail.

Uses gills to absorb oxygen.

Must stay moist to live.

Latrodectus mactans

Does not need to stay moist to live.

Uses eight legs to move over surfaces.

Uses lungs to absorb oxygen.

Rhynchocinetes rigens

Must stay moist to live.

Has many hairy legs used for swimming.

Uses gills to absorb oxygen.

Has a hard exoskeleton.

Schistocerea gregaria

Has a hard exoskeleton.

Does not need to stay moist to live.

Uses six legs to move over surfaces.

Use trachea to absorb oxygen from air.

Squalus acanthias

Has a streamlined body.

Has a skeleton made of cartilage.

Uses gill slits to absorb oxygen.

Must stay moist to live.

Lays eggs to reproduce.

Perca flavescens

Has a streamlined body.

Has a skeleton made of bone.

Uses gills to absorb oxygen.

Must stay moist to live.

Lays eggs to reproduce.

Eurycea longicauda

Uses four legs to walk over surfaces.

Uses lungs to absorb oxygen.

Must stay moist to live.

Lays eggs to reproduce.

Chelydra serpentina

Does not have to stay moist to live.

Uses four legs to walk over surfaces.

Uses lungs to absorb oxygen.

Lays eggs to reproduce.

Mimus polyglottis

Walks on two feet or flies.

Does not need to stay moist.

Uses lungs to absorb oxygen.

Body covered in feathers.

Lays eggs to reproduce.

Ursus horribilis

Walks on four legs.

Does not need to stay moist.

Uses lungs to absorb oxygen.

Body covered in hair.

Gives birth to live young.

Extraterrestrial Biospheres

Concept: Other planets have environments very different from Earth's and may or may not be suitable for life as we know it.

Objectives: Using the properties of one object as a standard to measure the properties of another object, researching a topic using books, magazines, and the internet.

Materials: Computers with internet access, list of internet sites dealing with astronomy.

Assessment: Obtain pictures of each of the planets in our solar system and tape them on the board. Ask the students if Mercury and Venus, the planets closest to the Sun have life. Why not? Ask if Pluto, the farthest planet from the Sun has life. Why not? Ask if gas giant planets like Jupiter have life. Why not? Then, ask the students what properties does Earth have that makes it suitable for life. Write their answers on the board. Then, for each property they listed, ask them if they can think of any other planet that shares that same property. Finally, ask the students if there are any other planets that have life on them similar to Earth's. Now, let's do an activity that will see if this is possible.

Investigation: Students should work alone.

1. Read the following information:

   The Earth has several characteristics that make it suitable for living things.

   The temperature of the Earth is at a good range for living things. The highest temperature is about 50°C at the tropics. The lowest is about -90°C at Antarctica.

   Liquid water is able to exist on Earth. Water is necessary for all living things. If temperatures are too high or too low, then liquid water cannot exist.

   Components of organic molecules, like carbon dioxide, oxygen, and nitrogen, exist on earth. These molecules are the building blocks of living things and must be present for life to exist. Also, methane and ammonia can allow very primitive organisms, like bacteria, to exist.

Protection from radiation from the Sun is provided by the atmosphere. Radiation from the Sun has ultraviolet rays, gamma rays, and x-rays that are all harmful to living things. An ozone layer in the atmosphere will protect the living things from ultraviolet rays.

2. From the following list, pick one world from each of the columns.

Mercury	Jupiter
Venus	Saturn
Mars	Uranus
Pluto	Neptune
Moon (moon of Earth)	Titan (moon of Saturn)
Europa (moon of Jupiter)	Io (moon of Jupiter)

3. Do some research on the internet. Compare each of those worlds to the Earth. Look to see if each world is like the Earth and has the same characteristics that allow living things to exist on it.
4. Answer the Key Questions in your notebook.

Key Questions:

1. What is the temperature like on the two worlds? Are they within the temperature range for life to exist?
2. Is there liquid water on the two worlds? Is there any frozen water on the worlds?
3. Are there any organic molecules on the worlds? Which molecules? Are they in the atmosphere or in some kind of ocean?
4. Is the surface of the world protected from radiation? If so, what protects it?
5. Do you think that one of the worlds you researched is suitable for life? Which one?
6. If neither of the worlds that you researched is suitable for life, then what would you have to change to make the world suitable for life?

What's Going On:

Most planets are either too cold or too hot for liquid water, necessary for life as we know it, to exist. Mercury and Venus are far too hot to allow liquid water to exist. Venus does have a large amount of water, but it is all water vapor in the atmosphere. All other planets and moons are too cold to allow liquid water to exist. Mars also has a large amount of water, but it is in the form of ice at the Northern pole. Europa may have liquid water underneath the icy crust. Some scientists believe that organisms may have developed underwater near volcanic vents on the ocean floor. Organisms such as these do exist on Earth; so, the theory is possible. However, there is no evidence to support or dismiss the hypothesis.

Many worlds are bombarded by radiation. Worlds, such as Mercury, Mars, and the Moon, do not have enough atmosphere to protect living things from the Sun's radiation. This radiation would very likely destroy any living organisms. It has been suggested that on Mars, organisms could develop underground where they would be protected from the ultraviolet rays that bombard the Martian surface.

Organic molecules are not a problem, however. The giant gas planets, Jupiter, Saturn, Uranus, and Neptune, have plenty of methane and ammonia in their atmospheres. Also, Titan has oceans of ammonia and an atmosphere full of methane. If it were not so cold on Titan, it would be just like Earth was when it first formed. The thick organic atmosphere does protect the surface from radiation. It is so thick, in fact, that we cannot see any part of Titan's surface at all.

Though there a few worlds, such as Mars, Europa, and Titan, that meet some of the requirements for life, they all have one or two characteristics that make them unacceptable. Much like when determining if something is alive or not, all characteristics must be met or life is just not possible.

As a possible extension of this activity, have the students go the website http://nssdc.gsfc.nasa.gov/planetary/marspath_images.html and look at the various pictures of the Martian landscape. Have them compare and contrast the Martian landscape to landscapes they have seen on Earth.

Possible Internet Sites:

Planetary Science at the National Space Data Center (nssdc.gsfc.nasa.gov/planetary/)

Welcome to the Planets (pds.jpl.nasa.gov/planets)

The Nine Planets (www.seds.org/billa/tnp)

Views of the Solar System (www.hawastsoc.org/solar/homepage.htm)

Stephanie's Earth Science Website (http://Edtech.ci.swt.edu./pub/ses/earthscience.html)

Draw An Alien

Concept: Plants and animals must have certain adaptations to help them survive in their habitat, regardless if that habitat is terrestrial or not.

Objectives: Creating an organism that has the morphology and physiology adapted to a given habitat, explaining the features of the alien to one's peers.

Materials: Drawing paper, pens, pencils, markers, crayons, paint.

Assessment: On the board, write 'Earth', 'Air', 'Water', and 'Ice'. Ask the students to list features of animals that live in each of those types of habitats. If the students have trouble, then suggest one adaptation for each category; such as, legs for 'Earth' and wings for 'Air'. Then, let the students come up with others. Then, explain the Investigation to them.

Investigation: The students should work alone.

1. Pretend that astronomers have just discovered a new planet with the following characteristics:
   a. Average temperature: $40^{o}C$ (about $100^{o}F$)
   b. Average precipitation: 4 $L/m^2/yr$.
   c. Average wind speed: 20 kph (12 mph)
   d. Amount of surface covered with water: 85%
   e. Air pressure: 1 atmosphere (same as Earth)
   f. A high amount of carbon dioxide and oxygen in the air.
   g. Many other types of aliens on the planet.
   h. Very high amount of ultraviolet light striking the surface.
   i. The planet's axis does not tilt.
2. Using the drawing materials, draw an alien that you think might live on this planet.
3. Once you are finished with the drawing, write a story about your alien. In your story, try to answer the Key Questions.

Key Questions:

1. Basically, explain where the alien lives on the planet. Does your alien live on land, near water, or in the water?
2. If your alien has a certain color, why does it need to be that color? If it has any features (extra arms, wings, gills, etc.), then why does it need those features?
3. Can your alien live anywhere on the planet or does it have to stay in one spot?
4. How does your alien deal with the temperature of the planet?
5. How does your alien deal with the precipitation of the planet?
6. How does your alien deal with the high ultraviolet light striking the planet?
7. Does your alien need oxygen or carbon dioxide to live? Does your alien need any other type of gas to live? If so, which ones and why?
8. Does your alien interact with any of the other aliens on the planet? If so, why and how?

What's Going On:

At this point in the curriculum, the students should be able to understand that the physical environment affects the way organisms live. This in turn affects the way organisms look and behave. This activity is designed to be a fun exercise where the students can be creative, but in such a way that they are still within the context of scientific reasoning.

This activity is a good way to assess the students' understanding of the role of morphology and physiology as the apply to an organism's ability to survive in it's habitat. A student that has a well developed understanding should give a logical reason for each of the characteristics that the student has given his/her alien. If the alien is blue, then the student should be able to give some reason such as, "My alien lives in the water and it is blue to hide from the other aliens that want to eat it." If the alien has any structures, such as large wing like structures on its head, then the student should give some explanation such as, "The alien uses them to catch food as it blows by in the wind."

An exceptional student should be able to explain the basic physiology of the alien. The student should be able to explain the air requirements of the alien. Also, food requirements should be addressed. The student should be able to explain if the alien is a carnivore or a herbivore. Also, the student should explain some adaptation that allows the alien to survive with the high amount of ultraviolet light hitting the planet's surface.

Finally, the student should make some decision on the interaction of his/her alien with other aliens. If the student decides that his/her alien does interact with others, then he/she should be able to describe how and why this interaction takes place. This not only means that the student has to consider the adaptations of the other alien, but the possible benefits of this interaction. A student that can develop a well planned interaction with logical reasons obviously has a good understanding of the nature of ecosystems as well as individual adaptations.

Extinctions

Concept: Normal and mass extinctions of organisms, which differ by their rates, have occurred in the past and continue today.

Objectives: Classifying objects using a binomial system, determining a percentage, using an operational definition to determine the type of extinction.

Materials: For each group, have one plastic baggie with one of each of the following: small piece of string, piece of clay, small plastic button, paper clip, metal thumbtack, plastic spoon, wooden match, marble, wooden clothespin, penny, piece of aluminum foil, metal screw.

Assessment: Obtain pictures of various extinct animals. Possible animals include dinosaurs, the dodo bird, trilobites, and *Archeopteryx.* Ask the students what do all of these animals have in common. The best answer is that they are all extinct.

Investigation: The students should work in groups of two or three.

A. Types of Extinctions

1. Read the following information:

   Scientists refer to two types of extinctions. The first is a normal extinction in which 10-20% of species will be extinct in a matter of 5-6 million years. This means that throughout the history of the Earth, many species of plants and animals have become extinct. Endangered and extinct species have existed long before humans were there to change the environment. The other type of extinction is called a mass extinction. During mass extinctions, 30-90% of all species became extinct over a much shorter amount of time, probably over a few thousands of years. Scientists think that during a mass extinction, the environment changed so much and so quickly, possibly due to volcanic eruptions, asteroid collisions, or solar flares, that most species could not adapt and died.

B. Create an Extinction

2. Open the bag and take out all the things inside. We will say that each one of these objects represents an animal. Count how many 'animals' are inside and write that in your lab notebook. Some live in the ocean and others live on land.

2. Classify the 'animals' into groups of what they are made of. For example, put all the plastic animals in one group, all the wooden animals in another, etc. In your lab notebook, record the name of each group then, count and record the number of animals in each group.

3. Now, let's say there was a massive asteroid that hit the Earth and changed the climate so that only metal animals can live. Remove all the non-metal animals and count to see how many are left. Write down how many animals survived in your notebook.

4. Find the percentage of animals that were killed by the asteroid. Do this by dividing the number of dead animals after the asteroid by the total number of animals before the asteroid, then multiply that number by 100.

# of Animals After Asteroid / # of Animals Before Asteroid X 100 = Percent Survivors

5. Answer the Key Questions in your lab notebook.

Key Questions:

1. Before the asteroid, how many animals were on the Earth? How many different groups of animals were there?
2. Were all the animals destroyed after the asteroid hit? How many survived? Which groups of animals were left after the asteroid? Which groups didn't survive?
3. What was the percentage of survivors after the asteroid?
4. In what ways will animals on the Earth be alike after the asteroid? Explain.
5. Using what you know about extinctions, do you think this was a normal extinction or a mass extinction? Explain.

What's Going On:

When mass extinction events occur, like the one that included the dinosaurs, many species of organisms die. However, not all organisms are destroyed in the extinction event. In the case of the mass extinction of the dinosaurs, birds and small, mole-like mammals were already present. The only fossils of mammals that we have ever found from that time were small mole like creatures that could fit into the palm of your hand.

During the time of the dinosaurs, all of the niches in the environment were filled. You can think of a niche as the 'job' of the organism in the environment. For instance, the 'job' of a lion is to eat large herbivores in the African savanna. If a niche is filled, an organism is already doing that job, then it is difficult for new organisms to move into that niche. The organism that is already filling that niche is most likely much better adapted to do that job than the new organism. In the time of the dinosaurs, mammals were not able to evolve beyond their mole-like form because there were no new niches to fill.

After the dinosaurs were wiped out, however, we begin to find fossils of mammals that are larger and rather different from their mole-like ancestors. This process is called 'adaptive radiation', which is the process by which, over time, a small group of similar organisms begin to evolve different characteristics that allows them to better survive their environment by occupying the empty niches in the environment. For instance, all of the large herbivores were removed, so we begin to see mammals like the horse evolve to fill the niche of a large, herbivorous creature. Today, because of adaptive radiation, the largest and most dominant creatures on Earth are mammals and birds. This only could have happened if the dinosaurs were removed.

For our experiment, an event occurred that made the environment uninhabitable for 58% of the organisms. We can assume from this percentage that this was a mass extinction. However, some students may notice that no time period was given for the extinction. Though it is impossible to know the exact rate of extinction, we can assume that because an asteroid collided with the Earth the time period was quite short.

Summary

This curriculum integrates astronomical and biological concepts. Because biological concepts rarely have an effect on astronomical phenomenon, basic astronomical concepts are explained, then the dependence of biological concepts upon the astronomical are demonstrated. For this curriculum, there are certain activities in which only astronomical or biological concepts are demonstrated. The integration of the concepts is not in the activities, but in the sequencing of those activities.

The curriculum is broken into four modules that are organized around themes from the National Research Council's Standards (NRC) (NRC, 1996): Transfer of Energy, Earth in the Solar System, Structure of the Earth, Personal Health, and Diversity and Adaptations of Organisms (NRC, 1996). The theme of each module is developed using a modified version of the Learning Cycle. The concepts in the modules are developed using investigative, hands-on activities, which are also organized using the same modified version of the Learning Cycle. Common, inexpensive materials are used to facilitate the usefulness of the curriculum for low income teachers and school districts. The students are required to maintain a lab notebook in which they will write data measured during the activities, answer key questions, and make any comments on the concepts learned.

The first module deals with the concept of Energy Transfer, particularly light and heat energy, and Earth in the Solar System. The basic concept is that as there is a direct relationship between the inclination angle of light striking a surface and the concentration of that light striking the surface. The first activities demonstrate this concept by using flashlights, grid sheets, and rulers to show that light does spread out more as it is removed from the perpendicular above a grid. Also, lamps and thermometers are used to show that this does affect the temperature of the surface. From this basic concept, other activities demonstrate how this affects the rate of photosynthesis of plants on a global scale, the cause of the seasons, and the changes the seasons have on the biotic environment.

The second module develops the concept of Energy Transfer, but with the characteristics of various wavelengths of light and how they affect living organisms. The first activity demonstrates that white light is composed of many wavelengths and introduces the students to the electromagnetic spectrum. Subsequent activities explain the effects of various colors on organisms, particularly the photosynthesis and growth of plants. Also discussed is the affect of ultraviolet light on plant growth. The final activity demonstrates how humans and other animals are able to resolve images at different distances.

The third module develops the concept of Personal Health and Structure of the Earth. In this module, the concept of the conservation of matter is explained. The first activity demonstrates in which trophic level, producer, primary consumer, or secondary consumer, the majority of matter is located. The next activity shows how much of that matter is consumed by higher tropic levels. The next activities deal with basic nutrition and food chemistry. Finally, the last activity demonstrates how the elements are distributed throughout the solar system. The intention of this sequencing of activities to show where matter exists in the environment, how it moves through the environment, the effect it has on humans, and where it originated. The major concept that should be gained from this module is that all matter ultimately came from the stars.

The fourth module develops the concepts Structure of the Earth and Diversity and Adaptations of Organisms. The first activities help explain the characteristics of living organisms. Also discussed are the characteristics and adaptations of organisms that live in the soil, water, and air. An internet research assignment is required for the students to learn about the environments of various moons and planets and compare them to the Earth's. Finally, the last activity demonstrates the difference between normal extinction rates and sudden mass extinctions. The intention of this activity is to stimulate student's interest and imagination of extraterrestrial life within a scientific framework.

Evaluation

One concern of educators who have examined this curriculum has been the means of assessing the student's learning. Some school districts and parents are not accustomed to the idea of the students not having homework or daily quizzes. Also, some teachers are not familiar or comfortable with evaluating their students by any other means except traditional exams. For these parents and educators, this curriculum may present an uncomfortable situation.

Meaningful evaluation strategies are possible in this curriculum without the use of homework, quizzes, and multiple choice examinations. The first and most obvious evaluation technique is the Key Questions at the end of each activity. Teachers may have the students simply turn in their answers to the Key Questions and grade them on the completion and thoughtfulness of their answers. The Key Questions are designed to evoke higher order thinking in the students. Using Bloom's Taxonomy of Educational Objectives, the majority of Key Questions involve application, analysis, synthesis, and evaluation of information (Bloom, 1956). Due to the nature of the inquiry activities, few content recall questions are used. The main advantage of this form of evaluation is that it provides a daily record of the student's performance.

A performance evaluation may also be used. One definition of a performance evaluation is an evaluation which "requires students to actively accomplish complex and significant tasks, while bringing to bear prior knowledge, recent learning, and relevant skills to solve realistic or authentic problems" (Herman, 1992). Each day, the teacher may choose three or four of the students and evaluate their participation in the activity, engagement in group discussions, and use of the equipment. The teacher should observe to see if the students are offering ideas for the group discussion, engaging in an open to debate with other students, and using evidence from the activity to support ideas. The teacher should also see if the students are using the equipment properly, following instructions, and inventing new and effective ways of using the same equipment. This evaluation can provide daily, long term reports on the students' progress in the curriculum. Also, because the students will not know that they are being evaluated, unless the teacher informs them, they will not feel 'test anxiety'. Again, this evaluation will provide an immediate measurement of the student's performance. More information on alternative evaluation techniques can be found in *A Practical Guide to Alternative Assessment* (Herman, 1992) or *Expanding Student Assessment* (Perrone, 1991).

The students are also required to maintain a lab notebook for this curriculum. At the end of each module, teachers may have the students turn in their notebooks and grade them on their completion, organization, and thoughtfulness of the student's answers to the Key Questions. In this way, teachers can obtain an overall view of the student's learning of the content.

Three of the activities require the students to write scientific papers, which can be graded using the rubric provided. In this way, students are not only graded on their scientific thinking, but also their writing ability. This is a useful skill to teach to students as it will allow them to better understand the process by which scientists conduct experiments and publish their findings. Also, writing scientific papers requires students to explain their ideas in a long, essay-like format, which forces students to think carefully about their ideas and their understanding of the concept.

It is suggested that rather than using just one or two of the above evaluation techniques, that all techniques be used. In this way the flaws of one will be compensated for by the strengths of the others. Of course, periodic quizzes over the material can also be useful to obtain a quick and easy evaluation of the students' understanding of the scientific terms and processes in a more traditional method that may be more comfortable for parents and administrators. However, the weight of each evaluation is not suggested, because each teacher has their own school requirements to fulfill.

Categories of Key Questions

Key Question	Category
What percentage of the ecosystem is made up of plants?	Analysis
Which group is the largest?	Analysis
Were any of the groups equal? Which ones?	Analysis
How close were your predictions?	Analysis
On the carnivore squares, there is nothing to show that carnivores are eaten by anything, why do you think this is so?	Evaluation
Where do you think carnivores get the matter they use to grow?	Evaluation
Which food would you eat if you wanted to get bigger muscles?	Evaluation
Which food do you think is the least nutritious?	Evaluation
Is a meal of beef and potatoes very nutritious? Why do you think so?	Evaluation
Using this information, how could you determine if a substance was a fat carbohydrate, or protein?	Application
In the beginning, where were all the elements located?	Comprehension
Over time, what happened to the elements?	Application
How is the model similar to our own solar system?	Evaluation

Implications

One of the main goals of this thesis is to demonstrate the possibility of integrating two very different disciplines of science into a coherent and practical curriculum. Based on the principle that the integration need not be in each activity, but could exist in the sequencing of activities, this was possible. Also, by demonstrating a basic concept of one discipline and then demonstrating the effects of the first discipline on another, effective integration of two disciplines can occur. For instance, in Module One, the first activities demonstrate how the inclination angle of light can affect the temperature of an object, a physical science concept. Then, that concept is used to demonstrate how it affects the distribution of organisms across the globe, a biological concept. Despite the many apparent differences between two disciplines, there will always exist a few concepts of one discipline that have an impact on another. Using these concepts, integrations between any two sciences can be made.

Another main goal of this thesis is to fill the void of biology/astronomy integrated curricula. After much research and communications with other educators and curriculum developers, only two other biology/astronomy curricula have been identified. The first is a high school curriculum written by a professor at the Pennsylvania State University and the second is by the Foundational Approaches in Science Teaching (FAST) Program at the University of Hawaii. However, the nature of these curricula is not publicized due to the insistence of both parties that educators receive training on the proper use of their curriculum and materials before receiving information. An astrobiology curriculum is being developed by the education section of the Astrobiology Division of NASA. However, they have stated that they are only at the initial stages of the development.

Finally, this curriculum, using inquiry-based instruction and an integrated science method of organization, should stimulate interest in students as well as effectively teach the content of biology and astronomy. According to much of the research on student attitudes on science, a higher improvement of attitudes was seen with students that experienced curricula using the Learning Cycle or integrated science in comparison to those using the traditional direct method or discipline-based curricula. Also, the Learning Cycle has been shown to be an effective method of teaching science content and processes. Considering that this curriculum uses both the Learning Cycle and integration, it is possible that this curriculum has potential to be successful at improving student attitudes and understanding. However, this cannot be said with certainty, because a study of the effectiveness of this curriculum to improve student attitudes and understanding of science is beyond the scope of this thesis. Future research is necessary.

Bibliography

Adams, T. W. (1971). A review of unified science and the high school. *School Science and Mathematics, 71*, 495-500.

Alderidge, B. G. (1992). Project on Scope, Sequence, and Coordination: A new synthesis for improving science education. *Journal of Science Education & Technology, 1* (1), 13-21.

Atkin, J. M., & Karplus, R. (1962). Discovery or Invention? *Science Teacher, 29,* 45-51.

Bardeen, M. G., & Lederman, L. M. (1998). Coherence in science education. *Science, 281* (5374), 178-179.

Barman, C. R. (1997). *The Learning Cycle revised: a modification of an effective teaching model.* Arlington, VA: Council for Elementary Science International.

Barnard, J. D. (1960). *Rethinking Science Education, the Fifty-ninth Yearbook of the National Society for the Study of Education, Part I.* Chicago, IL: National Society for the Study of Education.

Bianchini, J. A. (1998). What's the Big Idea? *Science and Children, 36* (2), 40-43.

Bloom, B. S., et al. (1956). *Taxonomy of Educational Objectives, Handbook I: Cognitive Domain.* New York: David McKay Co.

Campbell, N. A. (1996). *Biology* (4th ed.). Menlo Park, CA: Benjamin/Cummings Publishing Co.

Chaille, C., & Britain, L. (1997). *The Young Child as Scientist* (2nd ed.). New York: Longman.

Chisman, D. G. (1973). Teaching integrated science. *The Science Teacher, 40* (2), 20-22.

Craig, G. S. (1932). *A Program for Teaching Science, the Thirty-first Yearbook of the National Society for the Study of Education, Part I.* Chicago, IL: National Society for the Study of Education.

Crow, L. W. (1993). *A Project on Scope, Sequence, and Coordination of Secondary School Science: Blocks I-VIII.* Houston: Baylor College of Medicine.

DeRose, J. V. (1965). Contributions to a unified program. *The Science Teacher, 32* (5), 83.

DeRose, J. V., Lockard, J. D., & Paldy, L. G. (1979). The teacher is the key: A report on three NSF studies. *The Science Teacher, 46* (6), 31-37.

Fertitta, N. V. (1975). K-12 unified science approach. *School Science and Mathematics, 75* (1), 65-69.

Fiasca, M. (1973). UNESCO helps science integrate. *The Science Teacher, 40* (2), 23-24.

Garafalo, A. R., LoPresti, V. C., & Lasala, E. F. (1988). Student evaluation of an integrated natural science curriculum. *Journal of Chemical Education, 65* (10), 890-891.

Gardner, M. (1975). A myriad of patterns on the international scene. *School Science and Mathematics, 75* (1), 69-79.

Hawkins, M. (1973). Reporting on the international conference on the education of teachers for integrated science. *The Science Teacher, 40* (2), 43-46.

Hayward, O. T. (1973). Integrated science-the untidy field. *The Science Teacher, 40* (2), 32-33.

Herman, J. L. (1992). *A Practical Guide to Alternative Assessment.* Alexandria, VA: Association for Supervision and Curriculum Development.

Hurd, P. D. (1975). Integrated science. *The Science Teacher, 40* (2), 18-19.

Karplus, R., & Their, H. D. (1967). *A new look at elementary school science. Science improvement curriculum study.* Chicago, IL: Rand McNally.

Karplus, R. (1974). *SCIS Teacher's Handbook.* Washington, D. C.: National Science Foundation.

Keating, J., & Keating, J. M. (1996, December). *Preliminary Results, Implications, and applications from a study comparing a traditional versus an integrated high school science program.* Paper presented at the Annual Global Summit on Science and Science Education, San Francisco, CA.

Klopfer, L. E., & McCann, D. C. (1969). Evaluation in unified science: measuring the effectiveness of the natural science course of the University of Chicago High School. *Science Education, 53* (2), 155-164.

Krebs, C. J. (1994). *Ecology: The experimental analysis of distribution and abundance* (4th ed.). New York: Harper Collins College Publishers.

Lerner, R. G., & Trigg, G. L. (1991). *Encyclopedia of Physics.* New York: VCH Publishers, Inc.

Lewis, M. C., & West, S. S. (1996). *Developing Integrated Science Courses for a Teacher Training Program: Curriculum Reform in Texas.* Unpublished paper.

Lockard, J. (1972). *Eighth Report of the International Clearinghouse in Science and Mathematics Curriculum Development.* College Park: University of Maryland.

Lomon, E. L., Becky, B., & Arbetter, C. C. (1975). Real problem solving in USMES: interdisciplinary education and much more. *School Science and Mathematics, 75* (1), 53-64.

Meyer, G. R. (1973, April). *The re-orientation of specialists for the role in the teaching of integrated science*. Paper presented at the Conference on Education of Teachers for Integrated Science, University of Maryland.

Munn, R. J. (1973). The British open university approach. *The Science Teacher, 40* (2), 27-28.

National Research Council (NRC) (1996). *National Science Education Standards.* Washington, D. C.: National Academy Press.

Osborne, R. and Freyberg, P. (1985). *Learning in science*. London: Heinemann.

Ost, D. H. (1975). Changing curriculum patterns in science, mathematics, and social studies. *School Science and Mathematics, 75* (1), 48-52.

Perrone, V. (1991). *Expanding Student Assessment.* Alexandria, VA: Association for Supervision and Curriculum Development.

Peterson, P. L. (1979). Direct Instruction Reconsidered. In P. L. Peterson & J. H. Walberg (Ed.), *Review on Research in Teaching* (pp. 97-112). Berkley, CA: McCutchan Publishing Corporation.

Purser, R. K., & Renner, J. W. (1983). Results of two tenth-grade biology teaching procedures. *Science Education, 67*, 85-98.

Renner, J. W. (1986, September). *Curricula which promote reasoning*. Paper presented at the United States-Japan Seminar on Science Education, Honolulu, HI.

Renner, J. W., Abraham, M., & Birnie, H. H. (1988). The necessity of each phase of the Learning cycle in teaching high school physics. *Journal of Research in Science Teaching, 25*, 39-58.

Rosenshine, B. (1979). Direct Instruction. In P. L. Peterson & J. H. Walberg (Ed.), *Review on Research in Teaching* (pp. 76-96). Berkley, CA: McCutchan Publishing Corporation.

Rubin, R. L., & Norman, J. T. (1992). Systematic modeling versus the Learning Cycle: Comparative effects on integrated science process skill achievement. *Journal of Research in Science Teaching, 29*, 715-727.

Schneider, L. S., & Renner, J. W. (1980). Concrete and formal teaching. *Journal of Research in Science Teaching, 17*, 503-517.

Showalter, V. (1964). Unified science: an alternative to tradition. *The Science Teacher, 31* (1), 24-26.

Showalter, V. (1971). *Toward a unified science curriculum.* Cleveland, OH: Educational Research Council of America.

Showalter, V. (1973). The FUSE approach. *The Science Teacher, 40* (2), 25-27.

Showalter, V. (1975). Rationale for an unbounded science curriculum, *School Science and Mathematics, 75* (1), 15-21.

Skinner, R. R., & Fairbrother, R. W. (1988). How do the A-level science grades of integrated science pupils compare with those who take all three separate sciences? *British Educational Research Journal, 14* (2), 149-155.

Smith, H. A. (1975). Historical background of Elementary Science. In Victor, E., & Lerner, M. S. (Eds.). *Readings in Science Education for the Elementary School* (pp. 3-11). New York: Macmillian Publishing Co.

Supinski, R., & Szabo, M. (1974, May). *A survey of unified science and enrollments.* A paper presented at the National convention of the Federation of Unified Science, Ohio State University.

Stephans, J., et al. (1988). The effects of two instructional models in bringing about a conceptual change in the understanding of science concepts by prospective elementary teachers. *Science Education, 72*, 185-195.

Wise, K. C., & Okey, J. R. (1983). A meta-analysis of the effects of various science teaching strategies on achievement. *Journal of Research in Science Teaching, 20*, 419-435.

Yager, R. E., & Penick, J. E. (1984). What students say about science teaching and science teachers. *Science Education, 68,* 143-152.

Yager, R. E. (1994). Integrated science: the importance of "how" versus "what". *School Science and Mathematics, 94* (7), 338-346.