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Science Concept Working Papers

PREFACE*

*"Knowing (unfortunately) is no longer the ability to summon up an organized view of some topic; it is the ability to recognize separate, discontinuous particles." Jacques Barzun, **Basic Education; Issues, Answers and Facts**, Vol. 3, No. 1, Fall, 1987.*

We can't study every natural phenomenon. In 1950, we couldn't make it through our science texts. So we have this challenge; to identify what is in science education that is of most worth.

But what is of most worth? In 1982 the National Science Teachers Association labeled it as scientific literacy(the ability to understand how science, technology and society influence one another and how this knowledge is used in everyday decision making). Interesting, scientific literacy is not a yes or no proposition. It is something that continuously develops either with or without help. Learning science, therefore, should be a continuous process. Furthermore, development of "and organized view of some topic."

Concepts and processes serve as organizers, unifying our approach to the learning of science. More important, they support the development of a scientifically literate population. They serve as the basis of most general goals for the science program. That is why it is to these organizers, that we need to turn our instructional attention.

Some teachers admit that they do not have a conceptual understanding of science. The real problem arises, however, when a teacher looks at a list of concepts and processes and says, "No problem. I already cover these." The problem is that most of us treat concepts as ends in themselves, not pointing out the qualities they have in common or the limitations they share in various contexts. Typically, we don't develop concepts as larger, logical organizers so that students can apply them not only in specific disciplines but in new situations as well.

Consider the concept of field. If the concept is developed only in terms of a magnetic field, for example, the students would most likely think that the concept is useful only for explaining magnetism. If it is a generalized interaction, however, then when they see one object fall toward another, they might say, "Oh, it must be in its field or sphere of influence." To use a non-science example, if the U.S. makes a statement and several other countries respond, they can be said to be in our field or sphere of influence. Within the scientific community, a concept-like field is also used as a basis for making predictions. On the basis of those predictions(when tested in the laboratory), we develop our theories and models. Thus, concepts become useful for organizing our understanding and for explaining things; useful in developing our scientific literacy.

For purposes of clarification, we can use learning psychology's definition of "concept" as an organizer for classes of events or objects. Concepts are usually identifies by one-or two-word descriptors, such as cycle, force, equilibrium, or energy-matter. In the mind, many concepts are developed naturally because they are related to readily available physical objects. Most scientific concepts, however, deal with the organization of the physical world and ate therefore invented. Invented concepts are much more difficult to structure because their organization is mentally constructed. To develop a student's understanding of these concepts requires a concerted effort on our part to change how we teach.

Since the construction of each concept requires a personal development process, teachers can not teach them, they must facilitate their development. Because multiple experiences with concepts are necessary for comprehension to develop, students must have different opportunities for input in multiple contexts, therefore new instructional strategies are indicated.

When we talk about concept learning, we are talking about things that teachers do in the classroom that enable students to develop these concepts at a more general level. Major concepts can create thinking frameworks that are so powerful that additional input becomes more meaningful. As a result, the content is richer, more diverse and more widely applicable. Concrete experiences, or hands-on learning, have been found especially useful in the initial stages of concept development, regardless of the age of the learner. Concept development does not occur by chance. You can't hope, as a teacher, that students will develop a concept. If you want that to happen, it has to be a planned part of instruction and the curriculum.

Because concepts are probably not uniformly understood in this new context, teachers may want to begin their own instructional development with this set of papers covering concepts. Each paper is designed to introduce the concept and help define it in teacher language using examples from the contemporary curriculum; suggest sample test questions with a commentary as to their appropriateness for measuring concept learning and sample instructional objectives that are desirable for concept learning. These teaching aids are intended to serve only as a starting point for understanding the concepts. They are not intended to be definitive statements about the concepts.

We hope that you find these papers useful in helping you think about, discuss and revise your instructional approach. We encourage you to pursue continued growth in understanding and application of the ideas in these thought-provoking papers.

** This Preface contains ideas excerpted from presentations made between 1984-87 by David C. Cox, Assistant Professor, Portland State University.*

CAUSE-EFFECT

Science Concept Working Paper # 1

Introduction

People seem to have an overwhelming desire to know what causes observations of interest (e.g., lightning, disease, rain, shadows, rusting). Therefore, perhaps none of the major science concepts is more frequently applied than *cause-effect*. Examples abound; among them are the rotation of the earth, causing night and day; gravitational attraction, causing things to fall to earth; excessive exposure to sunlight, causing sunburn; oxidation, creating "rust"; a lack of fuel, causing an automobile engine to stop; and the entrance of sin, causing decay and death. This powerful explanatory and predictive idea is a key element in enhancing one's ability to understand accumulated scientific knowledge, the laws of health, and the dynamic world in which we live.

The Concept

The cause-effect concept operationally refers to those situations in which one particular observation or event is always followed by another specific observation or event. By assigning causality in such cases, one concludes that the first observation/event somehow brings about the second observation/event at a later time. Scientists regularly search for such cause-effect relationships, often between seemingly unrelated observations.

The term *always* in the description of a cause-effect situation is very important. In order for causality to be assigned, the two observations/events must always occur and always occur in the same order. Since we can only document the past and present, all cause-effect relationships are tentative, waiting for continued confirmation or rejection on the basis of later observations.

Ideally, cause-effect relationships are established by means of carefully controlled experiments. Control is necessary, since any one or more of a large number of suspected or unsuspected variables may be contributors to the observation of interest. In some situations, such as human disease, the ability to conduct various types of controlled studies is necessarily limited. This constraint sometimes results in the need for extended periods of time for identification of the relationship and/or less certainty regarding the findings.

One example of a long-term study is the "sin experiment" from the "great controversy," in which millennia are involved, and during which many effects of the sin "cause" have been experienced. However, the experiment will be concluded only when all intelligent life in the universe has become convinced of sin's destructive effects.

The mechanism of the cause-effect linkage is often of interest. Once the cause-effect relationship has been established, the work to uncover the mechanism becomes more focused. Sometimes the mechanisms may be observed directly, while in other instances they are inferred and reported in the form of models.

The search for the cause of that group of diseases collectively known as malaria provides an example of observed and inferred mechanisms. For years, doctors believed that swamp exhalations were the cause. Doctors Bignami, Grassi and Bastianelli identified the bite of the Anopheles mosquito as the cause. Years later, microscopes made it possible to ascertain that the mosquitoes were the transfer agent for parasitic protozoans that were responsible for the illness.

While cause-effect relationships often involve single observations/events, multiple observations or events may also be involved. In addition, examples of cause-effect relationships can occur naturally, because of the intervention of humans, and/or between human technological creations.

One needs to be especially cautious about inappropriately assigning causality. Many events, conditions, phenomena, etc. can be found to have a large positive correlation coefficient (e.g., when one is present the other is always present). An example would be students who are high achievers in science are also found to be high achievers in mathematics. It is tempting to infer that high achievement in science is a result of (caused by) the high achievement in mathematics. Or said another way, it is tempting to speculate that one can increase science achievement simply by increasing the level of math achievement.

Causality is not established on the basis of correlational studies alone, even though these studies can assist in the identification of important variables to consider. As mentioned earlier, cause-effect relationships are identified by means of carefully controlled experiments, where the phenomena of interest can be observed with all potentially significant variables controlled.

Although the identity of the "first cause" has been debated for centuries, Seventh-day Adventist Christian educators consider their Creator the ultimate First Cause of all life and action.

Closely related major science concepts include change, cycle, energy-matter, equilibrium, field, force, gradient, interaction, model, order, origin, perception, probability, replication, significance, system, and time-space.

Sample Test Questions

Question 1: ***Cause-effect relationships***

A. are established by the observation of one event being followed by another event.
B. are proven to be true by scientists before being accepted.
C. need to be established by the use of controlled experiments.
D. are found only in the physical sciences.
E. A and B

Commentary: This concept-based question is concerned with the nature of cause-effect situations, and in particular with how appropriate examples are identified. Distractor "A" erroneously suggests that an observation of one event following another is adequate for establishing cause-effect. Choice "B" describes an impossible condition, "proven to be true," as a prerequisite for identifying examples of cause-effect. "D" incorrectly limits cause-effect to one category of phenomena. The correct choice is "C"

Question 2: ***Which is believed to cause malaria?***

A. Bacteria
B. Swamp exhalations
C. Parasitic protozoans
D. Genetic predisposition
E. Mosquitoes of the genus Anopheles

Commentary: This is NOT an example of a concept-based question. While the question deals with an example of a well known cause-effect relationship, the ability to respond correctly requires recall of previously-provided information regarding this particular category of diseases. A correct response provides little or no insight into the learner's level of understanding of the concept cause-effect.

Question 3: ***AnAn educationAn educational study found that mathematics achievement was the best pAn e success in science.***

A. This is a good example of a study that established a cause-effect relationship.
B. ThereThere may be a cause-effect relationship present, but additiThere may be a cause-effect r would be needed to determine this.
C. The findings probably represent a coincidence rather than a cause-effect relationship.
D. BasedBased upon the results of thBased upon the results of this sBased upon the results o improving mathematics achievement.
E. A and D

Commentary: This rather challenging concept-based question requires the learner to assess the findings of a simulated study relative to the possible application of cause-effect. Distractor "D" is especially interesting, since it represents a prediction based upon the assumption of a cause-effect relationship. The correct response is "B".

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Cause-Effect**.

The students will be making progress when they are able to:

1. Further develop the concept of cause-effect.
   a. Operationally define cause-effect.
   b. List examples of cause-effect
   c. Critique a given definition of cause-effect.

2. Expand the concept of cause-effect.
   a. DifferentiateDifferentiate between caDifferentiate between cause-effeDifferentiate between cau between two events.
   b. Identify situations where the use of the concept of cause-effect is appropriate.

CHANGE

Science Concept Working Paper # 2

Introduction

That which we call *change* is what adds dynamic diversity to our world. Change in varying degrees, rates, and kinds is everywhere around us. The seasons change, leaves change color, automobiles change speed, and even we change. Perhaps one of the most important changes that occurs in our lives is accepting Jesus Christ as our Lord and Savior. And changes continue as we are "transformed into His likeness". (II Corinthians 3:18 NIV). Nothing escapes change!

Change, and especially its causes and results, is often the focus of scientific investigations, because it is an integral part of our environment. The concept of change provides a powerful, widely applicable, explanatory and predictive tool.

The Concept

When we speak of change, we are referring to the process of becoming different. Becoming different can encompass an amazing variety of change, including change of state (e.g., liquid to solid, solid to gas, moving from Iowa to Oregon), the change of one or more physical characteristics (e.g, volume, density, texture, color, shape, temperature, pressure, heat content), and the host of changes that occur in a living thing as it is created, matures, and finally dies. Radioactive elements transform themselves into other elements by virtue of nuclear change. Many life cycles (e.g., butterfly, frog) contain different types of organisms as part of the sequence of life events.

Closer to home for all of us is the use of change as a way of describing ourselves or those around us. Most of us have heard someone say, "You've changed since I saw you last." This could make reference to a difference in height, weight, hair style, personality, hair color, vocabulary, hair quantity, or any one of a large number of other physical, spiritual, and/or psychological characteristics that, in combination, are "us."

The rate at which change occurs plays a role in our awareness of it. Some changes are occurring so slowly, for example, that we recognize that change is taking place only over prolonged periods of time. Some examples would be the movement of a glacier and the burning out of a star. In other situations, the change can occur so rapidly that we have difficulty observing or describing the process. Some examples are the explosion of a firecracker, the wingbeat of a hummingbird, and the vibration of a tuning fork.

Some changes occur naturally, such as erosion, radioactive decay, and the maturation of living things. Other changes are the result of human interaction, for example farming, cloud seeding, and resource depletion. It is possible for some changes to be reversible (e.g., freezing water, movement up into the air), while others are "one way" (e.g., the passing of time, a life cycle).

Of special significance, because of the frequency of its use, is the classification of change into the categories of physical, chemical, and nuclear. Some traditional descriptions and examples of each category follow:

Physical change: occurs while the composition and identifying properties remain constant. Examples of physical changes are melting, freezing, evaporating, dissolving, and mixing.

Chemical change: involves the formation of "new" substances with "new" properties. Examples of chemical changes are burning, rusting, and the electrolysis of water.

Nuclear change: changes within the nucleus of an atom, may or may not result in the formation of a new element(s). Examples are fusion, fission, and neutron absorption.

The concept of change is especially crucial for science educators. The rates of change in our natural and humanmade environments, and the rate at which technology is being applied, are increasing. This increasing rate of change requires us to deal with (or cope with, plan for, understand, manage, accommodate, adapt to) change in a shorter time frame than ever before. Furthermore, change impacts all aspects of our lives. In general, our ability to deal effectively with change is a measure of our success in a contemporary society. To put the point forward more bluntly, an accelerating rate of change creates a world that becomes an increasingly complex and demanding environment. Personal interaction and decision making therefore become increasingly difficult.

One of the most important specific types of change for people to comprehend is that known as exponential growth. While this aspect of change has been a focal point of many discussions regarding fossil fuel resource depletion, it has potentially staggering implications in a wide range of areas, such as population growth, resource depletion, and food supply requirements.

Many other major science concepts are closely related to change. Among these concepts are cause-effect, equilibrium, field, force, gradient, interaction (change is often cited as evidence of interaction), and matter-energy.

In summary, change is the process of becoming different or something else. The process can occur at a variety of speeds, and the rate can even vary during the process. Some change is reversible, while other is not. Change is often categorized into the major groups of chemical, physical, or nuclear. The mechanism of change is often a focus of scientific investigation.

Sample Test Questions

Question 1: ***Which is NOT an example of change?***

A. A falling rock
B. Burning wood
C. Freezing liquid water to form solid ice
D. Radioactive material
E. All are examples of change

Commentary: This concept-based test item requires students to recognize diverse examples of change (e.g., change of position, chemical change, physical change, nuclear change). The correct response is "E."

Question 2: ***Which is a characteristic of ALL change?***

A. Occurs in a positive direction
B. Rate is increasing
C. Is reversible
D. Something is becoming different or something else
E. Is caused, directly, or indirectly, by the actions of humans

Commentary: This item, which is concept-based, requires students to thoughtfully evaluate a number of statements to determine which one is true for all types of change. The correct response is "D."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Change**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of change.
   a. Operationally define change.
   b. Differentiate change, interaction and gradient.
   c. Critique a given definition of change.

2. Increase their ability to recognize change.
   a. Identify examples of change in their environment.
   b. Identify examples of change with different rates of change.
   c. List at least three tests that could be used to determine of change is occurring in a given situation.

3. Improve their ability to quantify change.
   a. When given appropriate data, calculate the rate of change.
   b. When given appropriate data, construct a graph that illustrates change.

4. Extend their understanding of the factors that influence change.
   a. Identify at least three factors influencing a given change.
   b. Predict the effect relative to change of increasing of decreasing the magnitude of a given factor.

CONSERVATION

Science Concept Working Paper # 3

Introduction

Perhaps no other science concept yields two distinctly different and yet related definitions or ideas. For many people, *conservation* conjures up visions of ecological consciousness, of actively saving resources, or of civil disobedience in protest of developing virgin lands.

To the scientist, the idea of conservation is a powerful unifying idea▌╬▌the that indicates that the sum of a given quantity remains the same before, during and after an interaction. There are concise and specific relationships used in applying the conservation concept in these cases.

The Concept

In its broadest sense, to conserve means "to save, to value," and hence "to protect or preserve." It is in this broad sense that the "conserve" finds its more familiar application. The conscientious teacher will find rich opportunity to include this topic and guide students in understanding current problems of energy and resource conservation.

The natural resources of soil, water, wildlife, forests, and the energy resources including solar, biomass (fuels such as coal, oil, gases, fermentation derivatives), and geothermal, are all in need of careful managing if humanity is to survive. This feature of the concept focuses not only on saving matter, but on saving the quality of life. Conservation involves an imperative, a moral obligation, to be faithful stewards of the gifts bestowed by the Creator. He will hold us responsible for their careful use, and for any neglect or disregard of their value.

Technology is aiding conservation with more efficient appliances, cars, and insulation, and recycling processes. Research is underway for the development of rapidly biodegradable plastics and other materials. Proper disposal and recycling of used oil, newspapers, etc., are considerations important to all of us.

The second aspect of conservation is more well-defined and has great predictive power. It may be expressed as follows: in a given physical system under specified conditions there is a certain measurable quantity that remains changeless (See Concept Invariance), regardless of what actions may occur within the system. The total amount of this quantity before a physical interaction is equal to the total both during and after, even though the quantity in question may change form, such as the change from potential energy to kinetic energy. The student of science may use such a concept to predict final states, given the initial conditions, or initial conditions, given the final states.

Three classical laws of this type are: (1) the law of the conservation of energy, (2) the law of the conservation of momentum, and (3) the law of the conservation of angular momentum. The concept of the conservation laws dates back to the early days of science. Since then scientists have modified these laws and will continue to do so as new knowledge is gained. One of the tasks of science is to explain the detailed rationale for laws that, on the surface, are "self-evident".

An outstanding example of how these laws are subject to modification is Einstein's elucidation of the mass-energy equivalence ($E = mc^2$). Before that, the conservation of mass and the conservation of energy were considered to be independently valid.

Conservation is a unifying thread through several disciplines and topics. Among them are conservation of charge and mass in balancing chemical equations, conservation of mass and atomic number when balancing nuclear equations, conservation of charge and current when analyzing electric circuits, conservation of energy and momentum when analyzing a physical interaction, and conservation of mass-energy in atomic and nuclear interactions.

The subject of much testing over the decades, the energy conservation law states that energy can neither be created nor destroyed, but is changed merely from one form to another. A fundamental implication of this law is that no device can emit (or put out) more energy than was put into it. Common sayings which express this law are "There is no such thing as a free lunch," and "You can't get something for nothing." Curious tinkerers, science explorers, and experimenters from ages past to the present have been and continue to be intrigued with the possibility of overcoming the limitations described by this natural law.

Many ingenious and creative approaches have been tried in the quest for perpetual motion, with the attendant expenditure of effort and resources, and resulting frustration, but so far no one has produced a device which will continue to run on its own, much less supply energy beyond that needed for its operation.

Creation has interesting implications in the context of conservation. Some believe that God was not dependent upon pre-existent matter in the formation of the universe. Coupled with the belief that He is omnipotent, as well as omnipresent and omniscient, He had more than abundant power and energy available for the transformation of that energy into the mass of planets, stars, living things, and created beings.

Major science concepts related to conservation include invariance, change, cause-effect, energy-matter, entropy, equilibrium, God-Designer/Sustainer, interaction, order, quantification, perception, system, theory, and time-space.

Sample Test Questions

Question 1: ***A conservative system***

A. is the only type found in nature
B. can exchange the conserved quantity with nearby systems
C. is composed primarily of non-living matter
D. is defined by the type of quantities within it
E. does not contain any subsystems

Commentary: This concept-based item assesses the learner's understanding of "conservation" in its physical sense. The key to responding correctly is in identifying which alternative statement describes an attribute of a conservative system. The correct response is "D."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Conservation**.

The students will be making progress when they are able to:

1. Further develop the concept of conservation.
   a. Operationally define conservation.
   b. List examples of the two types of conservation.
   c. Critique a given definition of conservation.
   d. Differentiate conservation, change, energy-matter and system.

2. Improve the ability to apply the concept conservation.
   a. Identify situations where the use of the concept conservation is appropriate.
   b. Critique another person's use of the concept conservation in explaining a phenomenon.
3. Value the concept of conservation.
   a. Choose to personally work to conserve our planet's resources.
   b. Choose to use the quantitative conservation laws to predict final states of a system.
   c. Value explanations based upon the conservation concept.

CYCLE

Science Concept Working Paper # 4

Introduction

The term *cycle* is widely used in both science and everyday affairs. While it is certainly debatable as to whether or not cycles are actually a fundamental part of the natural world, the identification of apparent cycles in nature has enabled humans to make many predictions with a very high degree of accuracy. Many believe that being able to successfully predict events is the fundamental basis for understanding a phenomenon. The cycle is a powerful concept having widespread application for both explanation and prediction.

The Concept

In the most straightforward sense, cycles are patterns identifiable because certain events or conditions appear to be repeated. This repetition can occur at regular intervals (rhythmic cycle), somewhat regular intervals, or widely variable intervals (nonrhythmic cycles). Examples of this cyclic behavior show tremendous diversity. Some are rather obvious, such as pulse, ocean tides, phases of the moon, or the eruption of . . . "Old Faithful" . . . geyser. Some of the other examples are less apparent; among these are the internal combustion engine, life cycles of a variety of organisms (e.g., insects, frogs, fish), the rock cycle (not the music, even though that's possible), water cycle, sunspot activity, comet sightings, population cycles, alternating electric current, and the nitrogen cycle. Other examples of cycles can be so subtle that there is serious debate as to whether or not they qualify. Examples of these are business cycles, stock prices, clothing fashions and educational reform movements.

In some instances, a cyclic phenomenon is an "object of interest" repeating a pattern of movement (e.g., pendulum, guitar string). In other situations, such as the life cycle of an organism, there is a repeating pattern of reproduction and development involving new generations of the organism. Other applications of the cycle concept have different forms of the same substance involved (e.g., water in the water cycle). Space does not permit the identification of additional examples of this variation, but this diversity of qualifying phenomena is one of the attributes of the cycle which makes it so rich and powerful.

The time required for a single cycle to be completed (recurrence of the identifying condition, event, position, etc.) is known as the *period*. Periods can range from incredibly short (e.g., the beating of an atomic clock) to extremely long (e.g., the life cycle of stars). The period is a significant variable in the identification of cyclic phenomena, since our senses may require assistance to observe the extremely short periods and we may need to communicate between generations in order to observe the very long periods. The consistency of the period is also crucial to the identification of cyclic behavior. Cyclic phenomena with little variation in period are more easily identified and provide more precise predictions.

Whereas the period is the time interval between the repeating events or conditions used to identify the cyclic nature of an observed phenomenon, the frequency is a related measure specifying the number of event or condition intervals occurring per unit of time. Frequency and period are mathematical reciprocals of each other. For example, alternating electric current can be described as having a frequency of 60 cycles/second or a period of 1/60 second/cycle.

Cycles can change in a variety of ways (e.g., period) or even cease to be cycles. To better understand cyclic phenomena, one must identify the interacting elements (or components, stages, events) and the force(s) driving the cycle. Once these identifications have been made, it is possible to alter or stop an existing cycle if this action is deemed appropriate. Examples of such efforts would be breaking the cycle of crime, altering or breaking the life cycle of a disease-causing organism, and improving food supplies by means of altering life cycles of agricultural products.

In summary, cycles are patterns identifiable because certain events or conditions are repeated. Cyclic phenomena can be rhythmic, somewhat rhythmic, or nonrhythmic. Cycles can be quantified in terms of period and/or frequency. Existing cycles can be altered or cease to exist either through natural events or due to the intervention of humans. Planned human intervention usually requires knowledge of the interacting elements within the cycle and the forces responsible for the observed behavior.

Sample Test Questions

Question 1: ***What best demonstrates the concept of a predictable cycle?***

A. The first snow of each year
B. Appearance of spring flowers each year
C. Beginning of the falling of leaves each year
D. Appearance of a full moon
E. The onset of the cold and flu season

Commentary: This item requires learners to assess the "degree of fit" of several familiar natural phenomena to the mental construct "cycle". While all of the examples could be considered cyclic phenomena, the most predictable recurring event or condition "D" is the best choice.

Question 2: ***The illustration below represents a cyclic phenomenon composed of four sequential events.***

Figure not available

The most probable effect on the cycle of preventing "event 3" from taking place is:

A. No effect
B. Stopping the cycle
C. Slowing the rate at which the events take place
D. Reversing the order in which the events take place
E. Creating a "new" cycle involving only events 1, 2, and 4

Commentary: This item utilizing a generic cycle is well suited to assessing a student's understanding of the concept. In order to respond correctly, the student must operationally grasp the sequential nature of the cycle's events and then analyze the impact of the intervention. The correct response is "B".

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Cycle**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of cycle as it is used in science.
    a. Select examples of scientific from a list of possibilities.
    b. List several examples of cycles.
    c. Write a definition of a scientific cycle.
    d. Critique a given description of a cycle.

2. Value the concept of cycle for its explanatory and predictive power.
    a. Value explanations and predictions based upon appropriate applications of the concept of cycles.
    b. Choose to use the concept of cycle when making observations, formulating explanations, and/or making predictions.
    c. Value cycles as an example of the orderliness of the Creator.

For Further Information About Cycle

Dewey, E. R. *Cycles* New York: Hawthorn Books, 1971.

Dewey, E. R. and R. R. Ward. "If You Look Hard, Cycles Are All Over." *Smithsonian* March 1977. This article is suitable for older student use.

Huff, D. *Cycles In Your Life* New York: W. W. Norton, 1964. This book is suitable for younger student use.

Exemplary Units

"Cycles" (Grade 10), Division of Instruction, Department of Science, Rochester Public Schools, Rochester, New York, 1977.

GOD-DESIGNER/SUSTAINER

Science Concept Working Paper # 5

Introduction

In the Christian school, the concept of *God-Designer/Sustainer* may be interwoven throughout the entire science curriculum. However, the teachers will need to develop their own emphases because the majority of textbooks do not allude to God in any way. Scientifically, God is not a proven or even provable fact, but there are many evidences for such a concept. The many laws and principles in the natural world indicate an intelligent designer. For those who choose to accept that designer as God, the God-Designer/Sustainer concept is very significant.

The Concept

Although God-Designer/Sustainer is given as a single concept, it really involves three ideas at once. While it is appropriate to discuss each idea individually, the unity of the three should not be forgotten.

God

It is impossible for the human mind to fully grasp the concept of God. It is not possible to design an experiment to determine exactly what role He plays in relation to our world. Therefore, individuals will form their own concepts of God based on their own observations and sensitivity to evidences that exist. Obviously, there is an element of faith involved in this idea . . .which removes it from the realm of empirical science. However, one can recognize the evidences of God in the world of science.

Designer

Design is apparent in every aspect of science. Design can be seen in the symmetry of patterns in nature (shapes of flowers), the combining of units to make biochemicals (combining amino acids to make proteins), the special arrangements of atoms to make specific units (the phosphate, the deoxyribose sugar, and the base of a nucleotide), the arrangement of subatomic particles to make the atoms, mathematical relationships (quantum physics), the processes of earth science (metamorphosis of rocks), etc. Where there is design, a designer is implied. One must be ask, "Who or what is that designer?" For the Christian, the designer is God!

Sustainer

Without a sustainer, even the best designed systems will deteriorate in time (entropy). Since deterioration of the basic laws of science has not occurred, it would seem that there is a sustainer. Science has not been able to identify who or what that sustainer is. For the Christian, the sustaining force comes from God.

Sample Test Questions

Question 1: ***Which of the following is NOT necessarily an evidence of God as Designer/Sustainer?***

A. Quantum theory of atomic structure
B. The green color of a leaf
C. Total internal reflection of light
D. The amount of matter in a sample of steel
E. Nuclear fusion as responsible for the energy from the sun

Commentary: In order to correctly respond to this item, the student must demonstrate substantial conceptual understanding. The student must be able to differentiate between phenomena that could be totally random as opposed to phenomena that are dependent upon design in the system. This question represents an appropriate concept oriented item. The correct response is "D."

Question 2: ***List the events of the seven days of creation week.***

Commentary: This question is asking for details of given events. The focus is not on the concept of God-Designer/Sustainer, but on the details of specific acts of God. If the question is to determine the student's knowledge of events, the question is acceptable, although low level. It is, however; a "content" rather than concept-oriented question. A student could respond correctly to this item and have little or no development of the concept of God-Designer/Sustainer.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **God-Designer/Sustainer**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of God-Designer/Sustainer as it is used in science.
   a. Select evidences of God-Designer/Sustainer from a list of possibilities.
   b. List several examples of evidences that indicate that God was the designer or is the sustainer of scientific laws or principles.
   c. State their own version of the concept of God-Designer/Sustainer.

2. Appreciate the wisdom and power of God's design and sustenance of the natural world.
   a. Explain how God's design and sustenance of the natural world benefits them personally.
   b. Explain observed phenomena indicating God's wisdom and power in the design and sustenance of the laws of science.

ENERGY-MATTER

Science Concept Working Paper # 6

Introduction

Most of us are operationally dealing with three concepts (i.e., energy, matter, energy-matter) when addressing the idea of *energy-matter*. Therefore, it is appropriate to use a three-pronged approach in this section. Of the three concepts, matter is perceived to be the most concrete and manageable, followed by energy, and finally energy-matter.

The Concept

Energy-matter is potentially the most fundamental concept in science, since it is concerned with the "stuff" from which everything is made and the "fuel" that drives our dynamic environment. For most of us, our common experience and, perhaps, formal education have led us to treat matter and energy as separate and distinct entities. The contemporary scientific view is quite different. Energy and matter are now treated as interchangeable expressions of one entity known as energy-matter.

Matter

Traditionally, we have described matter as anything that has mass and takes up space. While there are a number of properties that can be used to help describe a given sample of matter (e.g., weight, volume, density, temperature, color, shape, texture), the one that appears to be most constant and useful is mass: the quantity of matter present. Mass is measured by using a balance and the standard unit for mass, the kilogram. Do not be confused mass with weight, the measure of the net gravitational force acting on matter.

Matter may exist in the various states identified as solid, liquid, gaseous, or plasma. Regardless of the state, pieces of matter are capable of interacting with each other.

Energy

Energy is a pervasive, but somewhat elusive concept. A concise, meaningful description of energy just doesn't seem to exist. Energy is a fundamental concept but, at the same time, extremely diverse and abstract. Literally, wherever you look, the concept of energy is applied.

In a simplistic sense, energy is that which can bring about change (e.g., change in location, speed, direction, chemical bonding, temperature, and state.) From a slightly different perspective, energy is that which enables a material system to bring about change in itself and other systems when interacting with them. Glossaries and other sources often describe energy as the ability to do work.

Matter has traditionally been viewed as possessing varying amounts of energy by virtue of structure (e.g., atoms, molecules, bonding), position, temperature, and degree of motion. The internal energy of the atom . . . as nuclear bonding and the location . . . interaction of electrons. Molecules have additional energy, not only because of the increased numbers of atoms, but also because of the bonding between the atoms. Energy associated with position is often called potential energy (e.g., gravitational potential energy, electrical potential energy), while energy associated with movement (e.g., speed) is usually referred to as kinetic energy. The sum of the kinetic energies of the atoms comprising a sample of matter is the sample's heat energy or heat content.

Energy appears to be in a nearly constant process of

being transferred from one place to another (e.g., sun to earth, stove to cooking utensil) or from one form to another (e.g., electrical to light, electrical to heat, kinetic to potential, kinetic to heat). Energy is supplied by many different sources and has a wide array of forms, such as chemical, heat, sound, light, electrical, potential, kinetic, and nuclear.

Fortunately, even though there are many forms of energy, it is measured in one standard unit and units easily converted to this standard unit. The unit for energy is the joule, which is equal to the amount of energy needed to accelerate a 1 kg mass at the rate of 1 m/s/s under frictionless conditions through a distance of one meter. That sounds a little complicated. One hundred joules of electrical energy are needed to keep a 100 watt light bulb operating for one second.

Energy-Matter

Energy-matter is the newest concept of the three we have been discussing. The basic idea of energy-matter is that what we have previously classified as different-matter and energy are actually two different aspects of the same thing. This "thing" is energy-matter. In other words, energy and matter are interchangeable!

This means that properties previously assigned to either matter or energy are now common properties of energy-matter. For example, any sample of matter has both a mass and an equivalent wavelength. A chunk (i.e., quantum) of energy has both a wavelength and a mass equivalent. Thought of another way, when something gains energy, it also gains mass, since it has gained energy-matter.

Closely related major science concepts include cause-effect, change, cycle, entropy, equilibrium, field, force, fundamental entities, interaction, order, origins, and system.

Sample Test Questions

Question 1: ***The quantity of energy-matter present in a given sample is appropriately measured in***

A. kilograms.
B. joules.
C. kilograms/m^3.
D. degrees kelvin.
E. A or B.

Commentary: This concept-based item requires the learner to acknowledge the interchangeable aspects of energy and matter in terms of the measurement units for quantity. Two of the distractors offer units for other measurable attributes of energy-matter. The correct response is "E" and the question is suitable for use with Sample Objective three.

Question 2: The idea of energy-matter is fundamentally that "matter can be changed into energy and energy can be changed into matter." This statement

A. adequately captures the basic idea.
B. would be adequate if he term "converted" were substituted for the word "changed."
C. is misleading since it suggests that matter and energy are two different "things."
D. needs to be amended to emphasize the difficulty of such conversions by adding, "under unusual and difficult to achieve conditions."
E. would be fundamentally correct if it had added, "when nuclear changes are involved."

Commentary: This high level, concept-based question requires the student to selectively critique a given description of the idea of energy-matter. Choosing any one of the distractors is indicative of the misconception that energy and matter are two different "things." The correct response is "C" and the item is suitable for use with Sample Objective three.

Question 3: Which is the calculated wavelength of a 1.0 kg mass moving with a speed of 100 m/s?

A. $3.0 \text{ X } 10^{8}$m
B. $5.0 \text{ X } 10^{-7}$m
C. $6.6 \text{ X } 10^{-36}$m
D. $9.9 \text{ X } 10^{-39}$m
E. none of the above

Commentary: Even though it is concerned with the concept of energy-matter, this is **NOT** an example of a concept-based question. In order to respond correctly, the student must recall a specific equation and a numerical constant. In addition, certain mathematical skills are assumed to be in place. It is unlikely that a correct response would be forthcoming without prior study and practice in solving similar types of problems.

Question 4: Which analog best conveys the idea of energy-matter?

A. Water in the solid and gaseous states
B. Hydrogen and oxygen combining chemically to form water
C. Water being decomposed into hydrogen and oxygen
D. A salt water solution
E. A sponge saturated with water

Commentary: This concept-based item requires students to utilize their concept of energy-matter to select the best fitting analog. The correct response is "A," and the item is suitable for use with Sample Objective three.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Energy-Matter.**

The students will be making progress when they are able to:

1. Further develop their concept of matter.
   a. Operationally define matter.
   b. List at least five measurable attributes of matter.
   c. Name and describe the various states in which matter exists.
   d. Differentiate matter, mass, and weight.

2. Expand their concept of energy.
   a. Operationally define energy.
   b. List at least five different types/forms of energy.
   c. Differentiate potential, kinetic, and heat energy.

3. Increase their understanding of the concept of energy-matter.
   a. Operationally define energy-matter.
   b. Critique a given definition of energy-matter.

4. Value the concept of energy-matter for its predictive and explanatory power.
   a. Choose to further develop their personal concept of energy-matter.
   b. Choose to use the concept of energy-matter when appropriate.

For Further Information About Energy-Matter

Reading Material

Karplus, Robert and Lawson, Chester A. *SCIS* Teacher's Handbook. Berkeley, CA: University of California, 1974.

ENTROPY

Science Concept Working Paper # 7

Introduction

The concept of *entropy* was proposed in 1850 by Rudolph Clausius, a German physicist, and is sometimes presented as the second law of thermodynamics. Clausius developed the concept of entropy while he was studying heat engines. Scientists in various fields developed the concept further and, whereas it started out as a mere adjunct to technology, it became more significant in the understanding of events and processes in the natural world. The concept of entropy is applicable to many types of probabilistic processes.

The Concept

Entropy is a measure of the disorder, randomness, or organization of a system. If a system undergoes changes that result in a more disorderly or random state, then the system is said to have increased in entropy. Take for example the system of a pool table with billiard balls "racked up" prior to the "break." The balls are in a very orderly pattern or state of being relative to each other. After the "break" the balls move to random locations relative to their original positions. The disorderliness or randomness of the system has increased, and therefore its entropy has increased.

A similar application to this idea is presented in theories relating to states of matter. When a substance is in the solid phase, it has low entropy because the particles of the solid maintain a fixed, orderly arrangement and are restricted in their motions. When a solid changes to a liquid, its particles have greater freedom of motion and more possible arrangements. Hence, the liquid is more disordered and unorganized than the solid, therefore; its entropy is greater.

Anyone who has lived with a typical teenager knows the concept of entropy without perhaps even realizing it. Consider the increasing state of disorderliness of the teenager's room if left without outside intervention. Clothes, and anything else not fastened down, become randomly located virtually anywhere in the room or throughout the house in a relatively short period of time. The entropy or disorderliness of the room and house has increased.

The concept of entropy has important implications relative to the available energy resources of the universe and the ways in which we use them. When you use a resource, such as natural gas, to heat your home, you do not use up the energy in the gas. The potential energy contained in the molecules of the gas is converted into thermal energy in the flame, which is transferred to thermal energy in the air of your home. Even if heat energy leaks out of the house, it is not lost because it heats up the environment outside. Energy has not been "used up". However, the entropy has been increased.

All spontaneous processes are irreversible. Hence, it has been said that the entropy of the universe is increasing: that is, more and more energy becomes unavailable for conversion into mechanical work, and because of this the universe is said to be "running down." For the Christian, the idea of increasing disorderliness fits very easily into a worldview that sees the world as undergoing progressive degeneration. Morally, physically, socially, and politically the world and its inhabitants are tending toward disorder and chaos increasing entropy.

Concepts closely related to entropy include the following: cause-effect, change, conservation, energy-matter, equilibrium, God-Designer/Sustainer, gradient, interaction, model, probability, symmetry, system, theory, time-space.

Sample Test Questions

Question 1: Which best describes the concept of entropy?

A. a change in concentration
B. a change in time
C. a change in color
D. a change in orderliness
E. a change in location

Commentary: This concept-based item requires the reader to differentiate between several types of changes in order to describe the concept entropy. The best description for entropy is "D."

Question 2: Which of the following illustrates an increase in entropy?

A. frost forming on a window pane
B. the combination of H_2(g) and O_2 (g) to form H_2O (1)
C. separating the sugar form the water in a sugar solution
D. acetone evaporates from nail polish remover
E. the cooling of a sample of gas

Commentary: This concept-based item requires the reader to evaluate several dynamic processes to determine whether the change described results in a more random or disorderly system. The correct response is "D."

EQUILIBRIUM

Science Concept Working Paper # 8

Introduction

The concept of *equilibrium* is deceptively evasive both inside and outside the realm of science. The evasiveness of this concept is perhaps largely the result of very narrow and isolated views of the meaning and application of the concept during instruction within the various science disciplines. This situation is especially unfortunate since the opportunity exists for many everyday applications of the concept. A more fully developed concept of equilibrium may even enhance the meaning of one of education's most common cliches-the more things change, the more they remain the same!

The Concept

The idea of equilibrium is closely related to that of balance, but the concept of equilibrium is much richer than balance in meaning. Most of us are aware of some of the classic examples of the concept. Among these are the static equilibrium of the balanced teeter-totter, the dynamic equilibrium of the reversible chemical reaction, the marvelous physiological stability (homeostasis) of the human body's systems, and the balance between light and heavy rocks in the earth's crust (isostasy) which explains some of the earth's land forms. Perhaps these examples illustrate another reason for our limited ability to generalize the concept; we seem to be using the same idea with a lot of different names, each one somewhat specific to a discipline.

The key to our further development of the concept, however, probably depends upon a better understanding of what these diverse applications have in common, and, in fact, what they have in common with some less widely acknowledged and controversial examples. Falling into this latter category would be such applications as balance of trade, cash flow, balanced budgets, and explanations involving such phenomena as learning, stress management and human behavior.

We realize that when something (usually a system) is in a state of equilibrium, a balance exists between opposing forces or opposing tendencies. This is a key to recognizing appropriate applications of the equilibrium concept. A system is characterized by certain properties (e.g., temperature) that remain constant. When labor-management negotiations are underway, for example, an acceptable balance of conflicting interests or desires is sought. Reaching an equilibrium position, although perhaps short-lived, often results in a settlement.

Two major categories of equilibrium, the static and dynamic, are rather easily differentiated. Examples of static equilibrium are balancing ourselves on one leg (balancing the forces acting on various parts of the body) and a building that will survive the stresses of its own weight.

The sometimes dynamic nature of the equilibrium condition is clearly illustrated in chemistry when the equilibrium state is reached in a reversible chemical reaction. The products of one reaction (e.g., H_2 and O_2) are utilized as the reactants for the opposite chemical reaction. When the reaction rates in opposite directions are equal, the system is characterized by constant properties and has reached equilibrium.

Figure not available

The movement of a system towards or away from an equilibrium state is also of interest. The changes within the system can either be spontaneous or initiated/sustained by external influences.

Some less frequently encountered examples of equilibrium are useful in developing the concept. Some psychologists, for example, explain learning as the process by which humans regain cognitive equilibrium when it has been upset (e.g., by an observed anomaly or discrepant event). Coping with stress might be viewed as an effort to regain the physiological and psychological equilibrium that characterize a person's comfort zone. Some political scientists view stable governments as representing an equilibrium state (no pun intended) between the opposing political forces of the right and left. Christians see the universe before sin as having been in a state of perfect balance or equilibrium. Because of sin, imbalances now exist between all segments of creation as well as between creatures and their Creator. Left to itself, God's marred creation can never return to a state of perfect equilibrium. It is only through divine intervention that the original state of perfect balance and equilibrium can and will be restored.

When developing the equilibrium concept, four other major concepts of science become critical. These are the concepts of system, force, interaction, and energy-matter. Equilibrium conditions exist in the context of systems and interactions within and between systems involving both forces and energy-matter exchange.

In summary, equilibrium is a state of balance or equality in a system existing between opposing forces, tendencies, or conditions. A system in equilibrium is characterized by key indicator properties that remain constant in which the overall balance is sustained despite changes in opposite directions. The major categories are static (e.g., rest) and dynamic (e.g., active).

Sample Test Questions

Question 1: ***Which of the following is not an example of an equilibrium condition?***

A. Plants living in a sealed container
B. A person maintaining constant weight
C. A 100 story office building
D. A burning piece of paper
E. A tug-of-war where the marker on the rope is not moving

Commentary: The concept-based question requires the learner to assess each possible choice to determine if it qualifies as an example of an equilibrium condition. The correct response is "D."

Question 2: ***Please use the illustration below when selecting an answer.***

Figure not available

What action(s) would not disrupt the equilibrium once the change(s) had been made?

A. add mass at location 1
B. add mass at location 3
C. remove the fulcrum (support) and suspend the system from the ceiling by attaching a string at point 2
D. reverse the masses that are located at positions 1 and 3 and leave everything else exactly as it is
E. C and D

Commentary: This concept-based test question requires the reader to identify those elements of a given system that are important to the present equilibrium condition and then predict the result of altering one or more of these elements, The correct response is "C."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Equilibrium**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of equilibrium.
   a. Operationally define equilibrium.
   b. Distinguish between static and dynamic equilibrium.
   c. Identify factors which have an affect upon the equilibrium of a given system.

2. Expand their ability to apply the concept of equilibrium to new systems and situations.
   a. Identify situations involving the concept of equilibrium both in the physical world as well as the psychological and social world.
   b. Apply the concept of equilibrium to the swings a society goes through between conservation and liberalism.
   c. Discuss the relationship between the concept of equilibrium and the imbalances now existing in the natural as well as the social world.

FIELD

Science Concept Working Paper # 9

Introduction

Explanations of such diverse observations as a satellite orbiting the earth, the turning of a compass needle, and the operation of a television picture tube all utilize the concept of *field*. While these examples are rather sophisticated science uses, the concept also has applications in everyday situations. We can talk about one nation being within the field or under the influence of another, or the temperature field surrounding or within the earth, or can also talk about something being in our field of influence. Many statements are made in the Spirit of Prophecy concerning the influence or "force field" we have on others. An important application of field in this sense is the statement that by beholding Christ, we, under the field of His influence, become like Him. (2 Corinthians 3:18).

It is important for the contemporary citizen to develop an understanding of and ability to apply the concept of field to deal effectively with explanations and predictions involving action-at-a-distance as well as a variety of other phenomena.

The Concept

In the most general sense, a field is a region or space where measurable values of some variable exist. The field is usually named after the variable of interest (e.g., force field, temperature field, pressure field).

There are two categories or classes of fields. One category is known as scalar fields, while the other is referred to as vector fields. In a scalar field, the variable whose values comprise the field has magnitude (i.e., size) only. Examples of such fields would include the temperature field surrounding the earth, various pressure fields, density fields and sound fields.

Vector fields are comprised of measurements of variables that require both a magnitude and a direction in order to be completely described. Examples of such fields include force fields (e.g., gravitational, electric) and velocity fields.

Fields are quantified by measuring the value of the variable at a variety of locations. In fact, the operational limits or boundaries of a field are established by this ability to measure. Where values for a field can be predicted by the use of a mathematical relationship (e.g., force field), a test or measurement must be made before it is known for sure that the field does exist in that location. An illustration showing values for the variable at a variety of locations is often referred to as a map of the field.

One of the most frequent applications of the field concept is in the form of a force field. Force fields are regions of interaction or influence established by a source. The specific force field is named for the type of "thing" that is influenced by or interacts with the field. The three most common force fields are the gravitational, which influences matter; electric, which influences electric charge; and magnetic, which influences magnetizable "things."

Contemporary findings indicate that a changing electric field can influence magnetized "things" and that a changing magnetic field can influence electric charge, but such extensions of the idea are beyond the scope of this paper.

The path that an interacting "thing" follows in a force field is known as a line of force, and collectively, these lines of force are often used to map these fields for purposes of describing their "shape." The sketches that follow illustrate a partial application of this technique for two common examples.

Magnetic Field Near a Bar Magnet
(Lines of Force /Flux Trace the Path of an Independent North Pole)

Figure not available

Electric Field Near a Charged Object
(Lines of Force Trace the Path of an Independent Positive Charge)

Figure not available

Two or more fields of the same or different type can occupy the same space at the same time. If something is influenced by more than one of these fields, the interactive effects are all experienced. In the case of force fields, the effects are additive.

Closely related major science concepts include cause-effect, change, equilibrium, force, gradient, and interaction.

Sample Test Questions

Question 1: ***A field -***

A. occupies a region of space
B. contains measurable values for a variable
C. is a region of influence or interaction
D. A and C
E. A, B, and C

Commentary: This concept-based item assesses a learner's knowledge of the attributes that define field. The correct response is "E".

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Field**.

The students will be making progress when they are able to:

1. Increase their understanding of field as it is used in science.
   a. Differentiate between scalar and vector fields.
   b. Recognize and apply the three types of force fields.

2. Improve their ability to apply the concept of field.
   a. Correctly utilize the concept of field when describing/explaining a given situation.
   b. Correctly predict the resultant force due to three or more fields.

FORCE

Science Concept Working Paper # 10

Introduction

Force is a critical concept in science's storehouse of explanatory power. The concept represents our primary explanation for starting, stopping, changing direction, floating, falling, and a host of other movement-related phenomena. Interestingly enough, we also use the force concept in explaining lack of movement.

Force is a powerful idea in helping us to better understand and interact with our environment. We use the idea in a diverse number of ways, ranging from the forces acting between and within the fundamental building blocks of matter to those that formed some mountain ranges and keep our solar system "together", as well as those that convince us to buckle our seat belts. Truly, force does "make it happen".

The Concept

In its simplest form, a force is a push or a pull. Forces can be contact (e.g., one car pushing another, someone pulling a wagon) or noncontact (e.g., acting at a distance as in gravitational force).

Forces have both a magnitude (size) and direction. The direct measurement of magnitude is accomplished by the use of a spring scale, where a force either compresses or stretches a spring that has been calibrated in force units. In the International System of Units (SI), force is measured in newtons, while in the English system force magnitudes are expressed in pounds.

The direction of a force can be described in a variety of ways. The simplest approach is up, down, forward, or backward. Perhaps a little more sophisticated approach would be to use geographic nomenclature such as north, south, east, or west or degrees variation from these directions. A complete description of a force requires both a magnitude and direction.

Forces can be represented by directed line segments or more commonly, arrows, and technically termed *force vectors*. The arrowhead indicates the direction in which the force acts, and the length of the arrow indicates the magnitude of the force. Forces can be added, subtracted, and can undergo other mathematical operations by application of a form of mathematics known as vector algebra.

If a force is partially or totally unbalanced (no equal force offsets it), it will produce a change in the state of motion (e.g., speed up, slow down, change the direction of) the object(s) upon which it acts. On the other hand, when two or more forces acting on a single object offset (balance) each other, the net force is zero, and the object is said to be in force equilibrium. The object will retain the state of motion it possessed at the moment force equilibrium was established.

Among the common examples of important contact forces are friction, buoyancy, and lift, as well as forces exerted by wind, water, steam, burning gases, and springs. The most often encountered forces acting at a distance are gravitational, electrical, and magnetic.

While there is some disagreement over the appropriateness of such a use, the force idea is used and useful outside the physical force range. We are all familiar with examples such as peer pressure, public opinion, political pressure and forced hand used to explain what caused people to take or not take certain actions. Operationally, these psychological forces are pushes and pulls influencing people's decisions, behavior, and emotions.

Additionally, there are the forces of good and evil, with their attendant influence upon the decisions of life. Seventh-day Adventists endorse the concept of the great controversy between those two forces, placing the origin of the controversy in heaven before our solar system began. Adventist have great confidence that the good forces, headed by God, the Designer/Sustainer, will ultimately triumph.

In summary, forces are pushes or pulls. They can be exerted by objects in contact or act at a distance. Forces have both magnitude and direction and can be added together to determine the net force acting on an object. Unbalanced forces produce a change in the state of motion of the objects upon which they act, while balanced forces do not alter the motion of objects upon which they act.

Sample Test Questions

Question 1: ***An object is at rest on a level table. In order to explain why it is at rest, the minimum number of forces needed, in addition to gravity, will be***

A. 0 forces
B. 1 force
C. 2 forces
D. 3 forces
E. 4 forces

Commentary: This item is suitable for assessing a student's development of the concept of force. In order to knowingly respond correctly, the student needs to know that rest can be explained by the use of the force idea, and that for such case, the net force acting must be zero. Since gravity acts downward on the object, at least one additional force must be balancing that exerted by gravity. The correct response is "B".

Question 2: ***Forces can be responsible for which of the following?***

A. Starting motion
B. Stopping motion
C. Changing the direction of motion
D. Keeping an object from moving
E. Any of the above

Commentary: This item is suitable for assessing the level of development of the concept force. In order to knowingly respond correctly and select choice "E", the student must be aware of the rich variety of connections between force and motion.

Question 3: ***How far will a 1 kg object near the surface of the earth fall in 0.1s when the only force acting on it is that due to gravity?***

A. 0.0005m
B. 0.0490m
C. 0.0980m
D. 1.0000m
E. An object will not move any distance in such a short period of time due to its inertia.

Commentary: This content-based item is inappropriate for assessing the level of development of the concept **force**. The ability to select the correct choice requires the recall of several pieces of specific information (e.g., acceleration due to gravity, formula for calculating distance) but no direct application of the concept force.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Force**.

The students will be making progress when they are able to:

1. Further develop their concept of force.
   a. Operationally define force.
   b. List examples of five types of force.
   c. Critique a given definition of force.
   d. Differentiate force, field, equilibrium and gradient.

2. Improve their ability to apply the concept of force.
   a. Identify situations where the use of the concept of force is appropriate.
   b. Critique another person's use of the concept in explaining a phenomenon.
   c. Evaluate non-physical as well as physical forces in their environment.
   d. Perceive the concept of force as applying not only to physical systems but also to the Great Controversy.

FUNDAMENTAL ENTITIES

Science Concept Working Paper # 11

Introduction

Atoms, cells, people, and bricks all have something in common. They are examples of basic components or *fundamental entities* useful in helping us understand and explain the world around us. The identification of fundamental entities is a critical step in our gaining an understanding of a wide variety of things, such as matter, living things, populations, and buildings.

The Concept

In the most straightforward sense, fundamental entities are basic units of structure and function. We are all familiar with examples of these key components. Some common science examples include bones (for the skeleton), chemical bonds (for molecules), molecules (for compounds), and stars (for galaxies).

The concept is also applied appropriately outside of science. Some examples are books (for libraries), words (for sentences), courses (for the curriculum), states (for the United States), and cells (for prisons).

The fundamental entities can be in contact (e.g., railroad cars in a train, links in a chain), separated (e.g., star and planets in a solar system, molecules in a crystal), or a combination of the two conditions (e.g., gaseous molecules, football players on a team, photons of light).

Sometimes the fundamental entities appear to be identical, as is the case with atoms of the same isotope and the quantity of charge on any single electron. In other cases, variation may exist; examples would be cells in living things, organisms in a population, isotopes of an element, and genes comprising a chromosome. It is also possible to have major differences between the fundamental entities comprising a phenomenon of interest. Examples of this situation would be the protons, electrons, neutrons, et al., forming atoms and the cell membrane, nucleus, et al., comprising living cells.

The identification of units serving as fundamental entities is a function of that which is being studied and the level at which it is being examined. Some units can serve as fundamental entities but themselves be composed of other fundamental entities. Examples of this would be molecules (fundamental entity is atoms), atoms (fundamental entities are protons, neutrons, etc.), chromosomes (genes are the fundamental entity), and genes (molecules are the fundamental entities).

In summary, fundamental entities are identifiable basic "units," "structures," or "building blocks" that are useful in explaining phenomena. These fundamental entities can be units of structure and/or function. In addition, they can be in contact, separated, or exist in a combination of these two conditions. The fundamental entities may be identical, similar, different, or very different. Fundamental entities identified for purposes of one explanation may themselves be composed of other fundamental entities.

Other major science concepts that appear to be closely related to fundamental entities include interaction, population, and system.

Sample Test Questions

Question 1: ***Which is NOT a component of a typical living animal cell?***

A. Cell wall
B. Nucleus
C. Mitochondria
D. Cytoplasm
E. DNA

Commentary: This is not a concept-based question, since it is asking for recall of detail regarding a particular fundamental entity. Correctly responding to this question does not necessarily indicate any aspect of the degree of development of the concept fundamental entity.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Fundamental Entities.**

The students will be making progress when they are able to:

1. Increase their understanding of the concept of fundamental entities.
   a. Operationally define fundamental entity.
   b. Critique a given definition of fundamental entity.

2. Extend their ability to recognize/identify fundamental entities.
   a. When given a list of "things" and another list of "fundamental entities," correctly match items from the two lists.
   b. List at least three characteristics common to all fundamental entities.
   c. Identify some fundamental entities for things in their environment.

3. Increase their skill at using the concept of fundamental entity.
   a. Briefly describe some explanatory and predictive benefits derived from the use of fundamental entities.
   b. Given a description and/or illustration for the fundamental entities characteristic of a group of things, identify some of the members of the group.
   c. When a given collection of "things," classify the "things" into groups based upon identifiable fundamental entities.

GRADIENT

Science Concept Working Paper # 12

Introduction

The concept of *gradient*, which is extremely valuable for its explanatory and predictive power, is representative of many situations that we have experienced. Some common examples are the sloping ramp leading into a building or stadium, the ear-popping evidence of pressure changes as we ascend or descend in an airplane, and the temperature changes experienced as we go deeper into the water of a pool or lake.

The Concept

Although overly simplified, a gradient may be thought of as the situation where a measurable, variable quantity (e.g., temperature, pressure, density, elevation) is increasing or decreasing at a more or less regular rate. Examples are surprisingly common and include such diverse phenomena as the regular increase in water pressure with depth, the more or less steady increase in temperature as one drills down into the earth, the highway that climbs a hill at a steady rate, and the density change of water as it is layered at different temperatures. Gradients can occur through either space or time.

Gradients are expressed in terms of the rate of change of the variable of interest. These expressions can carry such units as ^{0}C/km, ^{0}C/hr, n/m^2/km, g/cm^3/^{0}C, and m/km to express temperature, pressure, density, and elevation gradients. Gradients are often portrayed graphically, and the value of the gradient in such cases is found by calculating the slope (e.g., rise/run) of the graph.

Gradients do not have specified minimum dimensions, such as distance intervals, temperature ranges, or time intervals for the varying quantities. The operational criteria for determining if the application of the gradient concept is appropriate is if it will serve a useful purpose for either explaining or making predictions relative to the phenomenon of interest.

The predictive power is especially interesting, since predictions can take several dimensions. The predictions may be interpolations (values between known values), extrapolations(values beyond known values), or even "road maps" to the location of the source of some phenomenon (e.g., radio wave source traced by following the gradient of increasing intensity).

Major science concepts closely related to gradient include cause-effect, change, cycle, energy-matter, field, interaction, invariance, order, origins, perception, quantification, scale, and time-space.

Sample Test Questions

Question 1: ***A student described the concept gradient as "a situation where the temperature is increasing at a regular rate." The student's statement***

A. adequately describes the idea of gradient
B. should not restrict gradients to temperature changes
C. should not restrict gradients to increases in a measurable quantities
D. should indicate that gradients occur through distance
E. B and C

Commentary: This concept-based item requires the reader to evaluate several basic portions of a statement attempting to describe the concept gradient. The particular choice made will provide useful insight into the level of development of the idea, with the highest state of development indicated by the choice of "E".

Question 2: ***Which depict(s) "Gradient?"***

Figure not available

Commentary: This is a concept-based item assuming that the prerequisite graphing skills and knowledge are in place. The reader is required to first determine if change in a measurable quantity is depicted, and if so, if it is occurring at a regular rate. The best answer is "E".

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Gradient**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of gradient.
    a. Operationally define gradient.
    b. Identify several examples of gradients.
    c. Predict new phenomena based on the concept of gradient.

2. Further develop their ability to apply the concept of gradient.
    a. Construct a graph to apply the concept of gradient.
    b. Use extrapolation to predict values based on the concept of gradient.

INTERACTION

Science Concept Working Paper # 13

Introduction

The concept of *interaction* may be the giant umbrella under which most, if not all, of the major science concepts fall. This idea transcends all of the science disciplines, as well as being widely used in the other human ways of knowing and many everyday situations.

This cornerstone idea of mutual influence lies at the heart of cause-effect relationships, cyclic phenomena, and systems, to mention just a few examples. To grasp the meaning of, and to develop the ability to appropriately apply this concept, is of genuine fundamental importance.

As Seventh-day Adventist Christians, we know that interactions on many levels have been affected by the entrance of sin on this planet. Not only nonliving and living things have been changed, but all the interactions possible between them are influenced as well. Predation, parasitism, violent forces that cause catastrophes or harsh living conditions, and even the concept of death itself are examples of the natural consequences of sin. The Creator intended eternal life and perfect order from the Garden of Eden and forward for us, but the Earth today shows many interactions resulting from the dysfunction of sin.

The Concept

In a nutshell, interaction is reciprocal or mutual action or influence between two or more objects or things. As this brief description implies, the concept is extremely useful across all science disciplines and is also widely applicable outside the realm of science.

The mutual action or influence between two or more things can occur between inanimate objects, between living things, and/or between the animate and inanimate. Examples of such diverse interactions include collisions between billiard balls, symbiosis (i.e., two dissimilar organisms living in close association or union advantageous to at least one member), and the many exchanges and other interactions between a tree system and its inanimate environment (e.g., soil, atmosphere).

Interaction can take place between things in direct physical contact, those that are separated in space, and/or those in a combination of these two conditions. Examples would include such phenomena as bank erosion created by a river or ocean waves, a satellite orbiting the earth, and the gaseous atoms and molecules in the atmosphere.

Many interactions are able to be observed directly (e.g., magnetic attraction and repulsion, fertilization of an egg, earthquake waves), while others are hypothesized as components of a variety of models and theories (e.g., plate tectonics, atomic model, kinetic-molecular theory, Mendelian genetics). Both categories are extremely useful for explanatory and predictive purposes.

Interactions occur both naturally (e.g., pollination, chemical reactions, lightning) and due to the planned activity of humans. Some of these human-created interaction situations are designed primarily to influence, such as television commercials, music and lyrics, and speeches. Other instances are targeted to cause a certain action, such as death of rats due to planted poison, a thermostat turning on or off the heating/cooling system, and a political campaign to generate votes.

Our primary basis for identifying phenomena involving interaction is the observation of change. The identification of change serves as evidence of interaction either having taken place or occurring at the time of the observation.

Closely related major science concepts include cause-effect, change, cycle, energy-matter, entropy, equilibrium, field, force, fundamental entities, gradient, model, order, organism, origins, perception, population, symmetry, system, theory, and time-space.

Sample Test Questions

Question 1: ***Which is an example of interaction?***

A. A magnet attracting a nail
B. A person breathing
C. A fish swimming
D. A satellite orbiting the earth
E. All of the above

Commentary: This concept-based question is concerned with the student's understanding of the range of phenomena that represent examples of interaction. Choices include contact interaction, interaction at a distance, interaction between inanimate objects, and interaction between organisms and their environment. The correct response is "E".

Question 2: ***Which serve(s) as evidence of interaction?***

A. Increase in temperature
B. Decrease in volume
C. No observable change
D. Constant mass
E. A and B

Commentary:Commentary: This concept-based This concept-based item focuses This concept-based item focuses o
as our primary evidence, the correct response is "E."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Interaction**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of interaction.
   a. Operationally define interaction.
   b. List examples of interaction.
   c. Differentiate interaction, cause-effect, change, and cycle.
   d. Critique a given definition of interaction.

2. Improve their ability to use the concept of interaction.
   a. Operationally define "evidence of interaction."
   b. Identify situations where the use of interaction is appropriate.
   c. Appropriately apply the concept of interaction when explaining a newly experienced phenomenon.
   d. Critique another person's use of the concept of interaction in explaining a phenomenon.

3. Value the concept of interaction for its explanatory
   a. Choose to further develop their concept of interaction and predictive power.
   b. Value explanations and predictions based upon the appropriate use of interaction.
   c. Choose to use interaction when explaining phenomena and/or making predictions.

INVARIANCE

Science Concept Working Paper # 14

Introduction

Invariance implies that some property of an entity will remain constant and unchanged though an interaction. Though a specific property may be invariant, other properties or characteristics of that entity may in fact change. Examples of invariance are the mass of an object remaining constant as it moves uniformly along a horizontal line, the number of protons in the nucleus of the several isotopes of a given element, the color of copper (II) solutions of fixed concentration but differing volumes, a proportionality constant between variables in a quantitative relationship, the constancy of volume of a quart of orange juice poured from a tall square container to a short fat pitcher, or the exclusive bonding between adenine and thymine in DNA molecules.

The Concept

Since controlled experiments are at the heart of the scientific method, and are ideally employed when pursuing cause-effect relationships, if certain entities are identified as invariant, the scientist's work is simplified. Further, in the process of control itself, only two variables must be allowed to vary—the independent and the dependent, all others being held constant or invariant. This may be the most practical application of the concept of invariance to the science investigator.

Theoreticians, including Einstein, have identified certain quantities which are invariant under specific transformations. The speed of light is invariant regardless of any relative motion between source and observer. This speed is truly one of nature's fundamental invariants and is so stated in the second postulate of special relativity.

It is tempting to believe that time is beyond change, that it should also be invariant under the same transformations as light, however, such intuitive or common-sense notions do not hold up when subjected to careful experimental scrutiny. Absolute time, it seems, is a figment of our limited experience.

The first postulate of the special theory of relativity states that the very laws of nature are invariant in all uniformly moving frames of reference. Included in such laws are those of classical Newtonian mechanics, Maxwell's equations for electromagnetic phenomena, as well as the expressions of modern quantum mechanics. Indeed the first postulate is broad in its outlook and absolutely inclusive in nature. Here is invariance in abundance!

Vector magnitudes remain unchanged or invariant during the rotation of a coordinate system. Actually, any conserved quantity is an invariant of a system. That last sentence was short, but consider—it combines three of the fundamental science concepts and hence involves many facets not immediately apparent.

Humankind seems to find security in identifying unchanging features not only within the scientific and natural realms, but within the human equation as well, such as within the psychological, emotional, sociological, or theological landscapes. One hears such judgments as "He/she is a 'moody' person, They've changed the rules again," and "Why can't they make up their minds?," implying variableness, changeability, or lack of constancy. Perhaps the need for a sense of security in the unchanging can best be met by the original and most constant Invariant in the universe—the great God-

Designer/Sustainer Himself who said "I am the Lord, I change not." (Malachi 3:6)(KJV)

Closely related major science concepts include conservation, energy-matter, entropy, fundamental entity, God-Designer/Sustainer, interaction, model, order, origins, perception, quantification, significance, symmetry, system, theory, and time-space.

Sample Test Objectives

Question 1: ***Which of the following illustrate a transformation involving an invariant property?***

A. A gold atom ejects a neutron from its nucleus.
B. A bar magnet is broken into three fragments.
C. A kilogram mass is moved from one position to another on the lab table top.
D. All of the above.
E. A and C only.

Commentary: Needing careful analyzation of each situation, and looking "deeper than the words" to identify properties that do not change, this concept-based item requires learners to demonstrate their understanding that certain characteristics of an entity may change while others do not. "A" involves knowledge that loss of a neutron leaves atomic identity intact; "B" requires consideration that the total mass would be same after fragmentation; "C" is more obvious. The intended correct response is "D."

Question 2: ***Which of the following scientists dealt extensively with the concept of invariance?***

A. Albert Einstein
B. Max Planck
C. Niels Bohr
D. Wilheim Roentgen
E. Werner Heisenberg

Commentary: Even though dealing with the concept of invariance, this item is directed toward historical interest, rather than being directed toward concept-based assessment. It is unlikely that the correct response would be forthcoming without prior exposure to the specific facts involved.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Invariance**.

The students will be making progress when they are able to:

1. Further develop their concept of invariance.
   a. Operationally define invariance
   b. Cite three examples of quantities that are invariant.
   c. Critique a given definition of invariance.
   d. Differentiate invariant, equilibrium, conservation, and fundamental entity.

2. Improve their ability to apply the concept of invariance.
   a. Identify situations where the use of the concept of invariance is appropriate.
   b. Critique another person's use of the concept of invariance in explaining a phenomenon.
   c. Perceive the concept of invariance as applying not only to physical systems but also to the Most Invariant, to God the unchanging Designer/Sustainer.

3. Expand their use of the concept of invariance in such a way that they can identify those quantities remaining unchanged in a given system during a given interaction.

MODEL

Science Concept Working Paper # 15

Introduction

The scientific concept *model* may operationally be the most pervasive concept cutting across the various science disciplines, and therefore one of the most powerful for learners to develop. Not only are scientific models used as explanatory and predictive tools within the science disciplines, but science textbooks and other instructional materials are literally loaded with them.

The development of the concept of scientific model both increases the student's personal level of scientific literacy and lays the foundation for an enhanced level of meaningful learning in science. Since scientific models play a central role in the scientific enterprise, an adequately developed concept of model is essential for an understanding and appreciation of the scientific "way of knowing."

The Concept

Scientific models are tentative, human-made schemes or structures which seem to correspond to real "things" or phenomena. Put in somewhat simpler terms, scientific models are our best idea as to the composition and "workings" of something of interest. Our explanations for electricity, magnetism, the stars, learning, and the behavior of volcanoes, for example, are all based upon models.

Scientific models are created when the phenomenon or object of interest cannot be observed directly in sufficient detail to provide a full and complete descriptive explanation. We often rely on models when the object or phenomenon of interest is too large (e.g., the earth), too small (e.g., atoms), too distant (e.g., the stars), or removed in time (e.g., the origin of the earth).

Some examples of commonly used scientific models that are often, unfortunately, treated as if they were descriptive fact, are the structure and composition of the earth's interior (remember the nicely labeled cross-sectional views that you've seen in texts), the Rutherford-Bohr model for the atom, the inheritance of traits (ah yes, Mendelian genetics), the description of our solar system (yes, really), the mechanisms of theories of origins (they really are only theories!), geologic processes, the nature of light, and the composition of and manner by which energy is generated within our sun and the other stars.

It is especially important not to confuse the physical models (e.g., scale or replica models of real objects or models constructed to illustrate scientific models) with the idea or construct that is the scientific model. For example, a world globe that can be separated into two hemispheres containing labeled cross-sectional views of the structure and composition of the interior of the earth is intended to illustrate our model for the interior of the earth. However, since many other models used in science teaching are scale or replica models of real things, there is a tendency to treat the globe described above as a scale model of the real thing. The spirit, value, meaning, and open-endedness of the scientific model is lost under such treatment.

Much of the highly creative work within the scientific community involves the making and testing of predictions based upon the current population of accepted scientific models. Scientific models may change, or evolve, when new or improved observations are made and/or predictions based upon the models are tested and found to be in disagreement. In some rather unusual but dramatic cases, the anomalies resulting from new observations or the testing of predictions can cause a model to be replaced (e.g., heliocentric replacing geocentric "world" system, wave model replacing particle model for light). However, the more usual situation is to adjust or modify the current model so that it can accommodate the new observations. In mature scientific disciplines, a working collection of accepted models for various phenomena of interest is considered to be a desirable state of affairs.

In summary, scientific models are a scientific discipline's best "guess" as to the composition of something and the interaction between its elements and with its environment. Scientific models are needed when the object or phenomenon of interest cannot be adequately observed directly. We use scientific models both to provide tentative explanations and as a basis for generating testable predictions.

Sample Test Questions

The sample evaluation items and their accompanying commentaries are intended to help illustrate the difference between concept-oriented learning outcomes involving the big ideas or major concepts in science and the more familiar content-oriented outcomes.

Question 1: ***Which is the best example of a scientific model?***

A. World globe
B. Working model of a steam engine
C. Map of the United States
D. Plastic skeleton containing all of the bones in the human body
E. Nuclear fusion as responsible for the energy from the sun

Commentary: In order to correctly respond to this item, the student must bring to bear substantial conceptual understanding. The student must be able to differentiate between replica models, scale models, physical models, and scientific models. An awareness of the type of phenomena requiring scientific models is also necessary. This question represents an appropriate concept oriented item suitable for use in measuring the degree of achievement of Sample Objective one. The correct response is "E."

Question 2: ***Scientific models are used primarily for***

A. illustrating important facts.
B. providing tentative explanations.
C. summarizing known facts.
D. expressing the opinions of individual scientists.
E. communicating information to the nonscientific public.

Commentary: This sample question is assessing student understanding of the model concept. To respond correctly requires students to understand the general purpose/role of models in science. It would represent an appropriate concept-oriented item for assessing Sample Objective five. The correct response is "B."

Question 3: ***Which of the following are limitations of scientific models? (Select all correct choices.) Scientific models are***

A. unable to provide absolute explanations.
B. based on opinion.
C. based on observations.
D. not able to be tested or challenged.
E. useful only to scientists.

Commentary: This is a question suitable for assessing a student's understanding of the concept of model. The student must know the general bases from which models are constructed, be cognizant of their tentative nature, and be familiar with the mechanism and potential for change in order to respond correctly. No specific content area recall is required. This item would be appropriate for assessing Sample Objective four. The correct response is "A" and "C."

Question 4: ***Sketch the Rutherford-Bohr model for the hydrogen atom and label all components.***

Commentary: This question is asking for detail regarding one example of a scientific model. The focus is not on the concept of model, but on the details of the Rutherford-Bohr model for the hydrogen atom. If the desired learning outcome is to have students develop an understanding of the Rutherford-Bohr model, the question is acceptable, albeit low level. It is, however, a "content" rather than concept-oriented question. A student could respond correctly to this item and have little or no development of the concept of model.

Question 5: ***The animal "x," black coat color is due to a dominant gene (B), and white coat color is due to the recessive allele (b). If a homozygous black male is crossed with a heterozygous black female, what phenotype distribution would you predict?***

A. 100 percent black coats
B. 50 percent black coats and 50 percent white coats
C. 25 percent black coats and 75 percent white coats
D. 75 percent black coats and 25 percent white coats
E. 100 percent white coats

Commentary: This is a "content" oriented question. The student is required to recall certain critical vocabulary (e.g., homozygous, heterozygous, phenotypes) and then apply the given information according to predetermined rules. A student could respond correctly to this item and not even realize that a scientific model was involved. If content specific information must be recalled in order to successfully respond to a test item, it is not a concept-oriented item at the desired level of generalizability.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of scientific **Model**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of model as it is used in science.
    a. Select the examples of scientific models from a list of possibilities.
    b. List several examples of scientific models.
    c. Write their own definition of a scientific model.
    d. List some common characteristics of scientific models.
    e. Explain the differences between scale models and scientific models.

2. Improve their model development skills.
    a. Design at least one test to help validate a given scientific model.
    b. Develop a beginning model for a newly observed phenomenon.
    c. Critique someone else's model for a given phenomenon.

3. Further their ability to test the validity of models.
    a. Describe in their own words the process used for validating scientific models.
    b. Identify from a list those tests which would be useful for validating a given scientific model.
    c. Make at least two testable predictions that would be useful in validating a given scientific model.

4. Expand their knowledge of the limitations of scientific models.
    a. Cite an example of a situation where two or more different models can be used to explain the same phenomenon.
    b. Cite examples of models that have been replaced or modified.
    c. List at least three limitations common to all scientific models.

5. Extend their understanding of the role of scientific models.
    a. Describe the role or purpose of models in science.
    b. Differentiate fact, opinion, model, and theory.

6. Extend their knowledge of the ways in which models evolve or change.
    a. Describe at least two general reasons that any given model may change.
    b. Cite examples of models that have been replaced or modified.

7. Value scientific models for their explanatory and predictive power.
    a. Demonstrate a preference for explanations based upon accepted scientific models.
    b. Choose to use a scientific model when making predictions regarding a phenomenon.
    c. Choose to develop a model for explaining a new phenomenon.

For Further Information About Model

Exemplary Instructional Units

The Guessing Game. Milwaukie, OR: Science Department, Rex Putnam High School, 1985 (grades 9-10).
US2. Seattle, WA: Science Dept., Matteo Ricci College, 1977 (grades 10-11).

ORDER

Science Concept Working Paper # 16

Introduction

Order implies classes, sequences, patterns, and consistent predictability. The concept is one of the broadest in range of applicability. It encompasses observable phenomena (e.g., physical patterns, cyclic phenomena) as well as underlying beliefs (e.g., the orderly universe). We seek to better understand our world by searching for order and many of our brilliant scientists have had the knack of discovering order where others saw nothing. Perfect order existed before sin entered the universe, and although marred by sin, there continues to be ample evidence of order in the universe.

The Concept

Order is so broad a concept that to attempt to discuss it in a singular straightforward sense would be a disservice. Order may take the form of classes; for example, our classification process labels groups such as living and non-living, acids and bases and floating and sinking. Membership in these various classes provides the basis for explanation and perhaps more importantly, predictability.

Another form of order is regular sequence and/or serial ordering. This can take the definite human creation patterns, such as alphabetical order, numerical order, or order by rank (as in the military). Order can also be identified by any one or combination of a number of characteristics, such as mass, weight, length, density, wave length, age, area, or volume.

Order may be identified by patterns such as the form of geometric arrangements in space (e.g., crystals, flowers, spider webs). It can also be displayed in repeated events or sequences in time (e.g., phases of the moon, various life cycles, tides).

Belief in the existence of an orderly universe is an article of faith for scientists. It is this belief in the existence of natural rules, fixed relationships, etc. that promises the power of predictability once these relationships have been discovered.

In summary, the concept of order encompasses classes or groups, a wide variety of sequences, and patterns. In addition, it includes the basic belief in a systematic, predictable universe.

Other major science concepts closely related to order include cause-effect, cycle, entropy, God-Designer/Sustainer gradient, origins, perception, probability, and symmetry.

Sample Test Questions

Question 1:

Figures not available

Which belongs in the blank space?

Commentary: This concept-based item requires students to identify the characteristic being used for ordering and then identify a missing element in the sequence. The correct response is "C."

Question 2:

Figures not available

Which represents order in the form of a sequence?

A. I, II, III, IV
B. I, IV, II, III
C. II, III, IV, I
D. III, IV, II, I
E. IV, III, II, I

Commentary: This concept-based item requires a rearrangement of data to create an orderly arrangement, in this case a sequence. The correct response is "D."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of the ability to appropriately apply the concept of **Order**

The students will be making progress when they are able to:

1. Increase their understanding of the concept of order.
    a. Operationally define order.
    b. Critique a given definition of order.
    c. Identify examples of order.

2. Extend their knowledge of how to achieve order.
    a. Identify critical elements of order.
    b. Manipulate variables to achieve order.

For Further Information About Order

Kemeny, John G., *A Philosopher Looks at Science.* Princeton, NJ: D. Van Nostrand Company, Inc., 1959.

Exemplary Units:

"Patterns" (Secondary Level), Science Department, Educational Research Council of Amenca, Cleveland, Ohio

ORGANISM

Science Concept Working Paper # 17

Introduction

The concept of *organism* is perhaps more closely associated with one particular area of science than any of the other major concepts. In its most basic application, organism is applied to those individual, open and dynamic systems that we characterize as living, be they plants, animals or microorganism.

Those living things that we categorize as organisms play a critical role in population, are key components of many cycles, and often serve as fundamental entities. An understanding of and ability to appropriately apply the concept of organism is critical for today's scientifically literate citizen.

The Concept

In the most direct sense, an organism is a complete individual living thing. An organism might be thought of as the "package" or entity that contains all of the necessary components to be classified as a self-contained living thing of its type. Examples of organisms include individual plants, animals, protists (i.e., having both plant and animal characteristics), and microorganisms (i.e., living things too small to be observed directly with the unaided eye). Phenomenal diversity exists among organisms, ranging from single-celled entities (e.g., paramecium, euglena, amoeba) to multicellular examples (e.g., rodents, fish, rose bushes, dandelions, camels, coleus plants, humans, algae, birds, frogs) featuring a variety of collections of tissues, organs, etc.

Regardless of the particular organism in question, it must exhibit those collective characteristics that define "living" things. These characteristics include, but are not limited to, the ability to use materials and energy for growth, maintenance of processes, etc., the capacity to reproduce its kind, and the ability to respond to the environment. Keep in mind that it is often difficult to distinguish living from nonliving things on the basis of a single property.

One of the key attributes of organisms is that they interact with each other as well as with other aspects of their environment. Some of these interactions, from the frame of reference of the organism are positive (e.g., necessary for survival), while others appear to be negative (e.g., deprive the organism of nutrients, cause death). On the larger scale, however, these interactions are key ingredients of natural cycles and other dynamic systems.

The concept of organism has several applications that expand its usefulness significantly. The concept can be appropriately applied to formerly living things, as well as those individual living things that are alive today. In addition, organism can be used as an analog. Among other things, factories, cities, automobiles, heavy machinery, and even the earth have been described as analogous to an organism.

Closely related major science concepts include cause-effect, change, cycle, energy-matter, entropy, equilibrium, field, fundamental entities, interaction, invariance, model, order, origins, perception, population, symmetry, and system.

Sample Test Questions

The sample evaluation items and their accompanying commentaries are intended to further illustrate the difference between concept-oriented learning outcomes involving the big ideas or major concepts in science and the more familiar content-oriented outcomes.

Question 1: ***Organism can appropriately be applied to***

A. a dandelion plant.
B. a dog.
C. a fossil of a prehistoric plant.
D. individual single-celled animals.
E. all of the examples listed above.

Commentary: This concept-based item is designed to assess the breadth of students' understanding of the concept organism. In addition to understanding the concept's use with living things, students must demonstrate knowledge of its appropriateness for use with things that were once living the correct response is "E," and the question is suitable for use with Sample Objective two.

Question 2: ***Organisms are characterized by currently or in the past***

A. being open dynamic systems.
B. having the capacity to reproduce their kind.
C. being able to utilize matter and energy for growth.
D. having the ability to sustain life processes.
E. demonstrating all that are listed above.

Commentary: This concept-based question is intended to assess the learner's knowledge of the attributes necessary for inclusion under the concept organism. The correct response is "E," and the item is appropriate for use with Sample Objective one.

Question 3: ***The structures identified by the designations 1, 2 and 3 respectively, are:***

Figure not available

A. Mitochondrion, flagellum, cell wall
B. Vacuole, septum, endoplasmic reticulum
C. Ribosome, strobilus, egg sack
D. Nucleus, cilium, cell membrane
E. Chloroplast, pedicel, cytoplasm

Commentary: This is NOT an example of a concept-based question. While the question deals with an example of an organism, it requires the recall of detail rather than an understanding of or ability to apply the concept.

Question 4: ***It has been said that a factory is like a giant organism. Which characteristic of a factory would NOT be consistent with this analogy?***

A. One or more energy sources is required.
B. Waste products are produced.
C. It can be shut down and restarted at any later time.
D. A variety of functions are performed by various portions of the factory.
E. It interacts with its environment.

Commentary: This concept-based item is designed around the use of organism in an analogous situation. In order to respond correctly, the learner must demonstrate an understanding of the attributes of an organism. The correct response is "C," and the question is consistent with the intended learning outcome described in Sample Objective two.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Organism**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of organism.
   a. Operationally define the concept organism.
   b. List examples of different types of organism.
   c. Differentiate organism, fundamental entities, and population.
   d. Critique a given description of organism.

2. Improve their ability to apply the concept of organism.
   a. Identify examples of organisms.
   b. Correctly utilize the concept of organism when describing/explaining a new situation.
   c. Appropriately use organism as an analog.

3. Value the concept of organism for its explanatory and predictive power.
   a. Elect to use the concept organism when the situation is appropriate.
   b. Choose to continue to develop your personal understanding of organism.
   c. Value explanations and predictions correctly based on the application of the concept organism.

ORIGINS

Science Concept Working Paper # 18

Introduction

The concept of *origins* relates to beginnings and has a wide range of applications. It can be related to things as narrow as the origin of a thought, "where did you get that idea?" all the way up to the all inclusive origin of the universe. Origins answer who, what, when, where, and why questions. Answers to these questions form the body of knowledge associated with science.

The Concept

Origin is a concept related to the start of an event. A knowledge of origin is important to many people. For example, adopted children frequently spend great amounts of time and money searching for their biological parents. We want to know who we are. In history we want knowledge about the origin of civilizations, the origin of motorized flight, the origin of the industrial revolution. In science we are interested in the beginnings of human life at conception, the cause of disease, the origin of animal specimens, the origin of elementary particles, and the origin of various forms of energy.

The origin of life has captured a great amount of interest and debate. The theories of creation and evolution have a multitude of variations, most of which center around either a God/Creator or around naturalistic processes. None of these theories can be tested for first cause, therefore, they are out of the realm of the scientific method and must be accepted on faith.

Your origins belief system can have a major effect on how you handle life. If you believe that you are a product of evolution, a concept in which survival-of-the-fittest is the driving force, your goal in life will likely be to survive at all cost. On the other hand, if you believe that you were created by the Master Designer of infinite love, wisdom and power and that He placed you here for a purpose then you will likely exhibit a more compassionate approach to life.

In summary, origin is a concept related to beginnings. Origins can be applied to present-day situations, however, this concept is more frequently used in association with creation and evolution theories.

Sample Test Questions

Question 1: ***At the present time, which is least likely to be able to be explained by the use of the concept of origins?***

A. The origin of man
B. The appearance of the landscape
C. Personal computers
D. Icebox
E. Eternity
F. Today's automobiles

Commentary: This concept based item requires students to determine the necessary criteria for the potential application of the concept of origins (e.g., beginnings) and then establish which of the choices has the poorest fit to these criteria. The intended correct choice is "E."

Question 2: ***If the modern home refrigerator has an origin, which one of the following would be its most likely origin?***

A. Assembly at the factory
B. The discovery of metals
C. The invention of electricity
D. The inventor's idea of a refrigerator
E. The discovery of coolant gases

Commentary: This concept-based item requires students to evaluate factor that are important in the origin of a refrigerator. Without the inventor's idea of how to make a refrigerator as in the answer "D," there would be no refrigerator and therefore no origin.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Origins**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of origin as it is used in science.
   a. Identify examples of at least two different types of origin.
   b. List several examples of scientific origins.
   c. Write their own definition of origins.
   d. List two advantages of knowing the origin of things.

2. Expand their knowledge of the limitations of scientific origins.
   a. Cite examples of situations where origin theories have been replaced or modified.
   b. List at least two limitations common to origin concepts.

For Further Information About Origins

References

Coffin, H.G., and R.H. Brown. 1983. *Origin by Design*. Review and Herald Publishing Association, Hagerstown, MD. 494 pp.

Gould, Stephen Jay. 1977. *Ontogeny and Phylogeny*. The Belknap Press of Harvard Univ. Press, Cambridge, Massachusetts.

Leupold, H.C. 1942. *Exposition of Genesis*. The Wartburg Press, Columbus, Ohio. 1,220 pp.

Shea, William H. 1978. "The unity of the creation account." Origins 5:9-38.

Webster, C.L.Jr.1989. *The Earth: Origins And Early History*. The Office of Education North American Division General Conference of Seventh-day Adventists. 122 pp.

Weisz, Paul B. 1963. *The Science of Biology*. Second edition McGraw-Hill Book Co., Inc., New York.

The origin of most things can be found in encyclopedias.

PERCEPTION

Science Concept Working Paper # 19

Introduction

The concept of *perception* relates to a process that we nearly continuously engage in without the benefit of much conscious thought or reflection. The same is true in the science classroom, where the concept receives little formal attention. Perception is crucial, however, since it is concerned with the origin of our individual world view or operational physical reality, which is the starting point for most formal and informal science learning experiences.

The Concept

Perception, in a straightforward sense, is a package deal involving the detection of input signals by the senses, transmission of these signals or messages to the brain, and the interpretation of these signals by the mind. In other words, perception is our individual connection to the real world; it is the process by which we create physical reality from sensory input.

If any one of the three components (sensory detection, transmission, or interpretation) is missing, we have no perception. In addition, a number of factors influence our perception. Perhaps foremost among these factors is experience. Since individuals differ in total experience, individuals can perceive the same environmental stimulus differently.

Our differences in perceiving the same stimulus are sometimes masked by associating certain descriptors with certain perceptions. For example, a group of people can be exposed to a stimulus and be told that it is "red." Without awareness of the similarities and differences in individual perceptions, we collectively learn to associate the descriptor with the perception, and we communicate the experience as red. This gives the appearance of a common perception—which may or may not be true. Put another way, does everyone perceive "red" the same? Or, from a scientific point of view, does it matter if everyone perceives red in the same way?

Let's move beyond the learned or shared association situation and ask another question. What happens to people's ability to communicate regarding the external world if the perception is being experienced for the first time? How do we explain a common phenomenon that is perceived differently by different observers? The perception issue is further complicated by the fact that many, if not most, environmental events are complex and stimulate several different senses.

The tentative nature of our perceived reality is often brought to our attention by means of optical illusions that we experience. Some of these illusions occur naturally, while others are created by the artist or skilled professional performer. The illusions need not be limited to the visual.

Do we have ways to check or validate our perceptions? Certainly we do, but that still doesn't eliminate the uncertainty of our perceptions. One commonly used procedure is to share perceptions with other observers. Our communication skills and the limitations of our language become important here, but the process certainly facilitates agreement. Another procedure is utilizing measurement, although this is not always practical. The application of logical thought is another aid in the perception clarification process.

In summary, perception is the meaning we give to sensory input that has been transmitted to the brain. Many factors influence perception, with experience perhaps being the most important. Acknowledgment of the tentative nature of our individual perceptions of the world is an important dimension of scientific literacy.

Sample Test Questions

Figure not available

Question 1: ***Two students were observing the lines above and disagreed as to which was longer. Which would be most useful in resolving their conflicting perceptions?***

A. Ask some other students which line they think is longer
B. Have the entire class observe the two lines and vote.
C. Ask the teacher which is longer.
D. Cover up the arrowheads and then compare the length of the two lines.
E. Measure the length of the two lines.

Commentary: This concept-based test item addresses the resolution of conflicting perceptions and asks students to select the most useful approach from a list of several viable alternations. The desired response "E," is the most appropriate choice, even though several of the others may produce the same final resolution.

Question 2: ***Perception is influenced by***

A. the prior experiences of the perceiver
B. The number of senses involved
C. the limitations of the senses involved
D. B and C
E. A, B and C

Commentary: This straightforward concept-based item requires students to demonstrate their awareness of some of the factors influencing perception. The intended correct response in "E."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Perception**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of perception.
   a. Identify examples of at least two different types of perception.
   b. Critique a given definition of perception.

2. Expand their knowledge of the value of perception.
   a. List three advantages of perception.
   b. Cite examples of how man has used perception to better our conditions on earth.

3. Expand their knowledge of the limitations of perception.
   a. Cite examples of where predictions based on perceptions have been found to be inaccurate.
   b. Cite examples of how the perceptions of several people observing the same event can vary greatly.

For Further Information About Perception

Exemplary Instructional Units

Educational Research Council of America. *Perceiving My World.* (secondary) Cleveland, Ohio: Educational Research Council of America, 1971.

Science Department, Rex Putnam High School. *Is Your World My World ?* (grades 9-10) Milwaukie, Oregon: Rex Putnam High School, 1976.

POPULATION

Science Concept Working Paper # 20

Introduction

When groups or collections of similar "things" are of interest or to be studied formally, the concept *population* is frequently employed. These designated populations, be they composed of people, trees, stars, or atoms are characterized by a number of descriptive factors (e.g., size, location) that may change through time. In fact, it is often these changes in the population that are of most interest to us, since they assist us in providing explanations and making predictions.

The Concept

In the simplest sense, populations are groups of "things" that are similar in one or more ways. For purposes of designing experiments, gathering data, etc., it is important that the population be specifically identified or described. In general it is necessary, at a minimum, to identify specifically the kinds of things to be included (e.g., dogs, black holes, deciduous trees, homeless people, radioactive elements) and specify the limits in time (e.g., current, year, day) and space (e.g., United States, Alaska, m^2, ml). The following examples identify/describe populations at the minimum level.

The coyote population in Reno County in July of 1987.
The red giant population in our galaxy at present.
The giant sequoia population in the Redwood National
Park in 1980.
The population of 1956 Ford Thunderbirds still in service.

There are a number of observable/measurable characteristics that can be used to describe populations. Some are generally applicable, such as size (e.g., the number of "things" comprising the population), location, and time frame. Many other characteristics are appropriate for use with certain types of populations. Examples of these would be density, growth rate, radiation emission level, behavior patterns, movement patterns, and distribution. When populations of humans are involved, sex, age, race, ethnic makeup, religion, education, occupation, and income are among characteristics studied.

In some instances, the entire population of interest can be observed directly (e.g., dandelions in a given yard, students in a classroom, geysers in Yellowstone National Park). There are other cases, however, where the size, location, distribution, etc. of the units comprising the population make direct observation impossible. In the case where complete direct observation is not possible, inferences about the population as a whole are made by sampling. This technique consists of selecting certain members of the population (usually randomly selected) and from measurements and/or other observations made on these sample members, inferring the characteristics of the population as a whole. A variety of statistical procedures, laws, equations, etc. has been devised to assist in this process. While individual populations are often intensely studied, interactions between populations are also frequently of great interest. An example of this would be predator-prey population relationships.

In summary, a collection or aggregate of similar things can be categorized as a population. At a minimum, a population must be defined in terms of its member "units", location, and time frame. Many other characteristics can be used to more completely describe a population. It is important rather than those of its individual members. When conditions do not allow complete direct observation of the population, sampling techniques are employed so that we can make inferences about the population as a whole.

Sample Test Questions

The sample evaluation items and their accompanying commentaries are intended to further illustrate the difference between concept-oriented learning outcomes involving the big ideas or major concepts in science and the more familiar content-oriented outcomes.

Question 1: ***Which contains the minimum information required for describing a population?***

A. Mice
B. Grasshoppers in a given field
C. Ants in an anthill in Texas
D. Automobiles sold in the United States during 1987
E. All of the above

Commentary: This higher level concept-based item requires students to demonstrate their knowledge of the minimum information required to identify a population. In order to knowingly respond correctly, the student must know and comprehend the minimum requirements, and then analyze each choice to see if the minimum requirements are present. The item is appropriate for assessing Sample Objective one. The correct response is "D."

Question 2: ***Which is an example of a population?***

A. The weeds currently in a given yard
B. The eagles nesting along the Fraser River in 1984
C. All glaciers in Alaska in 1987
D. All fifteen-year-old students enrolled in United States public schools during 1988
E. All of the above

Commentary: This concept-based item requires students to know, comprehend, and apply their understanding of the attributes associated with a "population." The intended correct choice is "E," and the item is suitable for use in assessing Sample Objective one.

Question 3: ***Which is closest to the present total population of people in the United States?***

A. 67 million
B. 100 million
C. 220 million
D. 510 million
E. 750 million

Commentary: This is not a concept-based question. In order to knowingly respond correctly (choice "C"), the student must have been exposed to the specific numerical answer and recall/recognize that answer. The act of recalling a number does not in itself indicate the level of development of the concept.

Question 4: ***A student defines population as "a group of individual organisms of the same species." This definition of "population"***

A. represents an acceptable view of the general concept *"population."*
B. is too narrow, primarily because it restricts members of a population to *"organisms of the same species. "*
C. would be acceptable if *"same species"* were dropped.
D. should be changed to indicate that populations are composed of *"a group of people living in a designated area."*
E. should have substituted *"plants or animals"* for *"organism."*

Commentary: This higher level concept-based item is suitable for use in assessing Sample Objective 1. The item requires students to evaluate the responses on the basis of their level of understanding of the general concept of population, and not just the biological definition. The intended correct response is "B."

Sample Instructional Objectives

From an Instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to apply the concept of **Population**.

The students will be making progress when they are able to:

1. Improve their ability to describe/identify populations.
   a. Operationally define a population.
   b. List the essential characteristics required to describe/identify a given population.
   c. Critique a given definition/description of a population.

2. Extend their knowledge of the characteristics useful in describing a population of inanimate things. List at least four characteristics appropriate for use in describing populations and changes within populations.

3. Increase their understanding of the process of making inferences about populations from samples.
   a. Differentiate population, sample, and population unit.
   b. In their own words, describe "random selection."

4. Extend their ability to quantify populations.
   a. List at least five characteristics of a population that can be quantified.
   b. When given size and time data for a population, appropriately display the data in graphical form.

For Further Information About Populations

Showalter, Victor, et al. (ed.). *Unified Science Premises and Prospects.* Columbus, OH: Federation for Unified Science Education, 1975.

Activities

Dyche, Steven E. "Population Activities for Middle School Science." *Science Scope* 9(Nov. 1985):26-27.

PROBABILITY

Science Concept Working Paper # 21

Introduction

The concept of *probability* is very useful for predicting possible results in new situations or for developing new hypotheses. However, it must be recognized that such predictions or hypotheses are not given the significance of scientific fact. The predictions or hypotheses may seem reasonable on the basis of evidence and logic, but they are neither certain nor proved. They must be tested further.

The Concept

The concept of probability enables the scientist to transfer prior knowledge and/or processes to a new situation and to interpret possible results. It can be applied in such areas as predicting the properties of elements based on the laws of periodicity, the products of a chemical reaction, the offspring from a genetic cross, the trajectory of a projectile; developing a mechanism for the deposition of sediments based on observations made from a specific sedimentary deposit; fore-telling the result of movement in the Earth's crust; describing the mechanism of a reaction; forecasting the weather, etc. Many of these things that we are tempted to classify as proven fact are really only probabilities.

The fossil forests of Yellowstone National Park illustrate how one might use the concept of probability. There appear to be a minimum of 27 layers of materials. Within those layers are petrified tree stumps, logs, roots, leaves, and cones. The layers are composed primarily of breccia and volcanic ash with each layer almost identical in consistency. There is some evidence that the layers were deposited in conjunction with water action. Many of the tree trunks are in an upright position.

From this collection of data, scientists have hypothesized that the many upright trunks and logs would be probable only if the forests had been growing in those positions. Since we have never observed one forest growing simultaneously on top of another, it is probable that these layers of forests grew at different consecutive periods of time. The presence of water-deposited volcanic ash and breccia in each layer leads to the probable conclusion that each forest was destroyed by volcanic activity in combination with heavy rains and/or localized flooding.

It has also been noted that no animal remains are found in these layers of forests. By combining our observations of animal behavior during earthquakes and volcanic eruptions, it seems probable that animals can sense the beginnings of such events much sooner than humans do. Thus, the probability exists, be it ever so slim, that all the animals were able to sense impending disaster and ran away.

Through additional, careful examination, more data has been collected. Growth rings of logs and adjacent tree trunks do not always correlate as one might expect if they had grown in the same place at the same time. Most of the wood specimens lack bark on the outer surfaces. There is no evidence of erosion between layers. Where wood is fractured, the breaks are smooth and clean, without the splintering that is typical of green, living wood. Some of these evidences reduce the probability that the forests grew in place as they are found. Therefore a new more probable explanation was needed.

The waters of Noah's flood and the floating plant debris combined with the tremendous amount of volcanic activity during and after the flood make it more probable that these layers were washed into place forming the many layers of forest deposits. Such an explanation also eliminates the need for explaining the absence of animal fossils.

The subsequent eruption of Mount St. Helens has provided further data to support this model, thus increasing the probability of its correctness. Although unproven, it makes sense and is based upon observed evidence.

In summary, the concept of probability involves using data and logic to predict an event that is likely to occur or to develop a hypothesis that best explains a phenomenon that has occurred. The development of scientific models relies heavily upon the concept of probability.

Sample Test Questions

The sample evaluation items and their accompanying commentaries are intended to help illustrate the difference between concept-oriented learning outcomes involving the big ideas or major concepts in science and the more familiar content-oriented outcomes.

Question 1: ***Which is the best example of a scientific model that has been developed using the concept of probability?***

A. World globe
B. Working model of a steam engine
C. Map of the United States
D. Plastic skeleton containing all of the bones in the human body
E. Nuclear fusion as responsible for the energy from the sun

Commentary: In order to correctly respond to this item, the student must bring to bear substantial conceptual understanding. The student must be able to differentiate between models based purely on hard facts and those that require prediction based on logical interpretation of data. An awareness of the type of phenomena requiring logical interpretation is also necessary. This question represents an appropriate concept oriented item suitable for use in measuring the degree of achievement of Sample Objective one. The correct response is "E."

Question 2: ***Probability is used primarily for the development of scientific models that***

A. illustrate important facts.
B. provide tentative explanations.
C. summarize known facts.
D. express the opinions of individual scientists.
E. communicate information to the nonscientific public.

Commentary: This sample question is assessing student understanding of the concept of probability. To respond correctly requires students to understand the role of logical prediction to develop models in science. It would represent an appropriate concept-oriented item. The correct response is "B."

Question 3: ***Which of the following is a limitation of Probability? Probability is***

A. unable to provide absolute explanations.
B. based on opinion.
C. based on observations.
D. not able to be tested or challenged.
E. useful only to scientists.

Commentary: This is a question suitable for assessing a student's understanding of the concept of probability. Although probability is logic based upon data and facts, the student must recognize that the interpretations of that information may lead to conclusions that are not yet proven. No specific content area recall is required. This item would be appropriate for assessing Sample Objective three. The correct response is "A."

Question 4: ***List the names of the geologic systems of rocks beginning with the Precambrian and ending with the Cenozoic.***

Commentary: This question is asking for detail regarding one example of a scientific model that was developed by probability. The focus is not on the concept of probability, but on the details of the rock systems. If the desired learning outcome is to have students learn the order of the rock systems, the question is acceptable, although at a low level. It is, however, a "content" rather than concept-oriented question. A student could respond correctly to this item and have little or no development of the concept of probability.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Probability**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of Probability as it is used in science.
   a. Write their own definition of the concept of probability.
   b. Differentiate between scientific facts and predictions based on probability.

2. Improve their skill of using logic to predict results in new situations.
   a. Analyze data and combine it with facts to predict the results of a new situation.
   b. Analyze someone else's model to determine the logic used in developing that model.

3. Expand their knowledge of the limitations of scientific models.
   a. Cite an example of a situation where logical interpretation of data may lead to the development of two or more different models.
   b. Cite examples where predictions based on probability have been found to be inaccurate.
   c. List some limitations to the process of making predictions based on logical interpretation of known data.

4. Value scientific models for their explanatory and predictive power.
   a. Demonstrate a preference for explanations based on the concept of probability.
   b. Choose to apply the ideas of probability when developing new models for explaining a

QUANTIFICATION

Science Concept Working Paper # 22

new phenomenon.

Introduction

The concept of *quantification* represents a critical idea in science and a valuable asset in everyday decision making. When observations (data!) are quantified (expressed in numbers or measurements), preciseness of communication is enhanced and the opportunity to interpret the data expanded. Therefore, the understanding of and ability to apply the concept of quantification is an important attribute of a scientifically literate citizen.

The Bible talks about the measure of the earth, the fullness of God's mercy. In some instances, we cannot quantify. How long will eternity last? How much will God forgive? How strong is the love of a mother for her child? While we would like to put everything on our level and be able to measure, we must remember that there is a God who is beyond our complete comprehension.

The Concept

In the most straightforward sense, quantification is the assignment of numbers or measurements to phenomena or observations. There is a wide range of application for this concept. Probably on one end of the application continuum is the formation of groups or classes and the subsequent arbitrary assignment of a numerical designation to each group. Examples of this type of use would be represented by experimental group 3, chimp family number 2, type 6 mountains, and excuse 1.

Another general application of the concept is represented by counting the number of observations or phenomena. This use is exemplified by population sizes, sizes of samples used, or events observed (e.g.,days with measurable rain, cell divisions, volcanic eruptions, radioactive disintegrations).

One of the most frequent uses of the concept is the quantifying of observations by the measurement of certain properties, such as length, mass, temperature, quantity of electric charge, intensity, density, electrical, conductivity, pressure, speed, and volume. In some cases, the quantification consists of measuring the duration of an observation or phenomenon (e.g., length of an earthquake, time required for an object to travel a certain distance, while in other cases it is the time interval between observations or events (e.g., period of Halley's Comet, monthly population count).

Numerical scales are often used to assist us in ordering observations, phenomena, properties, etc. Examples of such scales are the decibel scale for noise level, pH scale for acidity, Richter scale for earthquake magnitude, and IQ for intelligence. Some of these scales are equal interval, while others, due to the nature of what they express, are exponential. Quantification can take many additional forms including expression as ratio, percentage, proportion, or calculated index (e.g.,index of refraction, biological diversity index).

There are several advantages to be realized by applying the concept of quantification. Among these advantages is an increased precision in making observations. Quantifying observations and phenomena expands the opportunity for data interpretation, since the power of mathematics and statistics can be added to the interpretation process. Finally, the ability to generate predictions is enhanced by quantification, since many mathematical procedures (e.g., interpolation, and extrapolation) can be utilized.

Closely related major science concepts include change, cycle, energy-matter, equilibrium, force gradient, invariance, order, perception, probability, population, scale, and significance.

Sample Test Questions

Question 1: ***Which is an example of the use of quantification?***

A. The leaves were bright green and the berries a florescent red
B. A high percentage of the eggs hatched
C. Group A had more weight gain than group B
D. There are twelve glaciers in the park boundaries
E. All of the above are examples of the use of quantification

Commentary: This concept-based item requires learners to select the statement that contains direct evidence of the use of quantification. While one choice, "A," is clearly qualitative, two of the other distractors use terms (e.g., percentage, weight gain) that imply the application of quantification. The correct response is "D."

Question 2: ***The use of quantification***

A. provides more precise description/observations
B. assists in the clarity of the communication of observations
C. can be useful when the data are to be interpreted
D. can facilitate make predictions based upon data
E. all of the above

Commentary: This item seeking information regarding the student's perception of the potential advantages to be realized from the application of the concept of quantification. The correct response to this concept-based item is "E."

Question 3: ***Which is NOT and example of quantification?***

A. The work is 10 cm long
B. The liquid boiled at 87 C
C. The mass of Sample A is three times that of Sample B
D. Experimental groups 3, 7, and 10 had no measurable changes
E. Experimental group C showed a large change in weight over the period of the investigation

Commentary: This concept-based item requires the student to identify the single statement that does not utilize quantification. Several different applications of quantification (e.g., length measurements, temperature, measurement, ratio, group designations) are included in the distractors.

Question 4: ***What is the mean of the five measurements : 3.10 cm, 3.26 cm, 3.25 cm, 3.33 cm?***

A. 3.23 cm
B. 3.24 cm
C. 3.25 cm
D. 3.36 cm
E. 3.33 cm

Commentary: Even though this item is concerned with numbers, it is NOT an example of a concept-based question for quantification. In order to respond correctly, a student must recall and properly execute the procedure for calculating the arithmetic mean. In addition, skill in rounding is required. A correct response provides little, if any, insight into the students's understanding of or ability to apply the concept of quantification.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Quantification**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of quantification by:
   a. Operationally defining quantification.
   b. Critiquing a given definition of quantification.

2. Value the concept of quantification by:
   a. Using appropriate units of measurement.
   b. Using appropriate degrees of precision.

3. Extend their ability to use the concept of quantification
   a. Interpret a given set of data.

REPLICATION

Science Concept Working Paper # 23

Introduction

The concept of *replication* is a very basic scientific concept in that it refers not only to the ability of DNA to duplicate itself before cell division, but the actual foundation of valid scientific research which is reproducibility. The ability to get the same results under controlled conditions is the cornerstone of experimental work. At times repeatability is used as a synonym, (but repeatability refers to the same controlled experiment/test/sampling giving the same answers—getting the same pH from six consecutive tests with a pH meter on a certain liquid. Reproducibility involves a broader scope and includes repeatability and the ability to get similar answers from different angles (e.g., demonstrating presence of electrons in atoms from any element).

The Concept

A person can observe many events and evidences of various activities in the world every day, but if there are no links to what could have caused those results, then there will be no progress in knowledge. Once a possible cause and effect or change is noted, the person can then learn from that information or manipulate it in some way. We turn the water faucet on, and generally water comes out. We flip a switch and the lights go on, and so on. We assume that we will obtain the same result from the same action every day. We count on this for smooth running of daily activities. Science counts on this same principle in the scientific method.

If certain conditions exist in a controlled experiment, certain results will be obtained. One need only to think of the various hoaxes, fads, and widely touted cures/abilities/powers of certain products, not only in the past, but still prevalent today to see the value in reproducibility. If wonder drug X exists, why can't other people reproduce its results? Cold fusion, the 'secret life' of plants, and laetrile are only a few non-reproducible results of the last few decades. Progress in science depends on its universality—many scientists in many countries, institutions, and cultures all contributing to the body of science. This global communication of ideas and advancement of science would scarcely exist without replication. Indeed, the credibility of research and the researcher depends on the ability of others to replicate the research results under the same conditions.

The concept of replication in biology has a more specific meaning—the complete duplication of the DNA molecule before the cell undergoes mitosis and cytokinesis. To ensure a complete copy of all the genetic information in each daughter cell, the DNA molecule "unzips," enzymes move in the correct nucleotides, and each half serves as a template for the construction of the other strand. This process is vital to the survival of the new cells. This narrower definition is not used in the other areas of science, generally.

Replication can be seen in certain laws in both the scientific method and cell processes—surely an aspect of the design and order in our universe. These laws reflect the orderly scheme given to us by God as Designer.

Closely related major science concepts include cause and effect, interaction, model, symmetry, and validation.

Sample Test Questions

The sample evaluation items and their accompanying commentaries are intended to further illustrate the difference between concept-oriented learning outcomes more familiar content-oriented outcomes.

Question 1: ***Which is the most generalized description of the concept replication?***

A. Repeating stripes
B. Electricity turned on/off by a switch
C. Increasing or decreasing at a more or less regular rate
D. DNA being copied in a cell
E. Agreement of results made under the same controlled conditions

Commentary: This high level, concept-based question requires students to evaluate each of several descriptive statements as a description of the concept of replication. The distractors generally describe the related concepts of symmetry and cause and effect. A broader term than just the narrow definitions of A-D is found in the correct answer E, and the item is suitable for use with Sample Objective one.

Question 2: ***Fast twitch fibers have been found in crickets and locusts; what other organism would you expect to have them?***

A. Amoeba
B. Oak tree
C. Cockroach
D. Dog
E. Snake

Commentary: This concept-based question directs the student to apply his/her understanding of replication to several organisms. Although several of the organisms may indeed possess fast twitch fibers, the predictive power of replication leads to the similar organism, cockroach; the correct answer is C. This item is appropriate for use with Sample Objective two.

Question 3: ***What variable is not likely to affect the growth of radishes?***

A. Light intensity
B. Amount of water
C. Wavelength of light
D. Temperature
E. Color of hair of experimenter

Commentary: This is NOT an example of a concept-based question. While the question is concerned with the effect of variables on replication, the learner must recall prior information in order to respond correctly. The primary reason for this is that even if replication is understood, only the variables are provided. Unless these are connected with replication, there is no basis for choice (e.g., the requirements for growth in plants are not given).

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to apply the concept of **Replication.**

The students will be making progress when they are able to:

1. Increase their understanding of replication.
   a. Operationally define replication.
   b. Critique a given definition of replication.

2. Value the concept of replication for its explanatory and predictive power.
   a. Value explanations and predictions based upon appropriate applications of the concept of replication.
   b. Choose to use the concept of replication when making observations, formulating explanations, and/or making predictions.
   c. Apply the concept of replication in evaluating data.

3. Extend their knowledge of how to achieve replication.
   a. Identify critical elements of an experiment to be replicated
   b. Manipulate variables to achieve replication.

SCALE

Science Concept Working Paper # 24

Introduction

The concept of *scale* is central not only to science, but to every day life. Without some kind of reference system, there is no way of comparing or visualizing quantities. While most students use scales regularly, (time, money, grades) many are not as familiar with scientific scales. To make any measurement meaningful, there must be some scale for comparative reference.

The Concept

Scales come in two main types, absolute and relative. Some scales depend on a quantity that can be replicated. These are absolute scales. Most of the scales we deal with are absolute. Types of absolute scales include temperature, length, mass, etc. The student will work mainly with this type of scale, (hours, feet) but may experience difficulty in applying different units, such as metrics.

The other type of scale is relative. This type includes Moh's hardness of rocks, litmus paper, and the amount of overcast. These scales cannot be measured with numbers, but can have some numeric value assigned to them. These scales are determined by comparing a quantity with another similar quantity. We talk about the hardness of a rock. by comparing it to another rock. In the same way we can talk about the amount of love we have, how cloudy the day is, and how tired we might be, by comparing each of these to a similar experience or quantity.

There are some objects that are measured using a scale that is based on an apparent quantity. An example would be the apparent distance between objects in the universe. While we like to be able to measure using some scale, there are always going to be some quantities that don't have a scale or a measurable quantity. We cannot talk about the age of God because He exists outside the realm of time. The dimensions of the universe seem to be infinite. Students may be able to relate to this concept by remembering that numbers themselves are infinite.

Scales come in a wide range, from the large parsec and light-year to the small angstrom. Whatever the scale may be, its usefulness is in conveying some value that allows us to personally visualize it. All scientific endeavors can be meaningful only as we are able to describe and quantify. The use of universally defined and accepted scale makes all this possible.

Closely related to scales are units. Units are the increments of the scale. There are seven fundamental units in science. (meter, kilogram, second, ampere, kelvin, mole, candela) All other units are derived. Outside science, there are many units that are not derived and are not considered fundamental e.g. people, bits, dollars. Regardless, a scale will contain units.

Sample Test Questions

Question 1: ***A scale***

A. applies only to science items
B. must have absolute standards
C. needs units to be meaningful
D. can be devised to measure anything

Commentary: Choice "A" does not allow for non-scientific scales. "B" rules out relative scales and "D" does not allow for non-measurable items. "C," the correct answer, addresses the necessity of making a scale useful and understandable.

Question 2: ***Which scale would be most useful in quantizing distance between galaxies?***

A. Miles
B. Angstroms
C. Kilometers
D. Parsecs

Commentary: While all of the answers are distance scales, only "D" is considered large enough to apply to the distances in space. It is important for a student to recognize the correct scale in terms of magnitude measured.

Question 3: ***Which of the following is NOT an absolute scale?***

A. Hardness of rocks
B. Temperature
C. Time
D. Mass

Commentary: This question checks for recognition of a relative scale and the correct response is "A."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to apply the concept of **Scale**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of scale.
   a. Explain the difference between absolute and relative scales.
   b. List examples of hard to measure items.

2. Improve their ability to apply the concept of scale by using the correct scale when describing/explaining a situation.

SIGNIFICANCE

Science Concept Working Paper # 25

Introduction

The idea of *significance* implies that we have attached value to a given item or piece of data. Significant events and responsibilities are what give our life meaning. Christ's death, your birth, birthdays, graduations, weddings, and your career are all examples of items that are significant in life. Significant events tend to serve as milestones or as points of reference as we move through our daily experiences.

Significance is also important in science as a scientist attempts to discern which events or pieces of data are going to be helpful in drawing accurate conclusions. This concept is too easily overlooked, especially when results and data are contradictory to the expected values.

Developing the concept of significance is a lifetime endeavor that can be improved with practice. Teachers have had much time to develop this concept but often fail to recognize that students still need an opportunity to experience significance in a hands-on way.

The Concept

When using the term significant we are saying that something has meaning or bearing and is of importance. The concept of significance is such an integral part of our lives that we often fail to recognize its presence in our day to day existence. However, our days are full of receiving information and deciphering the significant events from those that we feel have no direct bearing on our lives. The degree of significance is directly proportional to the affect the events or data have on the individual.

Examples of significance range from deciding what type of toothpaste to buy to what the United States will do with nuclear wastes. As the concept is developed we learn to prioritize all significant events and data in such a way that we are able to use this information to draw valid conclusions.

At a very early age we begin to learn the significance of decisions that we make as we realize that there are consequences, both good and bad, that go with every decision. As we continue to grow we also learn that decisions we make may be significant to and affect others as well as ourselves. What we do individually with Christ's sacrifice is significant both to us as well as those who are able to see Christ in us.

With further maturity comes the realization that significant decisions can change not only one's life but one's community (i.e. city, state, country, world) as well. There are many significant issues facing society today, such as environmental and medical topics, that require us as a world community to take prompt, responsible action.

In science, the concept of significance can be developed using many different situations; each adding a new dimension to the overall meaning and understanding for the student. For example, students might be asked if there is one day of the year that is more significant than all the others (i.e. birthday) or if light is significant to plant growth. At this point it is helpful to bring in some false examples such as asking "is a rock next to the plant significant to its growth." By thinking through such questions the student learns to determine the significance and relevance of any piece of data.

Significance also applies to the use of numbers. The significance of numbers deals with which numbers or digits are valid in any measurement or piece of data.

When conducting scientific investigations the concept of significance serves an important role in guiding the scientist as experiments are designed and implemented. Factors affecting the investigation must be categorized according to their significance in possibly affecting the results obtained.

In conclusion, the proper understanding of the concept of significance is crucial to the development of competent, responsible scientists. However, this concept also plays a vital role in helping every student grow in decision making skills. This process will not only be of daily benefit to the student but will prove to play an important role in the future of our planet.

Sample Test Questions

Question 1: ***Significance refers to***

A. data relevant to drawing conclusions
B. any data collected
C. digits that are appropriate to instrumentation
D. A and C
E. A, B, and C

Commentary: This concept-based item assesses a learner's knowledge and ability to apply difference of significance. The correct answer is "D."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to apply the concept of **Significance**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of significance.
   a. Operationally define significance.
   b. Differentiate between items that are significant and those that are significant in a given situation.

2. Improve their ability to recognize significance.
   a. In a given set of circumstances, identify those items that would be significant.
   b. Given a situation, and a list of variables, determine those that would be significant.
   c. When given significant items, suggest the situation that they describe.

3. Use their knowledge of significance for making predictions.
   a. Given raw data chose the items that are significant and predict the outcome of the experiment.
   b. Given a conclusion, suggest significant data that would have contributed to this conclusion.

SPACE-TIME

Science Concept Working Paper # 26

Introduction

Newton and others before Einstein thought of space as an infinite expanse in which all things exist. We are in space, and we move about in space. It was never clear whether the universe exists in space, or space exists in the universe. Is there space outside the universe? Or is space only within the universe? The same question can be raised for time. Does time exist in the universe or does the universe exist in time? Was there time before the universe existed? As Christians we may ask, "Was there time before creation or before sin? Will there be time after the sin problem is solved?"

Einstein's answer is that both time and space exist only within the universe. There is no time or space "outside". Einstein reasoned that space and time are two parts of one whole called *space-time*.

The Concept

We are in time and space. Everything that happens takes place in time and space. We can talk about a chemical reaction in terms of time and space. Two entities cannot occupy the same space at the same time. They may occupy the same space at different times, or one of them occupy a different space at the same time.

Many scientific inquiries are an examination of the relation of time and space, i.e. d=vt. We want to know how far we have gone in a given amount of time, or how long it will take to travel a given distance. We could also be interested in the rate of reactions or the growth rate of an organism.

This is only a part of the story. We are moving through time at the rate of 24 hours per day. In the concept of space-time, we are traveling through not only time or space, but space-time at a constant quantity. If we stand still, then all our traveling is through time. If we move a bit, then some of our traveling is through space, but most is still through time. If we were to travel the speed of light, then all travel is through space and time does not exist. Regardless of whether we are at complete rest or moving at high velocity, we are still moving in space-time. It does not appear to be reversible.

Time is a very precious commodity. Christ lays claim to our time because He purchased it on Calvary. Time is therefore, a great treasure that in this life must be spent wisely. Once we spend time, we can never recover it. It can be seen as the ultimate non-renewable resource.

Another interesting aspect of space-time comes from the experience of Daniel. While he was praying, an angel came and indicated that he was sent from the throne when Daniel began to pray. Is it possible that angels can travel so close to the speed of light that time practically stands still? In a similar vein, we can ask whether time will exist after the end of sin. These questions are beyond our resolution now, but they can be used to help the student gain new perspectives on the infinite wisdom of God.

Sample Test Questions

Question 1: ***An object at rest***

A. doesn't fit under the space-time concept.
B. is moving through time and space.
C. is moving through space only.
D. is moving through time only.

Commentary: This item tests the basic understanding of space-time. According to the theory, being at rest doesn't exempt a body from space-time, it is moving through time only, which is answer "D."

Question 2: ***Two entities can occupy the same space***

A. if they do so at different times.
B. only at a the speed of light.
C. if they have different physical properties.
D. when completely at rest.

Commentary: Similar to the first question, this item is testing basic understanding of the concept of time-space. The correct answer is "A."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept on the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Space-time**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of space-time.
   a. Explain the relationship between space and time.
   b. Apply the correct space-time formulas to explain/describe a given situation.

2. Value the concept of space-time for its predictive and explanatory power.
   a. Choose to use the concept of space-time when appropriate.
   b. Choose to further develop their personal concept of space-time.

SYMMETRY

Science Concept Working Paper # 27

Introduction

The notions of harmony, balance, similarity, proportion and arrangement seem to combine uniquely to capture the broad meaning of the concept of *symmetry*. We've all used the concept in a variety of ways (e.g., cutting out paper figures such as stars, pumpkins and hearts, explaining why the left hand of a mirror image moves when we move our right hand, expressing why a building, pattern, etc, seems pleasing). While symmetry is often perceived as pleasing (e.g., architecture, farmland viewed from the air, formal garden), it is sometimes purposely avoided (e.g., composing a photograph, creating the unexpected perception).

The overall designs of the universe on both a macro- and microscale display symmetry from every angle, and give evidence of God as Designer. Aesthetics in nature exist far beyond the level of function and show the generosity of the Creator. We are designed such that beauty is a necessity for the human mind. However, as we become aware of the extravagant beauty scattered almost casually in our everyday environment, we are given a glimpse of the scope of God's love for us. The concept of symmetry was also intended in our relationships with God and each other. The flow of love and power to us and the returning love, worship, and gratitude to our Creator were designed for eternal symmetry. Sin has, of course, changed this symmetry by trying to make us distrustful of God. Jesus came to Earth to exemplify that relationship and will come again to take us to the ultimate restoration of God's plan.

Symmetry seems to play an important role in art, mathematics, music, and a host of other seemingly divergent areas. The concept of symmetry is also widely used in science. In fact, a powerful explanatory and predictive skill is to be able to see or "feel" symmetry where others have failed to perceive it. Symmetry is certainly a concept whose increased development will enhance the intellectual/perceptual power of the learner.

The Concept

The idea of symmetry is somewhat simply captured by the thought of arrangement in accordance with a certain similarity (i.e., balance). For many situations, this similarity can be in reference to a point, a line or a plane.

When the symmetry is relative to a point, it is referred to as spherical, rotational, central, or point symmetry, depending upon the particular example. The point itself is referred to as the center of symmetry or point of symmetry. Any straight line through this point will find "sameness" at equal distances from the point in both directions. A few common examples are snowflakes, many crystals, rectangles and wheels. The examples that follow should further illustrate this type of symmetry

Figures not available

If the symmetry is relative to a line or plane (imagine the line or plane to be like a mirror whose reflection forms the other half of the "thing"), it is generally referred to as reflective or bilateral symmetry (e.g., both halves the same). With younger learners, this type of symmetry is often called mirror symmetry or mirror balance. The line is known as the axis of symmetry, and the plane is referred to as the plane of symmetry. Mathematically speaking, the axis of symmetry would be the reference for two dimensional figures, and the plane of symmetry used for three dimensional situations. There can be one or more axes or planes of symmetry present. A cube, for example, has four planes of symmetry (1 horizontal, 1 vertical, and 2 along diagonals).

Some common examples are the external human body, "valentine" hearts, the letter A, and a butterfly. The examples below may help further clarify the idea.

Figures not available

A type of symmetry known as radial symmetry is closely related. In this radial symmetry condition, the sameness of structure occurs around a central axis. This term is frequently used in biology when making reference to such animals as sea anemones and jellyfish.

It is also important to note that things can simultaneously possess several types of symmetry. A snowflake, for example, has both reflective (bilateral) and rotational (point) symmetry.

There are, of course, nonspatial applications of symmetry, such as time reversal, color complements, and black/white inversions. Things that do not possess the attributes of symmetry are referred to as asymmetrical.

Closely related major science concepts include equilibrium, fundamental entities, interaction, invariance, order, organism, and perception.

Sample Test Questions

The sample evaluation items and their accompanying commentaries are intended to further illustrate the difference between concept-oriented learning outcomes involving the big ideas or major concepts in science and the more familiar content-oriented outcomes.

Question 1: ***Which is most descriptive of the concept symmetry?***

A. Repeating a pattern at regular time intervals
B. Balance between opposing forces or tendencies
C. In order by increasing size, weight, etc.
D. Increasing or decreasing at a more or less regular rate
E. Arrangement or condition that has perceived balance

Commentary: This high level, concept-based question requires students to evaluate each of several descriptive statements in terms of a "match" with their concept of symmetry. The distractors generally describe the related concepts of cycle, equilibrium, order, and gradient. The correct response is "E," and the item is suitable for use with Sample Objective 1.

Question 2: ***Which organism(s) display radial symmetry?***

A. Human being
B. Snake
C. Sea anemone
D. Drosophila
E. All of the above

Commentary: This is NOT an example of a concept-based question. While the item is concerned with the concept of symmetry, the learner must recall prior information in order to knowingly respond correctly. The primary reason for this is that even if radial symmetry is understood, only the names of organisms are provided. Unless these names can be connected with a type of symmetry, there is no basis for choice (e.g., the structure of the organisms is not illustrated).

Question 3: ***Which has at least two different types of symmetry?***

Figures not available

Commentary: This concept-based question directs the student to apply his/her understanding of the types of symmetry to several "things." The distractors all possess only one form (although there may be several axes) of symmetry. The correct response is "D," which has both point and bilateral symmetry. This item is appropriate for use with Sample Objective 2.

Question 4: ***An organism is known to have bilateral (reflective) symmetry. Part of such an organism is observed as illustrated.***

Figures not available

The "hidden" portion of the organism is probably most like:

Figures not available

Commentary: This concept-based question requires students to apply their understanding of symmetry by making a prediction. The correct response is "C," and the item is suitable for use with Sample Objective 3.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Symmetry**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of symmetry.
   a. Operationally define symmetry.
   b. Identify examples of at least two different types of symmetry.
   c. Differentiate point, bilateral, and radial symmetry.
   d. Critique a definition of symmetry.

2. Expand their ability to recognize symmetry.
   a. When given a collection of things (e.g., objects, pictures), identify those that possess symmetry.
   b. When given a group of symmetrical "things" and a list of types of symmetry, correctly match the "things" to the types symmetry

3. Extend their ability to apply the concept of symmetry.
   a. Appropriately use the concept of symmetry when making observations.
   b. When given that a particular type of symmetry is present and appropriate starting information, use the concept in making predictions.

4. Value the concept of symmetry for its predictive and explanatory power.
   a. Choose to further develop their personal concept of symmetry.
   b. Choose to use the concept of symmetry when making observations, formulating explanations, and/or making predictions.
   c. Value explanations and predictions based upon an appropriate application of the concept of symmetry.
   d. Value the symmetry in nature as a gift from our Creator.

For Further Information About Symmetry

Illustrated reading for students and teacher: Kim, Scott. *Inversions.* Peterborough, NH: BYTE Books, 1981.

SYSTEM

Science Concept Working Paper # 28

Introduction

Probably no major science concept has its name used as frequently as *system*. The list of common uses covers the full realm of science and everyday affairs, and is represented by such diverse examples as the nervous system, solar system, ecosystems, weather systems, chemical systems, highway systems, and weight loss systems. In addition, we hear about people who work as systems analysts or are in the process of utilizing a systems approach.

With the widespread use of the concept, it is imperative that everyone develop an understanding of and ability to appropriately apply the concept. Its explanatory and predictive powers make it a central idea for functioning in today's world.

The Concept

A system consists of a group or collection of interacting or interconnected "things" and is the largest collection of objects taken under consideration for purposes of describing, explaining and/or predicting. In other words, a system is a collection of related "objects" that collectively represent a whole. Because of the necessary interaction or connection between the objects comprising a system, each element or component plays a role in the overall functioning of the system.

The components of a system can be physically separated, such as the members of our solar system, or in contact all or part of the time, as is the case with gear systems and pulley systems. In other cases, the observer can mentally create the components of a system, even when a single object is involved. An example of the latter would be imagining a sheet of paper to be composed of two halves or four quarters.

Subsystems are groups of interacting or interconnected objects within a larger system. For example, the earth/moon system is a subsystem of our solar system, which is in turn a subsystem of our galaxy. It is possible for a given object within a system to be a component of several subsystems.

Systems are often categorized as either "open" or "closed." The closed condition, which may or may not actually be able to be achieved, can range from closed for some specified condition (e.g., mass, force) to completely closed. When not specified, closed generally refers to closed for energy-matter exchange with any other system. Therefore, it is reasonable to think of a closed system as being closed for at least one component, preventing any exchange of that component into or out of the system. In other words, whatever a system is identified as being closed for can neither enter nor leave the system. If such an exchange does happen to occur, the system becomes a new and different system.

Open systems exchange energy-matter with other systems. Therefore, open systems are defined by a bounded region of space rather than by the energy-matter present. The space above the water in a jar partially filled with water is an example. Of course, the most personal example of a dynamic open system is a human being.

The components or elements comprising a system can be inanimate, animate, or a combination of the two. A classic example of the latter category is an ecosystem.

Major science concepts closely related to system include cause-effect, change, cycle, energy-matter, entropy, equilibrium, field, fundamental entities, interaction, organism, population.

Sample Test Questions

Question 1: ***Which is a subsystem of a house?***

A. The city in which the house is located.
B. The family.
C. The electrical wiring in the house.
D. Street lights visible from the house.
E. All of the above are subsystems of a house.

Commentary: This item is designed to determine the student's ability to appropriately apply the idea of subsystem. The attributes "within a larger system" (in this case designed as house) and "group of interacting or interconnected elements" must both fit the best choice. The correct response is "C."

Question 2: ***Systems***

A. must be closed in order to be useful in explaining phenomena.
B. are natural phenomena as opposed to human-created phenomena.
C. must contain at least one subsystem.
D. are collections of interconnected things.
E. B and C.

Commentary: This concept-based item requires students to select the statement most descriptive of or consistent with the concept of system. The desired response is "D."

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **System**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of system.
   a. Operationally define system.
   b. Differentiate system, subsystem and population.
   c. Differentiate open and closed systems.

2. Improve their ability to identify system.
   a. List several examples of natural systems.
   b. List several examples of human created systems.

3. Value the concept of system for its explanatory and predictive power.
   a. Demonstrate a preference for explanations and predictions.

THEORY

Science Concept Working Paper # 29

Introduction

The concept *theory* represents one of the most powerful explanatory and predictive vehicles in all of science. Examples of theory range from the widely known, such as Newton's universal theory of gravitation, theories of origins, cell theory, and continental drift, to the lesser known (but still important), such as the unified field theory, the theories of human color vision, conditioning theory of human behavior, and the theory of relativity.

Science as a holistic enterprise is one human way of knowing (e.g., explaining, understanding, predicting, answering questions). Science has a number of explanatory/predictive tools, including facts, concepts, principles, generalizations, laws, models, and theories.

While theory is often treated as synonymous with model, hypothesis, or educated guess, it in fact has a unique set of attributes that clearly differentiate it. To have a well developed concept of theory is the key to a richer, fuller understanding of and ability to apply those numerous scientific theories that form the skeleton of science.

The Concept

A theory represents the broadest level within science at which a scientist is likely to concentrate his or her effort. Theories are the basic or fundamental formal systems developed to account for observations. The better theories are simple, concise systems that serve as explanations for a large number of observations.

A theory consists of a set of interconnected statements relating to a certain aspect of the natural world. These statements can be in the form of words, symbols, mathematical equations or a combination of the three. The statements attempt to represent, in symbolic form, events that can be observed, those that are unobservable, and predict what will be observed under certain specific conditions.

In general, the statements that comprise theories are structured in the following manner:

1. The identification of the terms that are the basic theoretical entities. (These terms are purposely left undefined. Examples of such terms are electron, positive charge, element, reinforcement, habit, bond, and nucleus.)

2. The specification of the relationships between the theoretical terms and the definition of any new terms.

3. The connecting of aspects of the theory to possible observations in nature.

These statements are usually referred to as operational definitions or coordinating definitions. These are necessary in order for the theory to be meaningful.

Theories that have been accepted by the scientific community are generally quite well substantiated. In other words, they have been confirmed by considerable evidence and are more or less verified or established explanations accounting for known observations, facts, or phenomena. In addition, they suggest additional investigation. However, they are still tentative, incomplete, and subject to amendment, correction, and/or rejection. It is also important to keep in mind that theories can be confirmed or verified only to the present time and cannot be proven to be true in an absolute sense.

Sometimes a theory becomes so widely accepted and set in people's minds that it becomes very difficult for anyone to challenge it. Theories that fit this description are referred to as "ruling theories." For some scientists, the theory of evolution has become a ruling theory. For other scientists, creation is a ruling theory. The problem with ruling theories is that objectivity can be lost. If scientists stop asking questions and challenging theories as more evidence is acquired, the scientific process suffers, and new ideas may never be given a chance.

Theories are tested or confirmed by designing and conducting experiments based upon them, explaining observed events with them, and predicting from them what should be observed under specified conditions. Especially meaningful experiments or crucial experiments are those testing a prediction based upon a theory that is contrary to prevailing knowledge. If the confirming activity (e.g., experiment) has observations that have a positive match with the theory, the theory gains in power and status. If, on the other hand, there is no match, then there is an error somewhere in the theory, the interpretation of the system, or the methodology of observing. It is also important to remember that theories are found in books, journals, and scientific papers, but not in nature. Theories are human-created systems useful in explaining some aspect of nature.

In summary, theories are the broadest scope devices created by humans to attempt to describe and explain observed and unobserved events and predict what may be observed under certain conditions in a particular domain of the natural world. When accepted for use and testing, they have been confirmed by considerable evidence. Theories are comprised of statements, both in words or other symbols, that identify the theoretical entities, relate these entities (including some created for the theory), and relate the system of statements to possible observations. Theories are tested by attempting to match their explanations, proposed observations, and predictions to the observations in the natural world. A method frequently employed for this purpose is the design and conducting of experiments based upon the theory.

Other major science concepts that appear to be closely
related to theory include cause-effect, interaction, model, origins, probability, and system.

Sample Test Questions

Question 1: ***Which is most descriptive of a theory?***

A. Observations agreed upon by independent observers.
B. A tentative explanation for a specific natural phenomenon.
C. A confirmed fixed relationship between two or more variables.
D. The equivalent of a non-testable scientific hypothesis.
E. A set of interconnected statements accounting for observed and unobserved events in one domain of the natural world.

Commentary: This item requires student to evaluate a series of given statements to determine which has the best "fit" with the concept of theory. The correct response is "E."

Question 2: ***Which is consistent with unified field theory?***

A. The proton is unstable.
B. Weak nuclear interaction is not a constant.
C. An average of one proton in a human being will decay during a lifetime.
D. A and E
E. A, B, and C

Commentary: This is not a concept-based question. While the item does deal with a theory, the focus is on understanding some specifics of a particular example. In order to respond correctly, the student would have had to have studied unified field theory and recalled selected information. A correct response in itself does not provide any evidence regarding the level of development of the concept of theory.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Theory**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of theory.
   a. Operationally define theory.
   b. Identify example of theory.
   c. Differentiate between scientific and nonscientific theory.

2. Recognize the limitations of scientific theory.
   a. Identify basic assumptions associated with theories of origins.
   b. Explain how scientific theories are developed.
   c. Identify problems associated with "ruling theories."

3. Extend their understanding of the role of scientific theory in the scientific process.
   a. Describe the role or purpose of scientific theory in the process of scientific discovery.
   b. Cite examples of scientific theories that have been modified or abandoned due to the acquisition of more complete evidence.

VALIDATION

Science Concept Working Paper # 30

Introduction

What is truth? This question been asked by philosophers, scientists, and ordinary people in every age. How valid is a statement? For science to maintain credibility, validation is a must, just as it is for other phases of life. We want to know that our beliefs have validity. To validate is to show that an idea is sound, logical, solid, well-grounded, correct, tested, convincing, trustworthy, and confirmed.

The Concept

In science, as well as other phases of life, there are thoughts, ideas, theories, and concepts that have not proven valid. True science is a process of testing and retesting to establish validity. The concept is also crucial to the formation of a Christian's set of beliefs. As Christians, we need to settle into our beliefs intellectually and spiritually. This is done by validating our beliefs.

Validation of scientific research is essential. To test something by two or more different methods and obtain the same result validates a given theory. A theory may also be confirmed through the use of mathematics.

It is important to recognize the degree of truth in a source, but it is of equal importance to recognize good sources of truth or validity. There are levels of validity. The lowest is on the level of tabloids such as the *National Enquirer*. A higher level of truth is a well known and trusted public figure such as Walter Cronkite. While you are not personally acquainted with him, you recognize his integrity. He is not necessarily an expert in all areas, but he tries to be sure of his facts. Your parents, believe it or not, can be another source of truth. They may not know all there is to know, yet experience and their love for you make them trustworthy. We have all used teachers as sources of truth. Our teachers are entrusted with our education and therefore, would not deliberately mislead us. The scientist is an expert. This source is in the business of finding truth. The scientific method requires testing and retesting before accepting a finding as fact. Personal investigation is the best. **YOU** search and investigate until you find truth for yourself. By doing this, there is no margin of doubt. Unfortunately, as Christians, we often leave the validation of our beliefs to our parents, our pastor, or the Bible teacher. We have not heeded the advice in Psalms, "Taste and see the Lord is good."(NIV) Therefore, the ultimate validation for a Seventh-day Adventist Christian is divine revelation.

It is important that the student be aware of the highest level of validation. Weight can be given according to the source. Only then will we not be susceptible to every rumor, idea, or theory that is presented. We must be able to determine the truth. Only then will we be sure of what we believe and will be able to defend our beliefs. What is truth? It depends on the validity of the source and our confidence in that source.

Sample Test Questions

Question 1: ***Validation occurs when***

A. you perform the test and confirm the results.
B. a write-up in a journal backs a previous finding.
C. an experiment can be replicated.
D. all of the above.

Commentary: This question is designed to check for basic understanding of the concept of validation. The correct answer is "D."

Question 2: ***Which is the best source of validation material on the Flood?***

A. "Scientific American"
B. "Newsweek"
C. "Adventist Review"
D. *Origins*

Commentary: This question deals with the best source of validation. While all of the magazines could carry articles concerning the Flood, *Origins* would be the best source for Christians who believe in creation.

Sample Instructional Objectives

From an instructional point of view, a concept takes on operational meaning when learner objectives are specified. The most meaningful concept development is likely to result from learning outcomes that address the concept in the most generalizable form possible. The sample objectives that follow are representative of a larger number that are particularly useful in promoting the understanding of and ability to appropriately apply the concept of **Validation**.

The students will be making progress when they are able to:

1. Increase their understanding of the concept of validation.
   a. Write their own definition of validation

2. Value the concept of validation for its foundation of truth.
   a. Rate sources according to their validity.