SCIENCE EDUCATION:

SELECTED LECTURE NOTES AND RESOURCES

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In honor of my parents who made education possible for many underprivileged children in India.
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INTRODUCTION

We live in a world influenced by information explosion, ubiquitous telecommunication technologies, faster intercontinental transportation, and improved health care, due to unprecedented developments in science and its technological applications. Calls for a science and technology literate workforce have been made by various sectors of society. As a result education reform in the sciences has become a national priority. According to a report from the Committee on STEM Education of the National Science and Technology Council (2013) “it is essential that the United States enhance U.S. students’ engagement in STEM disciplines and inspire and equip many more students to excel in STEM” (p. vi).

Science as a key component of STEM education is of critical importance and motivating students to learn and comprehend science still remains a challenge to teachers. “We all have a stake in ensuring our kids are ready to compete in today’s technology-based economy” (US Secretary of Education Arne Duncan Discusses STEM at Wheeling High School, 2013). Teachers play a very important role in classroom learning and according to the National Commission on Teaching and America’s Future (1996) teachers’ knowledge and their teaching skills impact students. Therefore preparing teachers to teach science effectively is a national priority. Moreover preparing teachers to motivate young learners to learn science is even a higher priority. Research in science education shows that children receiving good science instruction early on in schools have a higher possibility of pursuing higher education and careers in science and related fields (National Science Teachers Association, 2014; Lederman & Abell, 2014). Thus it seems that the age-old proverb “train up a child in the way he/she should go, and when she/he is old he/she will not depart from it” (Proverbs 22: 6) applies to science education also.

The reason for putting together the Lecture Notes is to provide research based ideas and strategies for teaching science to elementary and middle school children. It is hoped that when supplemented with prescribed textbook this Lecture Notes will provide the foundational science content and pedagogical knowledge and skills to be an effective science teacher.

REFERENCES

GOALS FOR TEACHING SCIENCE AT K-9

“One of the aims of science education is to prepare students for life through the cultivation of cognitive skills needed to solve real-world problems. Traditional learning methods such as rote memorization are often found ineffective in producing meaningful learning experiences. In The Aims of Education, Whitehead [1] addressed this concern when dealing with passive learning and inert knowledge. Inert knowledge may be defined as what is recalled under explicit conditions, but not applied spontaneously to solve problems. It is believed that inert knowledge that is a part of the semantic memory lacks autobiographical references when applied in problem solving. This simply means that it is difficult to recall inert knowledge without prodding questions. Enriching the context of learning might provide schema (mental associations) that helps the learner create autobiographical references to new information in learning situations centered on problem solving.”


Goal Number One: Personal
Science education should enable students to use science for improving their lives

Goal Number Two: Societal
Science education should enable students to deal with responsibility, and make informed decision concerning science and technology related societal issues.

Goal Number Three: Career
Science education should enable students to be aware of career opportunities in science and technology

Goal Number Four: Academic
Science education should enable students to acquire the academic knowledge necessary to pursue academic science

SCIENCE PROCESSES (Selected)

**Observing**
To take notice of (the properties of) a situation or object using any of the senses

**Predicting**
Foretelling situations, events anticipated existing

**Hypothesizing**
Making a testable statement or supposition or “educated prediction” based on rationale

**Experimenting**
Hypothesis testing involving the effect of independent variables on dependent variables

**Collecting Data**
Collecting information about situations, objects, and events

**Measuring**
Collecting quantitative information using a standard of measurement

**Interpreting Data**
Analyzing and explaining information

**Classifying**
To arrange information, materials by traits, and properties, etc.

**Inferring**
Reaching a conclusion or deduction based on a rationale explanation of a situation/observation

**Generalizing**
Making a general conclusion from specific information

**Space/Time relations**
Manipulation involving time, speed, shape, and distance

**Defining Operationally**
Producing statements to describe a situation or event
PROCESS IDENTIFICATION ACTIVITY

As teachers, we are concerned about designating learning experiences for children. To do this, we create a sequence of events such that the total experience is designed to produce an identifiable change in behavior in the students, such as a new concept or idea that is discovered. This is our main objective, to produce an identified behavioral change. Yet, each of the things we do as teachers, the questions we ask, the directions we give, evoke certain behaviors in children. In most cases, the behavior may not be a new one, merely a behavior previously learned, just used in a slightly different context. As teachers, it is important to recognize the behavior or “process” a student will be using in responding or complying with our questions or directions.

What “processes” are we talking about? For a starter, the following list processes can serve as a means to classify how students will respond to what we ask of them.

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<td>Using Space/Time</td>
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The list of “processes” is not exhaustive. Other processes not included above but related to critical thinking and creative skills are:

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What follows is a guided discovery science lesson. You are to identify from the question or activity, the proper thinking process using the list from above. Once you have identified the process, write it in the space provided to the left of the question or the
PROBLEM: How Does a Cocoon Change as It Grows and Develops?

GRADE LEVEL: 3-5

CONCEPTS: 1. Some animals change in shape and size as they grow and develop.
2. Small animals have a heart.
3. Growing and developing animals may not look like their adult parents.
4. Animals need air (oxygen) in order to live.

MATERIALS: Cocoons of different moths, scissors, cover jar with air holes in lid

DISCUSSION QUESTIONS:
______________How does your favorite animal change as it grows and develops?
______________How do humans change as they grow and develop?
______________How does a cocoon change as it grows and develops?
______________How could we find out?

TEACHER NOTE: This lesson should follow lessons in which various worms have developed cocoons in order to develop the concept of life cycle in a unit on life cycles.

STUDENT DISCOVERY ACTIVITY:

1) ______________Obtain a pair of scissors and a cocoon.

2) ______________Take the scissors and very carefully cut through the outer layer of the cocoon.

3) ______________Observe the inside of the cocoon.

4) ______________What does the movement you see inside the cocoon tell you about the cocoon?

TEACHER NOTE: The larva inside the cocoon has a heartbeat. Movement indicates the larva is alive.

5) ______________Try to count the number of times the larva moves in a minute.

6) ______________How does this rate compare with your heart rate?

7) ______________Place some cocoons in a covered jar with several air holes in the lid.
8) ________________Why does the lid to the jar have holes in it?

9) ________________Observe the cocoon carefully for several days.

10) ________________Record the number of days it takes before any changes are evident.

11) ________________Describe the changes made in the cocoon.

12) ________________When a moth appears, watch it closely.

13) ________________What can you say about how a cocoon grows and develops?

14) ________________What name could be given to the changes that the moth has gone through?

OPEN ENDED QUESTIONS:

15) ________________What do you think would happen to the cocoons if they were placed in a refrigerator for a long period of time?

TEACHER NOTE: The cocoon goes several changes in form during its development. This process of changing form, situation, and function in development is called metamorphosis.
COUNTER INTUITIVE/DISCREPANT EVENTS

One technique to motivate and involve students in solving problems with a high degree of creativity and critical thinking, force students into a mode of explanation, or to set the stage for discovery is to use a counterintuitive (discrepant) event. These two terms have been used interchangeable by science educators and refer to the same type of activity.

An event is counter intuitive or discrepant if the presentation of phenomena runs counter to what a person intuitively thinks is likely to happen. For example, if a bar magnet is suspended by a string and another bar magnet is brought near it without touching it, the suspend magnet will turn. If the experimenter flips the magnet he is holding and brings it close to the suspended magnet again, the latter will now turn in the opposite directions. To children, this event or discovery goes against what they intuitively believe should happen. It appears like magic to them. Their curiosity is triggered.

An event is counter intuitive or discrepant only if the event is slightly mismatched from the person’s current cognitive structures or experience. The fact that the “behavior” of the phenomena is different from what would be expected indicated that critical experiences are present in the individual to recognize that something is wrong. Once an event has been incorporated into the individual’s experience base, it no longer is counter intuitive. Without necessary experiences, the events are not recognized as running counter to what one would intuitively expect. In effect, what would counter intuitive for students at one level of their development, will not be counter intuitive at another level of development.

Counter intuitive events catch the attention of students through their mismatch and result in sheer wonderment. With children, their eyes grow larger, they make sounds to express their amazement. Questioning and discussion follow at a rapid pace. Since curiosity is heightened, intense involvement can be utilized to resolve this discrepancy. The objective might be focused on arriving at a satisfactory explanation of the phenomena in question. Activities of the “messing about” variety, guided discovery, inquiry development sessions, or units of instruction can follow. Because of their attention grabbing capacity, counterintuitive events can be used to initiate a wide variety of classroom activities.

Because of a vast experience base, many events are not counterintuitive to adults. Sources of counter intuitive events can be found in books of demonstration, activity booklets, books that lean toward amusement, and magic with science.

EXAMPLES OF COUNTERINTUITIVE EVENTS (With Teacher Notes – TN)

1. A non-waxed paper cup is one-tenth filled with water and is heated by a candle placed under it. Although the flame of the candle is directly below the cup, the cup does not burn. (TN: the paper cup does not burn because as the water is heated the warm water in the cup rises, carrying away the energy. Cold water then falls to the bottom to replace the warm water. This process is called convection. The convection process and the water itself, takes energy away from the flame fast enough so that the paper does not reach its kindling temperature. The temperature of the paper stays below the point at which it would burn. When all the water boils away, the cup will burn, as there is little transfer of heat energy from the bottom of the cup.)

2. Two sealed bottles of liquid are placed in the freezer of a refrigerator and left for twenty-four hours. When the bags are taken out the next day, one of the bottles is broken and the other is not. (TN: One of these bottles was filled with water and the other with alcohol, but the student doesn’t know this. The alcohol freezes at a much lower temperature than the water and the refrigerator is not cold enough to freeze the alcohol. The bottle with water in it froze and broke as the water changed from a liquid to a solid state; the water expanded.)

3. An ice cube is held in the lower part of a test tube by some steel wool that has been pushed into the tube above the ice cube. The tube is almost filled with water. The water in the test tube above the steel wool is heated by flame for some time. The ice cube doesn’t melt (TN: Warm water rises and cold-water falls or stays at the bottom. The tube is heated at a point where the water there is heated continually rises and is replaced by cooler water from the surface above. There is little circulation between the colder water near the ice cube and the water heated above the ice cube and steel wool.)

4. A wagon is pulled with a ball in it. When the wagon starts the ball goes to the back of the wagon, when the wagon stops, it moves forward to the front of the wagon. (TN: This is an example of the law of inertia. The law of inertia states: A body of rest tends to stay at rest, and a body in motion tends to continue moving at the same rate and in the same direction, unless influenced by an outside force that has direct contact with the moving body. Because the ball has such a small surface in contact with the wagon, the force of friction is not enough to overcome the inertia of the ball.)

5. Water flows from a tap slowly and is deviated from its normal fall when a comb charges with static electricity is brought near it. A charged comb picks up small pieces of paper, flow, and dirt. (TN: This shows the electrical nature of matter. When you rub a comb, it becomes negatively charged. When it is placed next to the following water, the negative charge forces some of the electrons away from the
side of the water nearest the comb, leaving its side positively charged. This is called induced charge. Since unlike electrical charge are attracted to each other, the water flow which is near the comb, positively charged, is attracted to the negatively charged comb.

6. A bucket or glass of water is swung overhead without water falling out of the bucket. (TN: This is another example of the law of inertia. The force of gravity does not act fast enough to cause the water to fall out of the bucket.)

7. Tie a piece of string to a paper clip and suspend the clip in midair by placing it near a magnet held above it (TN: The magnet field acts on the paper clip keeping it suspended in the air.)

8. Put a magnet into a beaker, fill the beaker with water, and pick up iron fillings with the beaker, magnet, and water. (TN: A magnetic field will pass through the glass of the beaker.)

9. Use phenolphthalein solution, acids, and bases, and other indicators like bromothymol blue (BTB) to show chemical solutions will change color by addition of an acid or base to them (TN: Phenolphthalein and BTB is used by chemists to indicate the presence of an acid or a base. In basic solution, phenolphthalein appears red to pink (wine) while in neutral solution (distilled water) and acidic solutions, it is colorless.)

10. Place 8 X 10 piece of paper in your hand and bring your hand to your lips. Hold each side of the paper by one hand using the thumb and forefinger. Roll the paper toward the lips and blow across it. (TN: The paper will rise because of a moving stream of air above the paper exerts less air pressure on the paper than the air pressure beneath the paper. Difference in pressure causes the paper to rise.)

11. Drill three holes in an empty coffee can, one near the top, one near the middle, and one near the bottom. Plug the holes from the outside of the can with soft clay. Fill the can with water under the faucet in the sink or a large deep tub. Pull out of the plugs and leave the faucet running just enough to keep the can full. The water will shut out further at the bottom hole than out of the hole above it, and farther out of the middle hole than out of the top hole. (TN: As depth increases the weight of the medium above an object increases.)

12. Fill a plastic cup with water. Cover it with a card or paper and invert it. The water stays in the cup. (TN: The atmospheric pressure outside the cup is greater than the pressure inside, hence holding the paper and preventing the water from coming out of the cup.)
13. Fill a large granulated cylinder with water and three mothballs. A small amount of mossy zinc is placed on the bottom and some concentrate HCl is added. The mothballs continually go up and down.
14. Attach two pendulums on a single string. Set one in motion. Soon the other pendulum will begin to swing and the first one will stop. The cycle repeats.
15. Fill two beakers with water. Add a teaspoon of salt on one. Boil both and take the temperature of each. You will get different boiling points.
16. Place a piece of paper under a glass. Pull the paper out quickly. The glass doesn’t move.
17. Place a needle very gentle in water. It floats.
18. A beaker of water, a beaker of alcohol, and a beaker with a mixture of water and alcohol are placed side by side. An ice cube is placed in each of the three beakers. The ice floats, sinks, and is partially suspended in the three beakers.
19. Mix 50 ml of water and 50 ml of alcohol in a granulated cylinder. The sum of the two liquids together is less than the 100 ml of liquid.
20. Take an ice cube and stretch a thin wire over it with heavy weights attached to the wires. All the weights hang on both ends of the wire. The wire will move through the ice cube. The path the wire takes in passing through the ice cube freeze behind the wire.
21. A pencil is immersed in a test-tube of water. It floats. If salt is poured into the test tube containing the pencil, the pencil will rise upward in the test-tube slightly.
22. Several pistachios shells are put into a beaker containing some Sprite. After a period of time, the shells begin to bob up and down in Sprite.
23. Blowing out a candle behind a bottle. Place a bottle between you and a lighted candle. Blow against the bottle toward the candle. The flame on the candle goes out.
24. Making a balloon almost impossible to blow up. Push a balloon into a bottle and stretch the open end of the balloon back over the mouth of the bottle…now blow hard into the balloon. The balloon will only inflate to a certain size and then stops inflating no matter how hard you blow.
25. Floating an egg in the middle of a glass of water. Place three tablespoonful of salt in a half-full glass of water and stir until salt dissolves. Now carefully place an uncooked egg in the center of the water. The egg will float because salt water is denser than the egg. Now carefully put fresh water on top of the egg, so that the fresh and salt water do not mix, until the glass is full. The egg will remain floating in the middle of the glass.

REFERENCES


Pictorial riddle are counter-intuitive events, and they:
Can illustrate
- An actual situation
- A situation which has been altered
- A process in which something is missing
Can be made by preparing diagrams or using
- Pictures taken from magazines; photographs or Polaroid pictures
Can be drawn on:
- Overhead transparencies
- Ditto masters
- Black board
- Cards
- HyperCard stacks
Can be used:
- To start units
- To start discussions
- To start lessons
- In HyperCard stacks
- On bulletin boards
- As evaluation items for lessons, tests
Assignment
Create a pictorial riddle of each type. Draw them on letter size paper. You may put all three on one sheet, or one on a single sheet of paper.

SAMPLE SCIENCE PICTORIAL RIDDLES

- Telephone poles
  - Summer
  - Winter

- Fresh grape
  - 7-Up
  - Fresh grape
  - 7-Up

- Ice cube
  - In water
  - Ice cube

- Rock
  - Cork

- Dry cell
  - Apple
  - Milk carton
Purpose: The purpose of this project is to determine which brand of paper towel absorbs the most amount of water.

1. **Background research**: Description/definition of scientific concepts/principles related to the project, General information about topic, description of related research if any by others, overview and related information that formed the background of your topic (cite references). Define Absorption; Capillary Action. Review three paper towel experiments and for each address: What the researchers did? How did they do the research? What did they find out?

2. **Hypothesis**: Paper towel Brand B will absorb the most amount of water.

3. **Variables**:
   - a. Independent Variables- The Brand of paper towels (brand A, B, C, D)
   - b. Dependent Variable- The amount of water absorbed (ml)
   - c. Constant- Amount of water used, temperature of water, amount of time each paper towel is submerged in water, color of paper towel, ply of paper towel, size of paper towel.

4. **Materials**: 20 cm x 20 cm paper towels brand A, B, C, D 10 sheets each, 100 ml graduate cylinder, thermometer, clock with second hand, water at fixed temperature, one paper plate, one soup bowl.

5. **Step by step directions**
   1. Cut each brand of paper towel into ten 20 cm X 20 cm pieces
   2. Label each brand of paper towel A, B, C, D.
   3. Measure the temperature of the water
   4. Measure 100 ml of water into soup bowl using the measuring cylinder
   5. Fold one Brand A labeled piece of paper four times
   6. Submerge completely the paper towels into bowl of water, and note the time
   7. After 15 seconds remove the paper towel and place it on the paper plate
   8. Measure the volume of water remaining in the bowl using the measuring cylinder
   9. Repeat steps 3-8 for remaining pieces and brands of paper towels

6. **Data table**

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<th>Amount of water absorbed in ml</th>
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   AVERAGE:
Amount of water absorbed = Amount of water before submerging the paper towel MINUS Amount of water left after removing the paper towel

7. **Bar graph**: X axis - brand, y axis - average amount of water absorbed (ml)
8. **Conclusion**
9. **Bibliography**: list all references cited in the text
MODLES OF INSTRUCTION

Reception Learning

Rote Learning
Meaningful Learning

Discovery Learning

Rote Learning

If students can see no connection between what is to be learned and what they already know, the learning material will be assimilated in such a way that it is tacked on to existing knowledge in a rather arbitrary manner. This new learning material is not integrated into what they already know.

A common example of this type of learning occurs when students look up definitions and memorize facts to reproduce on a test when they have not had any type of physical experiences with the learning material.

Reception Learning

A total block of learning is presented to the student by the teacher, most often by means of lecture or show and tell. The task of the student is to assimilate the material that is offered. The student has no obligation put on him/her to independently discover new relationships.

Depending upon the background of the student, the material will be assimilated in a rote fashion (tacked on to existing knowledge in a rather arbitrary manner), or will be assimilated in a meaningful way (integrated into existing knowledge). How often do you think reception learning occurs in science classrooms?

Meaningful Learning

If the students can see a connection between what is to be learned and what they already know, the learning material will be assimilated in such a way that it relates to existing knowledge or cognitive structures in a rather non-verbatim and non-arbitrary manner. This new learning material is integrated into what they already know.
The new learning material can be related to existing ideas as examples, special cases, extensions, elaborations, or qualifications. Learning material can be acquired meaningfully by either reception or discovery learning. It might be argued that meaningful learning is the most important type of learning because it extends from what a student already knows.

**Discovery Learning**

Discovery learning occurs when individuals must use their mental processes to figure out the meaning of something for themselves. The principal content of what is to be learned is withheld from the student. The task of the student is to autonomously figure out (discover) the meaning of what is to be learned. In order to do this, the students must add up observations and inferences, make comparisons, and analyze and interpret data to create a new insight they have not known before. What students have learned is personal to them as the new material must extend from existing cognitive structure.

The task of the teacher is to arrange the learning environment or conditions in such a way to provide situations in which students use their mental processes to figure out the meaning of something for themselves. Most situations in which students engage in discovery learning have a general pattern to them. (Learning by discovery is centered around a series of problem-solving investigations that actively involves students.)

According the US National Science Education Standards it is through Scientific inquiry/discovery often referred to as the discovery method which comprises of a “set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories” (National Research Council, 1996, p. 214). The Discovery method has its roots going back to the fifteenth century British philosopher Francis Bacon who advocated inductive processes to scientific inquiry. The processes may include the following generic steps in the form of a learning cycle or in any combination as determined by the teacher: Asking simple questions about the natural world, Planning investigations and collecting relevant data, Organizing and analyzing relevant data, Thinking critically about relationships between evidence and explanations, Using observational evidence and scientific knowledge to construct and evaluate alternative explanations, and Communicating investigations and explanations to others.

Discovery method could be implemented in many ways. According to research, at the primary grades, to promote discovery learning, teachers must implement a variety of science teaching strategies through Hands-on Minds-on activities.
GENERAL PATTERN OF DISCOVERY LEARNING

1. A question or series of questions is raised, and through discussion a problem, is identified (a question to be answered).
2. The teacher prescribes (or with the help of the teacher, the student propose) ways of investigating the problem and gathering the data.
3. Working either individually or in small groups, the students conduct investigations in which they manipulate materials, make observations, gather and interpret data, and draw inferences.
4. At the end of the activity, students figure out what their data means or says, draw conclusions, make generalizations, and answer the questions.

TYPES OF DISCOVERY LEARNING

Based on who generated the question or problem to be solved and who generated the way to solve the problem or answer the question, there are three types of discovery learning.

<table>
<thead>
<tr>
<th>Source of question/problem</th>
<th>Guided</th>
<th>Modified</th>
<th>Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of solution</td>
<td>Teacher</td>
<td>Student</td>
<td>Student</td>
</tr>
</tbody>
</table>

GUIDED DISCOVERY LEARNING

In situations where the teacher has a particular concept for the student to learn by discovery, the use of guided discovery has been particularly successful. By introducing a thought provoking or curiosity arousing question or demonstration, student questions are raised, and further discussion helps to identify a problem to be solved or question to be answered. Generally, this problem to be solved or question to be answered will allow students to discover the concept identified by the teacher with teacher guidance throughout. The teacher is also the source of the investigation to answer the question. In guided discovery learning provided by the teacher or the student to follow, the student is led through a series of steps in which they manipulate materials to make observations, gather and interpret data, and draw inferences. A series of questions at the end of the lesson will cause the students to take the results and formulate a general statement (make generalization) or state a rule based on their investigation. Example: What can you say about___________?

At this point in the lesson, a term may be invented by the teacher to provide the appropriate terminology based on the physical experience. In essence in guided discovery lesson students are truly provided a path to follow to figure out the meaning of what they do.
Example of a Guided Discovery Lesson, see Video on CONDUCTION

The teacher engages the students in a discussion and facilitates in identifying a problem to be solved (e.g., which cup – plastic, Styrofoam, metal – keeps ice from melting the longest.)

The teacher guides the students in planning an investigation and collecting data (e.g. students make a prediction, place one ice cube each in plastic, Styrofoam and metal cups, and determine the rate of melting by observe the size of each melting ice cube every minute, and collect data.)

The teacher guides the students in analyzing the data and arriving at a solution to the problem (e.g., teacher helps students organize their data into a matrix, analyze the data, test their predictions, arrive at a solution, and arrive at an operational definition - Insulators.)

The students communicate their solutions to the problem to others.

MODIFIED DISCOVERY LEARNING

In situations where the teacher would like to provide a more explanatory type of environment, to provide students initially acquaintance with phenomena, or develop investigate and/or problem-solving skills of modified discovery has been particularly successful. Generally, this problem to be solved or question to be answered can allow students to discover the concept identified by the teacher with less or no teacher guidance. In this sense, the teacher is the source of the question or problem. In modified discovery lessons, the teacher does not provide a series of steps in which the students manipulate materials to take observations, gather and interpret data and draw inferences, how the students solve the problem or answer the question is up to them. They must decide how to manipulate the materials and what data to gather. The solution to the problem or question is provided by the students. The teacher acts as a facilitator or guide during this process.

FREE DISCOVERY LEARNING

Rarely situations occur where students may have a question that they have to find the answer to. This question can be resolved by the students manipulating materials. The students decide how to design the investigation, what data to gather, and how to interpret data. The student is both the source of the problem and the solution to the problem. Rarely do opportunities for free discovery arise in a formal way. More often than not, in the context of a modified discovery activity, questions like: “What would happen if I did this instead of that..?” , “What if we used….instead of…?” arise from students. If the freedom to pursue that question and the materials are available, students are able to answer their questions by trying this and that. This would be free discovery episode.

EFFECTIVE SCIENCE TEACHING COMPETENCIES

The following list of effective science teaching competency categories and student behaviors were derived from synthesizing effective science classroom research studies available in the literature.

TEACHER COMPETENCY CATEGORIES

I. Lesson Planning

II. Lesson Introduction

III. Developing Conceptual Understanding

IV. Developing Critical Thinking and Problem Solving Skills

V. Presenting Developing Goals of Science Education

VI. Developing Positive Attitude Towards Science

VII. Management

STUDENT BEHAVIOR CATEGORIES

I. Involvement

II. Understanding and Interest

A description, definition, or example of each behavior follows.
I. LESSON PLANNING

Effective science teachers demonstrate planning procedures in an effort to prepare students for instruction and to maximize learning outcomes through the following strategies.

A. Selecting materials and learning experiences to stimulate student curiosity and support student investigation or activities

When thinking about the lesson as a whole, did the teacher make an effort to stimulate student curiosity through the use of discrepant events, pictorial riddles, novel activities, or questioning strategies that led to student activities or investigations in which the student was actively involved? Does the current lesson set the stage for further activities in succeeding lessons? The lesson should provide evidence that is in the context of a larger unit of instruction.

B. Preparing for a broad range of alternative ideas and situations which students may raise questions related to central topic

When the situation presents itself, did the teacher anticipate possible student questions related to the central topic or objective and have alternative activities prepared to disseminate? The teacher’s response could be in the form of a redirection of the student’s question to a possible activity or resources that the student could possibly perform or look up on an individual or small group basis.

C. Designing lesson in which students gather information, drawn inferences, and make conclusions based on the information and inferences (students do not know the answers ahead of time; they must figure out the meaning for themselves)

This category is the heart and soul of the discovery, hands-on learning. Lessons of the guided discovery format basically follow a general pattern in which a problem is introduced via a discussion strategy, a pictorial riddle, or by other means in which a question is used for the students to find out the answer. Ways and means may be suggested to answer the question. The teacher may suggest or provide an activity for the students to follow. In the lesson, students gather data, make observations, and draw inferences. At the conclusion of the activity, students either individually or collectively are asked to figure out what their data means or says. This may be in the form of a question such as: “What can we say about …?” or the initial problem question may be restated for the student.

For younger students, the lessons may not be so formal. After the initial problem statement, students may be given objects and materials for them to investigate in relation to the initial question, the lesson may take on the characteristics of students just “messing about” to find out something about the materials and how they behave in a variety of circumstances. Questions may be asked by the teacher in an attempt to stimulate further inquiry on the part of the
students. Lessons of this sort have the characters of students having an initial experience with a new phenomenon and just finding out something about the phenomena to provide a baseline of experiences about the phenomena in question. At the conclusion of the “messing about” phase, the teacher may gather the students together to find out from the students what they found out from their investigations. Information and data are shared and the teacher may attempt to help the students summarize what they found out or figure out what it means as was done in the more formal guided discovery lesson. Throughout this activity, the teacher demonstrates evidence of planning by asking questions at appropriate points to stimulate inquiry and provides additional materials in an effort to restructure the direction of the student inquiry.

The following items are also required part of the lesson plan critical assignment.

(i) Science Concept(s), (B) Behavioral Objective(s), (C) Clear Connections to previous lesson, (D) Clear connection to following lesson, (E) Incorporating a theoretically based Learning Cycle, (F) Identifying and addressing Misconceptions, (G) Examples of Common Misconceptions. These items are explained with specific examples.

a) Scientific Concept(s) of the Lesson (sample): Density tells how closely the matter in a substance is packed together in a unit volume. Density of an object is the ratio of its mass to volume. The unit of Density is gm/cc.

b) Behavioral Objective(s) of the Lesson (sample): Students should determine the mass and volume and calculate the density of various objects (liquids and solids) provided to them, and develop the concept of density as a characteristic property of matter.

c) Connections to a Previous Lesson (sample): In the lesson previous to this lesson on density, students will develop an understanding of mass and volume. Mass is the amount of matter in a substance and it is measured in grams. Unlike Weight, Mass of an object does not depend on gravity and it does not change from elevation to elevation. Volume is the amount of space occupied by matter and it is measures in cubic centimeters (cc, cm³).

d) Connection to a Following Lesson (sample): Based on density differences certain materials (gases, liquids, solids) with lower densities float on top of liquids with higher densities. For example, cooking oil is less dense than water and when mixed together with water it floats on top of water. (TEACHER NOTE: This type of floating is different from buoyancy where a ship made of cast iron floats in water, considering the fact that the density of cast iron is higher than that of water and salt water.)
e) Incorporating a Theoretically Based Learning Cycle

Background

- The interaction of knowledge and skills with experience is key to learning” (John Dewey)
- Quality of learning depends on how one interacts with the environment from where the information is derived…
- Personal Involvement
- Learner Initiation
- Evaluation by Learner

Learning Cycle in Education:

System of how people learn from experience
Contains a number of stages
Based on development and cognitive learning theories

Examples of Learning Cycles

Four Step Model (David Kolb)

1. Concrete Experience
   2. Reflective Observation
   3. Abstract Conceptualization
   4. Active Experimentation (testing in New Situations)

5-E Model (Biological Science Curriculum Study)

1. Engage
   2. Explore
   3. Explain
   4. Extend
   5. Evaluate (throughout the cycle)

CPU Model

1. Elicitation
   2. Development
   3. Application
Legacy Cycle (Adapted Problem Based Learning) Model

1. Challenge
   2. Thoughts
      3. Perspectives & Research
      4. Assessment
      5. Wrap Up

Outdoor Biology Instructional System (OBIS) Model

1. Exploration
   2. Concept Introduction
      3. Concept Application

f) Misconceptions and Ways to Identify Misconceptions

What is Misconception?
A misconception is a:
   Mistaken Idea
   Mistaken Thought
   Mistaken Notion, or
   Misunderstanding
resulting from
   Erroneous Thinking or
   Wrong Facts

How to Identify Misconceptions in Classrooms?
   1. Look for error patterns in student assignments
   2. Pay attention to student communications in class
   3. Be aware of your own thinking
   4. Make sure your understanding of the concept/topic/principle under review is
      free from errors
   5. Check with an authoritative source such as an encyclopedia, textbook when in
      doubt

REFERENCE: Novak, J. D. (Ed.) (1994). Proceedings of the fourth international seminar on
misconceptions and educational strategies in science and mathematics education. Ithaca, NY:
Department of Education, Cornell University.
EXAMPLES of Common Misconceptions (K-9)

1) Mass and volume both vaguely describe the “amount of matter.”

2) Air neither has mass nor can it occupy space.

3) Air and oxygen is the same thing.

4) Gold atoms are hard.

5) Water molecules are tiny droplets.

6) When you change the shape of something you change its mass.

7) Mass is the most important factor determining whether an object will sink or float.

8) Plants need to be fed.

9) Gravity is the same as air pressure.

10) Gravity stops at the top of the atmosphere.

11) Chairs or tables cannot exert force since they have no motion.
12) All things fall down, but heavy things fall fastest

13) Current leaves a battery from one terminal but since some is "used up", less returns to the other terminal.

14) The size of a magnet determines its strength.

15) All metals are attracted to magnets.

16) While magnetism may be able to pass through paper, it cannot pass through wood, a notebook, a table, plastic or glass.

17) Soft things melt more easily than hard things.

18) Heat makes things rise.

19) Cold is the opposite of heat

20) There is no difference between heat and temperature.

21) Metals get hotter than other substances because they attract heat better.
22) Sound does not travel through solids and liquids.

23) A color filter adds color to a white beam.

24) Light helps us see by illuminating objects and making them visible.

25) Energy is not stored in food.

26) Force and energy is the same thing.

27) Seasons are caused by a change in distance between the earth and the sun.

(NOTE: This list is not exhaustive. Adapted version of ALM/7/27/02 All A, B, C, E Benchmarks)
II. LESSON INTRODUCTION

Effective science teachers demonstrate pre-instructional strategies and focusing strategies to introduce the lesson to students in an engaging manner. Effective lesson introduction strategies in elementary science classrooms are Communicating the Objectives, Set Induction, and Advance Organizers.

A. Set induction techniques by directing or focusing attention on what is to be learned, by motivating students to attend to the lesson, or by developing interest in the topic

Set induction techniques prepare students for learning by focusing attention on what is to be presented or learned by frequently motivating students to attend to the lesson and by encouraging students to become involved in ongoing discussion and activities.

Set induction strategies may take the form of questions that spark the interest of the students and are answered later in the session; e.g., a unit on mammals could be introduced by showing pictures of a whale, a shrew, and “Alf”. The following questions may be asked: “What do these three animals have in common? Do you think they are the same kind of animal? We will begin studying a series of lessons today about a certain group of animals and I want you to see if you can tell me at the end of the lesson why the whale, the shrew, and “Alf” are all the same kind of animal”.

B. Communicating the objective of instruction to the student

Communicating the behavioral objectives to the students prior to the beginning of instruction may take the form of describing to the students the specific behaviors expected from them as a result of instruction. For example, the teacher might say “When we finish this unit in mammals you will be able to look at pictures of mammals and be able to tell me four things that make mammals different from other animals.”

C. Advance organizer

Advance organizers are employed by teachers to relate what is to be learned to pre-existing knowledge. For example, when beginning a unit on mammals the teacher might preface the lesson by saying, “We studied a group of animals called fish last week. We learned about some things that make fish different from other animals. We learned about the surface of their bodies. Who remembers what covers a fish’s body? We learned about how they reproduce. We learned about their body temperature, and we learned about the environment in which they live and who they are able to move in it. Today we will begin studying another group of animals and we will discover the same kinds of things about them”. Advance organizers relate the unfamiliar to the familiar. Not all concepts lend themselves to the use of advance organizers.
When effectively utilized by teachers advance organizers are a way of organizing new information to ways that are familiar and in some instances, a mental road map that can be explored successfully. Effective use of advance organizers is also achieved by contrast reference of the new information to the familiar information throughout the lesson or lessons.
Effective science teachers to use a variety of strategies for developing conceptual understanding of science topic in students and they include the following.

A. The use of scientifically correct explanations or representations

Behaviors relative to this competency must be evaluated in terms of the teacher’s ability to explain phenomena in a scientifically correct manner and use appropriate terminology; the observer must be knowledgeable in science for this to be accurately assessed. The observer must be knowledgeable in science for this to be accurately assessed. Therefore, it may be easier to recognize negative than positive examples of such teacher behavior. For example, if a teacher uses phrases such as “this ‘thingamabob’ causes the wheels to turn”, or represents a whale as a fish not as a mammal, such behavior is clearly inappropriate. However, less blatant errors in scientific phenomena should be discussed in terms which are appropriate for the student’s developmental stage. The use of representations that clearly involved the use of abstractions is beyond the scope of explanation and conceptual understanding. For example, atoms, ions, DNA, mathematical formula are clearly beyond the understanding of most elementary students. They can be memorized and utilized in a knowledge level, but the student possessed only the veneer of science, not the full conceptual understanding.

The use of terminology or representation that are couched in the language of the student is appropriate if at some point in the lesson, appropriate terminology can be “invented” for the student. It is helpful to remember that science might be thought of as a language students are learning. The appropriate strategy is to invent language based on experience rather than invent the language isolated from the physical world.

B. The use of appropriate examples (or non-examples) in lessons

The teacher supplies or elicits from students adequate and appropriate examples or non-examples to help students comprehend the content. Effort is made by the teacher to utilize the content of science is the primary source of examples. If needed, other examples are utilized with which the student may be familiar, either from the classroom or from the immediate environment of the home and surrounding community. The teacher demonstrates an awareness of the student’s range of experiences appropriate to cultural background of the student and their developmental level.

C. The use of (concrete manipulative >> demonstrations >> pictorial stimuli >> text material) in sufficient variety that enhances understanding

Instructional materials may be placed on a continuum from concrete to symbolic. Manipulative are more concrete than pictorial stimuli, which in turn, are more concrete than printed materials. Similarly, a student’s laboratory activity is more concrete than a teacher’s
demonstration, and the teacher’s demonstration is more concrete than a lecture by a teacher. Greater realism or concreteness in supporting instructional material is associated with greater cognitive achievement and understanding.

Activities involving readily available, everyday objects may serve to “demystify” science. For example, a battery, a bulb, and a wire to demonstrate a simple electrical current; a rubber band, tin can, and a pencil to construct a “tin-can car” demonstrating the properties of motion; construction of a terrarium during a unit on ecology. Providing students with the opportunity to participate in meaningful science exercises with everyday objects that are consciously integrated into the curriculum can greatly enhance positive attitudes toward science.

Teacher demonstrations offer another opportunity for students to witness scientific phenomena when, perhaps, it may be unsafe for students to carry out independent investigations. For example, activities involving caustic materials, electricity, or when there are insufficient materials for students to do independent or group experiments demonstrations can be effectively used as “attention getters” or advance organizers. For example, a teacher may pour sulfuric acid over table sugar producing a smoking, black substance which rises in its container to demonstrate that a calorie is a unit of heat which may be used during a unit on diet and nutrition. A less effective method of developing conceptual understanding is utilization of pictorial stimuli, such as pictures or filmstrips.

It should not be construed that a teacher should rely entirely on lab activities to develop in students a conceptual understanding of scientific principles and ways of thinking. Teacher should make effort to provide students with a variety of mechanisms to accomplish this goal: discussions, laboratory investigations, demonstrations, films, text materials and other relevant approaches; the balance of which must be at the discretion of the individual teacher. When the students are enthusiastic, asking questions and involves, the teacher has found the proper balance for his/her students.

D. The use of questions to clarify understanding

Included in this category are teacher questions that guide students through a process. From the series of questions asked and the position of the questions in the lesson, that teacher is making a deliberate attempt to help students interpret what they have learned, apply the knowledge or concepts in other contexts.

Also included in this category are questions that refer to previous learning or to advance organizers presented previously.

E. The use of questions or strategies to evoke explanations on the part of the student

Similar to but slightly different from understanding is the role of explanation. Explanation involves the utilization of scientific facts and concepts to describe a particular phenomenon.
For example: A student observes a milk carton filled with water. On one side of the milk carton are a series of holes in the carton with tape across the holes. If tape is removed from the bottom hole, the water shoots out of the hole in near horizontal fashion, successively testing each of the holes from top to bottom with a full carton of water each time reveals that as one moves from the bottom to the top, the force with which the water comes out becomes less. When asked “Why”, it is up to the student to choose the proper principles to account for phenomena. If the student can apply the principle that water pressure varies with depth of the water, they will be able to state that the water pressure is less at the top of the container and becomes greater as one goes for top to bottom. Increased water pressure will cause a more forceful ejection of water. By explaining phenomena, a more powerful and observable understanding of scientific concepts is illustrated.

Teachers may set up situations in which students are forced to explain phenomena through the use of teacher demonstrations, pictorial riddles, discussions, or as incidental part of a science lesson, teachers may ask students to explain how something works or how this happens. When these events occur, the students are in the explanatory mode.
IV. DEVELOPING CRITICAL THINKING AND PROBLEM SOLVING SKILLS

Effective science teachers promote higher-level cognitive and problem solving skills by the use of appropriate questioning strategies with special attention to developing in children the ability to explain various phenomena. Whereas in the previous category where the purpose was to evoke explanation on the part of the student to demonstrate conceptual understanding, teachers may set up situations in which the primary goal is to utilize explanations as a means to promote the development of higher-level thinking and problem solving skills, one such questioning strategy is the use of Suchman Yes/No technique. A phenomenon is presented to the students. The phenomena may be a counterintuitive event presented as a demonstration or a pictorial riddle. Students ask the teacher questions in which the teacher response with yes or no. Students continue to ask the teacher questions, or perform their own mini-investigation to gather data until they are ready to offer an explanation for the phenomena illustrated.

In other instances, the teacher may set forth a phenomenon for the students to explain. Though the use of questions like: What do we know about this event? What do we need to find out?, How can we use this idea to help us? the teacher can lead the class to figure out an explanation for phenomena. The purpose of the lesson would be to get students to think about phenomena in ways that may seem strange to the student.

A. The selection and use of questions, problems, and activities designed to develop higher-order thinking and problem solving skills and curiosity

Through the selection of activities offered in lessons for the students, it should be a apparent that the teacher desires more than knowledge acquisition, student are given pictorial riddles, counterintuitive events, and hands-on activities in which they must answer a question through the manipulation of phenomena. The teacher’s questions are of the type in which students must hypothesize and figure out how to find the answers to questions. The classroom atmosphere is one of discovery/inquiry.

B. Redirecting student questions in such a way that students are encouraged to draw their own conclusions or figure out the meaning for themselves

When students have questions for the teacher either individually or collectively, the teacher has a choice of either giving the answer or redirecting the student’s questions in such a way as to cause the student to figure out the answer. The teacher questions may take the form of: What do you think? What would happen if you did….instead of…? What does this mean? While this technique is often over used, it can be effectively used to encourage students to answer their own questions.
C. **The use of appropriate wait-time in asking questions and in responding to student responses**

Wait-time occurs when a teacher pauses from three to five seconds after asking a question and again after the student response is given. When teachers employ wait-time, researchers have found the length of student response increases, the failure to respond decreases, the incidence of speculative thinking increases, student-to-student interactions increase; more questions are asked by the students and the variety of types of responses increases. Teachers utilizing wait-time ask more questions requiring high-order thinking skills of a more speculative nature. When teachers use a longer wait-time, the classroom atmosphere seems to be one inquiry instead of inquisition.

D. **The provision of opportunities for students to engage in non-routine problem solving activities**

This category of behavior involves opportunities providing for students to think about science in ways that seem to be a departure from the ordinary. Students may engage in synectics type activities in which they construct metaphors and analogies as part of a whole class activity. Then the students may be asked to engage in creative writing, poetry, art, body movement, or music to express their analogy or metaphor.

The teacher may prepare the children to be very quiet and read a fantasy trip in which students mentally explore some aspect of science (being energy inside a complete electrical circuit, being in a cocoon and turning into a butterfly, being a fish and swimming in a lake, etc). A discussion may follow in which students are asked to express their feelings about being energy or a butterfly or fish. They may be asked to express orally or in writing an essay or poetry what they saw on their trip.

Students may engage in non-routine problem solving when they interact with computer stimulations which depict realistic situations, other non-routine activities may include the use of student projects, particularly in preparation for science fairs. Students may participate in field trips, either in their schoolyard, museum, or other site in which they have a question or problem they must solve. They may gather data, specimens, or observations to draw conclusion in regard to the problem to solve.

E. **The use of evaluation techniques designed for students to apply what they have learned in different contexts, draw conclusions from data, and to explain various phenomena**

The teacher evaluates students’ understanding and problem solving skills through the use of evaluation devices not perceived as a simple restatement or identification of facts, definitions, principles or rules. On formal evaluation devices such as test, students are asked to explain phenomena, interpret data that may be represented as tables or graphs, draw conclusion from
problem statements with supporting data, utilize ideas learned in one context in a different context. They may be given questions in which they reflect application and analytical skills.

On an informal basis, in the course of the lesson, the teacher may ask the students to explain or apply concepts learned in the lesson a different context. While this may be perceived as an extension of the lesson, the inability of the students to apply the concept can be seen as a lack of full understanding of the concept. A discussion at the conclusion of the lesson may be perceived as an evaluation tool if the teacher asks questions that require students to explain and justify their findings or conclusions.
V. PRESENTING/DEVELOPING GOALS OF SCIENCE EDUCATION

Effective science teachers make every effort to develop content-based lessons for various topics and to promote goals of science instruction by implementing following strategies.

A. Use of activities and lesson formats which are appropriate to the learning level of the students

Consideration of the learning level and attention span of the students is reflected by the choice of activities and lesson formats presented to students. In the primary levels, lessons are much shorter than they would be for middle school students. For primary activities it may be apparent that students are becoming acquainted with various phenomena. At the middle school level, students will be expected to carry out more extensive lessons, requiring more steps to the process in which they find out about phenomena in greater detail.

B. Selection of content appropriate to the learning level of the students

The teacher takes into account the learning level of the students when selecting content. Generally speaking, a continuum of simple to complex, or concrete to abstract may be utilized to justify the content appropriate for a learning level. Often in the context of a single lesson, this may be difficult to judge without representation that involve the use of abstractions or mathematical formula are beyond the scope of elementary students for conceptual understanding.

C. Appropriate sequencing of content and pedagogy—both within the given lesson and in the larger context of the science unit or curriculum

This category includes the sequencing of content and pedagogy. A teacher uses appropriate content sequencing when there seems to be a logical progression of ideas developed within a single lesson, and when various lesson are viewed in the whole. For example, when looking at lessons involving the properties of magnets, a lesson about the interaction of poles of different magnets, should follow lessons about the substance attracted to magnets, where magnetic attraction is the strongest, and the magnetic field generated by the magnet.

A teacher uses appropriate pedagogical sequencing when new content is introduced at the concrete level through a variety of experiences, particularly when students have opportunities to handle and manipulate the materials. From those initial experiences, concepts and terminology may be invented. Additional information may be presented to students in an expository manner or the students may be referred to reading from the textbook. The final phase of the sequence is the provision of opportunities for students to take this knowledge and apply in a variety of contexts different from the one in which they learned the knowledge initially. Other instructional patterns may be utilized but it should be apparent to the observer lesson sequencing goes beyond the mere acquisition of knowledge alone.
D. **Use of lessons and activities that promote career awareness, science, society, and technology issues, and the development of personal interests**

From what appears to be a departure from the focus on content, teachers provide activities and lessons in which the goals of science education are sought. In some lessons, students may have the opportunity to either study the lives of various figures of the history of science, or may be exposed to various career opportunities for those individuals with science background. In other lessons, the role of science in relation to societal problems may be examined. Various issues facing public may be examined such as acid rain, nuclear energy, landfills, etc. Lessons may be designed to encourage the building of hobbies such as star gazing, specimen collecting, rock or fossil collecting. Lessons maybe provided that cause students to look for science in the world around them and just not in the classroom.

E. **Monitoring of student understanding during the course of a science lesson**

Evidence of this behavior includes the teacher’s use of questions to seek student feedback as the lesson is being presented as well as provisions for opportunities within the lesson for students to demonstrate understanding. The teacher may circulate among the students as they work individually or in groups, finding out where students are in the course of the lesson, finding out if they are having difficulty, and correcting misunderstanding in or redirecting when appropriate.

F. **Use of a variety of procedures and materials**

Variety applies to the materials the teacher uses in the classroom and to the methods the teacher uses in the presentation of content and the development of conceptual understanding, thinking and problem solving skills, and other goals of instruction. The observer should evaluate where there the mix of activities services to hold the attention and interest of the students but does not overwhelm them or confuse them.
VI. DEVELOPING POSITIVE ATTITUDES TOWARD SCIENCE

Effective science teachers know what teaching strategies promote positive attitude towards science through their knowledge base and experience, and consciously promote strategies like to ones discussed below.

A. Providing for a variety of hands-on activities that are interesting and challenging to students

To be considered in this category the techniques used should create interest in the lesson. Techniques that are counterintuitive or novel, that challenge or pique the curiosity of students are fruitful for providing for the development of positive attitudes toward science.

B. Relating science instruction to contemporary societal issues

An effective technique to develop positive attitudes toward science is relating science to contemporary societal issues confronting citizens everyday. The examination of topics like acid rain, AIDS, air quality, flood control, food preservatives, fossil fuels, nuclear energy, the greenhouse effect, hazardous waste disposal, the ozone layer, pesticides, and others force the student to gather information about the topic in order to understand the issues around which the topic centers. While teachers should not attempt to force their opinion on the students, students should be encouraged to formulate their own opinion about these issues.

C. Relating science instruction to their personal lives

An effective technique to develop positive attitude toward science is to relate the topics or point in the lesson to the personal lives of the students. This may include examples found at home, in the neighborhood, the city, or locations nearby that are familiar to the students.
VII. CLASSROOM MANAGEMENT

General Classroom Management: Effective science teachers demonstrate appropriate management skills in the area of student work and behavior to facilitate an orderly progression of learning activities.

NOTE: Effective science teachers design a set of procedures for certain instructional routine and install these procedures early in the school year.

During the first days of school, teachers should discuss with students official rules of conduct and classroom operations. A complete description of appropriate rules and procedures are too numerous to list. They vary from teacher to teacher and from class to class; however, they are likely to include the following: Rules concerning tardiness, talking in class, gum-chewing, fighting, bringing materials to class; procedures for handing in complete work, sharpening pencils, going to the bathroom and getting drinks of water, getting a in line, asking for assistance from the teacher; rules for asking and answering questions during a lesson; rules for movement around the classroom, distribution and collection of materials; and teacher expectations of classroom tidiness.

A. Reviewing and reminding students of existing rules and procedures and providing quick response to inappropriate behaviors

Rules and procedures should be explicit, concrete, and uniformly enforced. They may be practiced, especially in the early grades at the start of school. Inappropriate behavior should be stopped quickly with a restatement of rules governing the infraction. It should be noted that rules which are not enforced are quickly forgotten by students. Action taken by teachers during the classroom activities demonstrates to students the applications of installed rules and procedures. This is demonstrable in the following examples: “Remember, Tom we raise our hands when we want to answer a question. We never call out.”, “Please push your chairs under your desks when you get on line.”, “Amy, I expect you to remember to bring your homework to school tomorrow”

B. Monitoring student work

Effective monitoring of students by teachers has been described in the literature as “withitness” (Kounin, 1970). The concept of “withitness” is best described as a situational awareness of the classroom on the part of teacher and has been shown to be positively correlated with work involvement and subsequent student achievement. Monitoring consists of three basic types of behaviors: Group monitoring occurs when the teacher scans the classroom and makes an overall assessment of classroom activities and how well the classroom is functioning as a unit. Teachers must also monitor student conduct and behavior and assess the consistency of the current situation with established rules and procedures. A teacher demonstrates “withitness”
will quickly correct a behavior or procedure infraction before it escalates into a more widespread problem. For example, a teacher might correct and refocus two student engaged in arm wrestling before neighboring students become spectators. Third, monitoring involves an assessment of the pacing, rhythm, and duration of the classroom events.

Smooth progress through classroom activities and appropriate pacing of events, which have been shown to enhance student achievement, contrasts with less effectively monitored classroom where they may be hesitations, and inappropriate, distracting pauses in activities. Communication of the teacher’s “withitness” to the students is also critical in the well-managed classroom. If students are cognizant of the teacher’s awareness, they are likely to deviate from the teacher-sanctioned activities.

C. **Consistency in applying standards**

Student achievement is maximized in the classroom where management and academic work are not considered as separate issues, since instruction cannot progress in the absence of a well-managed classroom. Superficially, it may seem appropriate to deal with all students similarly in regard to classroom management, individual students, however, may necessitate the use of unique strategies to achieve similar results. For example, teachers often relax management standards for low-achieving students in an effort to reduce the tensions that exist between academics and the management structure. The low-ability student is often better served by reinforcing management organizations which may serve to provide an atmosphere where the teacher is then better able to address the learning problems.

Monitoring of higher-ability students may take a less-controlled form where such a student is granted the freedom to make mistakes in a non-threatening atmosphere. With such students, management structures are still in place, but teacher control over student work may be less stringent and less diligent.

D. **Preparing for transitions in advance with a concluding or “wrap up” phase of the lesson**

Transitions refer to a change of contexts between segments of a lesson and between lessons as a whole. Transitions signal the end of one activity and the beginning of another. Smooth, efficient transitions maximize learning time by moving students quickly through the activity change.

A teacher’s use of a “wrap-up” or lesson summary can aid in signaling the students that a transition is about to occur. Cues signaling a transition may include such phrases as: “*Let’s sum up what we learned today*”, “*Today we discussed what an ecosystem is. Tomorrow we will collect plants to place in our own ecosystems which you will construct in the jar that you brought to class*”, “*You have five minutes to finish what you’re working on*”. 
E. **Organizes instruction using appropriate time allocated in various phases of the lesson**

Pacing and quantity of instruction are consistently linked by the literature to academic achievement. Efficient learning, on the part of students, necessitates the provision of materials at a level and of difficulty appropriate for the student. The teacher must progress through the curriculum at fairly rapid pace without frustration and confusion on the part of the students. Lessons which move with small steps at a fairly rapid pace have been shown to maximize student achievement, this approach requires a teacher who is capable of diagnosing the needs of students on a moment to moment basis and who can modify instruction and techniques based on the current needs of the students.

Activity Management: The teacher will demonstrate appropriate skills in the area of activity management by:

F. **Informing students of needed materials**

When activities require the manipulation of materials, students are informed of the needed materials by listing on the chalkboard, via an overhead transparency, or on the activity sheet which they will complete. The students are provided information where the needed materials can be obtained in the classroom and provisions for their cleaning and return are made. Not all materials may be provided at the start of the lesson. Some materials may be withheld to introduce at appropriate points in the lesson to restructure the activity or provide new direction of investigation.

G. **Preparing materials in advance**

The teacher has the materials for the students prepared in advance of the activity. At no time, do the students have to sit and wait for the teacher to “get something together, or find it somewhere” for the activity to begin or proceed.

H. **Clearly defining task**

The activity in which the students will engage is clearly presented to the students. Students know what is expected of them, how they are to complete the task, and what they will do when the activity is completed. The directions may be given orally, or in writing. The observer will note that students are not confused about what to do with repeated trips by students to the teacher to find out what to do first, next, and so on. While the classroom appears to be one of activity on the part of the students, there is an order as the students display a sense of purpose about what they are doing.
STUDENT BEHAVIORS

I. INVOLVEMENT

A. Student involvement in the lesson

Ratings for this category should be based on the extent to which students volunteer comments or answers and ask questions (pertaining to the learning task at hand) during class discussions, contribute to group work, or are engaged in productive work during the lesson. If students regularly contribute to class and small-group discussion and are spending little time waiting to begin their assignment or for the teacher to begin a new activity or examine their work, a high rating should be assigned. Consideration should be given to the counts taken of students waiting during the lesson. The average percent of students waiting determined from the counts of students waiting should be calculated. An average of 10% or more students waiting calls for negative consideration in student involvement. The observer should enter the average percent waiting on the Post-Observation Rating Instrument in the Comments section of this item.

B. Students on-task

Students are behaving on-task if they are engaged in an activity to which the teacher has directed them. Instances of off-task behavior include talking, sleeping, day breaking, passing notes to classmates, and working on a task other than the assigned one. The observer should refer to the discussion of counts of students off-task, probably on-task, and definitely on-task presented in the Observation Forms section of the “Observation Training Guide”.

Frequency counts taken at ten-minute intervals are required for this item. Mean on-task behavior (including definitely on-task and probably on-task) is to be calculated and recorded as a percentage on the Observation Form. No rating should be assigned to this item.
II. UNDERSTANDING AND INTEREST

A. Students’ understanding of purpose of instruction

To be considered when assigning a rating for this category are student confusion regarding what students are expected to do or learn in the lesson and student questions regarding procedures for completing activities or assignments. A high rating suggests students seem to relate to the lesson. A low rating suggests confusion on the part of the students.

B. Students’ interest in the lesson

Interest in the lesson is indicated by student cooperation and enthusiasm in participating in the activities of the lesson or performing the required tasks. A high rating indicates students were trying to learn the lesson through active involvement. A low rating indicated minimal compliance by students.


OBSERVATION RATING INSTRUMENT FOR SCIENCE INSTRUCTION

Teacher__________

TEACHER COMPETENCY CATEGORIES

I. LESSON PLANNING

__________ a. selecting materials /learning experiences which stimulate student curiosity and support student investigation
Comments:

__________b. preparing for alternative ideas and situations*
Comments:

__________c. designing lessons for inferential learning*
Comments:

II. LESSON INTRODUCTION

__________a. set induction techniques
Comments:

__________b. communication of objective
Comments:

__________c. advance organizers
Comments:

III. DEVELOPING CONCEPTUAL UNDERSTANDING

__________ a. scientifically correct explanations/ representations
Comments:

__________b. appropriate examples/ non-examples
Comments:

__________c. sufficient variety of (manipulative >> demonstrations >> pictorial stimuli >> text material) to enhance understanding
Comments:
d. questions to clarify understanding
Comments:

e. questions /strategies to evoke student explanations
Comments:

IV. DEVELOPING CRITICAL THINKING AND PROBLEM SOLVING SKILLS

a. questioning strategies designed to use student explanations to promote development of higher-level thinking and problem solving skills
Comments:

b. questions/ problems/activities to develop higher-order thinking and problem solving skills*
Comments:

c. redirecting student questions to draw their own conclusions
Comments:

d. appropriate wait-time
Comments:

e. non-routine problem solving activities
Comments:

f. evaluation techniques designed for students to apply what they have learned**
Comments:

V. PRESENTING/DEVELOPING GOALS OF SCIENCE EDUCATION

a. activities/lesson formats appropriate to level of the learner*
Comments:

b. content appropriate to level of learner
Comments:

c. appropriate sequencing of content and pedagogy**
Comments:
d. lessons/activities that promote science and career awareness, and stimulate student interest in science
Comments:

e. monitoring understanding
Comments:

f. use of a variety in procedures/ materials
Comments:

VI. DEVELOPING POSITIVE ATTITUDES TOWARD SCIENCE

a. providing for a variety of interesting and challenging hands-on activities
Comments:

b. relating of science instruction to current societal issues and students’ personal lives
Comments:

VII. MANAGEMENT

General:
a. instructional routines*
Comments:

b. reviewing and reminding students of existing rules/procedures and providing quick response to inappropriate behavior
Comments:

c. monitoring student work
Comments:

d. consistency in applying standards
Comments:

e. efficient transitions
Comments:

f. appropriate time allotment
Comments:

Activity:
g. informing students of needed materials
Comments:

h. advance preparation of materials
Comments:

i. clearly defining task
Comments:

STUDENT BEHAVIOR CATEGORIES

I. Involvement
a. student involvement in lesson
Comments:

b. students on-task
Comments:

II. Understanding/Interest
a. students’ understanding of purpose of instruction

b. students’ interest in the lesson

* May require interview of teacher
** May require examination of teaching materials

SCIENCE ACTIVITY CODE CATEGORIES

Activity Code No.       Explanation

1. Introducing Lesson
   The teacher is setting the stage for the lesson to follow. The teacher may have a
discussion to review what was done in previous lessons and how this leads into this
lesson, may communicate the objectives of the lesson, teach an advanced organizer
(bridging concept), present a demonstration, pictorial riddle.

2. Content Development: Teacher presentation of content
   The teacher is presenting academic content to the whole class. Including lecture,
demonstration, and explanation of academic content. It may also include some
questioning or comments from students, but the main function of this activity is
informing students, introducing new material, explaining new material, or reviewing
previously introduced material to reinforce the concepts.

3. Content Development: Recitation/Discussion
   Teacher is providing student practice of skills or review of material. This category
includes questioning of students by the teacher.

4. Content Development: Student Activities (Discovery or Inquiry)
   Students are actively trying to discover concept through various activities, principally
through the manipulation of materials. The content of what is to be learned is withheld
from the student. Through the activity, the student must figure out the content to be
learned themselves.

5. Content Development: Student Activities (non-inquiry)
   Students are performing an activity to verify what is already known. The concept may
have been given to them first and the activity serves to illustrate the content. Students
can also be performing activities in which concepts are extended into new contexts.

6. Content Development: Post-Activity Discussion
   The teacher is using a discussion after an activity to help student conceptualize
understanding by helping students figure out the meaning of something for themselves.
This teacher may also “invent” terminology for concepts developed by the students or
may rephrase concepts in scientific language.

7. Content Development: Individual Seatwork
   Students work individually at their seats on tasks specifically reacted to content
development. They may be analyzing and interpreting data from a student activity,
writing a report of an investigation, reading the textbook or other sources to find out
information for an activity. The work the students are doing must be judged by the observer as meaningful.

8. **Problem Solving Activities**
Through teacher led activities, the obvious goal is the development of thinking and problem-solving skills. This may occur when pictorial riddles, counterintuitive events, or written tasks are given to students. Students are attempting to solve problems or explain how something happened or how something works.

9. **Non-Routine Problem Solving Activities**
This category includes activities that seem to be a departure from the ordinary. Activities may include creative writing, computer stimulations, student projects, and field trips.

10. **Whole Class Activity**
The whole class is engaged in some activity led by teacher in which none of the above categories apply. Examples might include reading the text aloud, going over the answers to the worksheet, questions at the end of the chapter, correcting homework, and review for a test.

11. **Individual Seatwork**
The students are working individually at their seats on tasks that may be designed to force them to read the textbook they may be filling out a worksheet, answering the questions at the end of the chapter. In contrast to Category 6, the seatwork in this category is not of a meaningful type, it may be judged as busywork. The tasks are coded as either as 6 or 10 if it lasts 3 minutes or longer.

12. **Directing for Assignments**
Teacher is explaining to the class, the exact procedures for completing an assignment, seatwork activity, student laboratory investigation, or homework.

13. **Small group Instruction**
The teacher works with a group of students (3 or more) for more than 1 minute while the rest of the class is in seatwork. This category takes priority over all others. e.g. …don’t code seatwork for the others during this period.

14. **Tests**
Students work independently on a test, quiz, assessment, or other evaluation task.

15. **Procedural/Behavioral Presentations**
The teacher presents or reviews classroom procedures or rules. This code should be used any time the teacher institutes and explains classroom procedures or rules governing student behavior. It should also be used when the teacher gives the class
extensive feedback on their behavior, or discusses problems related to classroom procedures. (NOTE: This does not include procedures for doing assignments. These are coded in category 12.)

16. Transitions
The teachers and students are involved in activities entailed in changing from one activity to another. Examples include moving between small groups, getting supplies or materials for a different activity, passing papers, going from a student investigation to some other activity in which materials must be put away, or waiting for everyone to get ready, get quiet, or to find the place. Activity codes for “Transitions” should not be used when the transition lasts less than 1 minute.

17. Non-academic Activity
Teacher monitoring students in activities such as games, discussions, TV, or anything else not related to the content of the class.

18. Waiting for the Next Activity
Two-thirds or more of the class have no assigned task. Either they are finished and have no other assignment or they are just waiting or the next activity.

19. Discipline
Two-thirds or more of the class is involved in some group discipline for misbehavior. For example, a teacher may require the students to put their heads down on their desks for a period of time if they have been too disruptive.

20. Other
Anything that doesn’t fall into one of the above categories.

CLASSROOM OBSERVATION FORM FOR HANDS-ON DISCOVERY LEARNING IN SCIENCE

1. Introducing Lesson
2. Content Development: Teacher Presentation of Content
3. Content Development: Recitations/Discussion
4. Content Development: Student Activities (Discovery or Inquiry)
5. Content Development: Student Activities (Non-Inquiry Oriented)
6. Content Development: Post-Activity Discussion
7. Content Development: Individual Seatwork
8. Problem Solving Activities
9. Non-Routine Problem Solving Activities
10. Whole Class Activity
11. Individual Seatwork
12. Directions for Assignment
13. Small Group Instruction
14. Tests
15. Procedural/Behavioral Presentations
16. Transitions
17. Non-Academic Activity
18. Waiting for Next Activity
19. Discipline
20. Other

WHY DO TEACHERS ASK QUESTIONS?

1. Find out what pupils’ now or don’t know
   a. Evaluate pupil preparation
   b. Assist in planning- direction to proceed
2. Arouse interest
   a. Motivate the lesson
   b. Encourage discussion
   c. Set the stage for the lesson
   d. Arouse curiosity
3. Punishment
   a. Control classroom behavior
   b. Discourage inattentiveness
4. Control direction of activities
5. Develop new insights
   a. Check on or develop comprehension
   b. Stimulate the seeking of new knowledge
   c. Stimulate critical thinking processes
   d. Develop questioning attitudes
6. Stimulate creativity
7. Stimulate explanation
8. Diagnose student difficulties
9. Review and summarize what was taught
10. Evaluate achievement

“When a teacher asks a question they are giving the student s an opportunity to use their minds.”
WAIT-TIME

Wait-Time is the time between teacher’s question and students’ responses.

Research shows that in average classrooms:

1. Teachers ask too many questions—2 to 3 per minute
2. 20% of teacher talk is spent on evaluative responses
3. 90% of all questions require knowledge only

But, when teachers practiced Wait-Time 3-5 seconds, research showed the following.

1. Length of student response increases
2. Failure to respond decreases
3. Incidence of speculative thinking increases
4. Student-to-student interactions increase
5. More questions are asked by the students
6. Variety of types of student responses increases

Note: Teachers utilizing wait-time ask more questions requiring high-order thinking skills of a more speculative nature.
- Involves professional judgments (based on measurement data)
- Feelings and observations
- Other information from the learning environment
  (Measurement- information gathering through tests, checklists, and worksheets)

**Types of Assessments**
- Diagnostic- performed before teaching to find out what’s students know and don’t know
- Formative- performed during teaching to find out what students are learning, to provide feedback
- Summative- performed after teaching to find out how much students have learned, to assign grades
- Blooms Taxonomies and Assessment
  o Cognitive domain- Intellectual Skills, Knowledge
    ▪ Make sure the behavioral objective of the lesson/topic matches the test
    ▪ Written tests to assess recall knowledge
    ▪ Pictures to assess knowledge of classification
    ▪ Oral tests
    ▪ Matching tests
    ▪ Multiple choice test
    ▪ Crossword puzzle
  o Essay tests to assess higher level skills
    ▪ Interpretation
    ▪ Extrapolation
    ▪ Application
    ▪ Analysis
    ▪ Synthesis
    ▪ Evaluation (internal criteria or external criteria)
  o Affective Domain- attitudes, values, interests, appreciations
    ▪ Scientific attitudes
    ▪ Feelings (free choice or forced choice)
    ▪ Values
  o Psychomotor Domain- physical skills, manipulative
    ▪ Practical assessment (e.g. discrepant events)
    ▪ Portfolio assessment
Grading
- Norm-referenced
  o Individual performance determined by overall performance of the group
- Criterion-referenced
  o Preset criteria
  o Different kinds of measurements
  o Gives opportunities for each and every student to perform well on tasks
  o Uses higher order skills
IDEAS FOR ASSESSING SCIENCE LABORATORY ACTIVITIES

When it comes to assessing student performance in science laboratory activities there should be provisions for assessing teacher lecture as well as laboratory sections. Traditional items such as true/false, multiple choice, end-of-chapter worksheets and short answers, and comprehensive items such as essays, reports, and portfolios are commonly used to assess lecture sections [29,30,31]. However, to stimulate student interest in science and promote creativity a more comprehensive approach to assessment may be needed. The types of such assessments may include traditional verification activities and comprehensive laboratory projects using already published and/or custom developed rubrics, making every effort to assure that the assessment rubric matches the course objectives. This is critical to determine whether the intended learning outcomes are achieved. Alignment is required for each assessment type with a suitable assessment focus to build in various levels of cognitive behaviors (e.g. Bloom’s Taxonomy) in the assessment rubric. Table 1 presents a sample matrix containing assessment type and assessment focus based on Bloom’s Taxonomy of cognitive behaviors (Verma, Hill, Niinisto, Mojumdar, & Kumar, 2012).
<table>
<thead>
<tr>
<th>Assessment Type</th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis</th>
<th>Synthesis</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>True/False</td>
<td></td>
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<tr>
<td>Multiple Choice</td>
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<tr>
<td>End-of-Chapter Worksheet</td>
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<tr>
<td>Short Answer</td>
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<td>Essay</td>
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<tr>
<td>Report</td>
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<tr>
<td>Portfolio</td>
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<tr>
<td>Verification Activity</td>
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<tr>
<td>Laboratory Project</td>
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</tbody>
</table>

Table 1. Assessment Type and Focus matrix (Verma, Hill, Niinisto, Mojumdar, & Kumar, 2012). Used with permission.

The science laboratory project assessment should also take into consideration laboratory skills, data management and laboratory reports. A sample rubric for laboratory project assessment is presented in Table 2 (Verma, Hill, Niinisto, Mojumdar, & Kumar, 2012).
Table 2. Sample Rubric for Lab Project Assessment (Verma, Hill, Niinisto, Mojumdar, & Kumar, 2012). Used with permission.

A wide range of skills can be assessed in science laboratory projects in addition to the accuracy of results. The skills to assess include basic lab safety, material handling and manipulating to more complex process skills like generating and testing hypotheses, conducting background review, data organization and analysis, graphing and graph reading, and writing a scientific conclusion.

REFERENCES:
PROBLEM SOLVING

Problem solving has been the "subject of extensive thought" for many years tracing back to John Dewey [2, 3], who proposed a theme-based approach to arranging related topics together under a theme to enrich the context of learning [4]. The intent was to help students see the relationships, similarities and differences between concepts. Much like Dewey, Gragg [5] advocated using case studies to enhance the context of learning. Flynn and Klein [6] concluded that the case-based method makes "learning relevant and meaningful to the student through active participation and analyzing, discussing and solving real problems" by redirecting "the focus of learning away from memorization of facts and to the application of concepts, theories, and techniques to practical, real-world problems" (p. 71). Such PBL has also been widely applied in law, management, and medicine.


Problem Solving

- is a goal directed sequence of cognitive actions starting from instructions to desired answer (Chi et al., 1982)
- involves finding a solution path from the initial problem state (information in the problem plus knowledge) to the final goal state (answer) (Newell & Simon, 1972)

Initial State + Solution Path + Goal State = Problem Space

Note: Strategies and processes employed in the problem space are vital and differ between expert and novice problem solvers.

Experts recognize notice patterns and features that are meaningful patterns of information compared to novices.

1. Experts have a strong content knowledge base reflecting a deeper understanding of subject matter compared to novices.
2. “Experts’ knowledge is context specific “conditionalized on a set of circumstances” (p. 31) compared to novices
3. Experts can access needed knowledge with ease and flexibility compared to novices.
4. Experts’ ability to teach is not guaranteed by their deeper understanding of subject matter.
5. Experts show flexibility in approaching new learning situations.

EXPERT NOVICE DIFFERENCES IN PROBLEM SOLVING

<table>
<thead>
<tr>
<th>EXPERTS</th>
<th>NOVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognize problem and work forward</td>
<td>Means-ends analysis</td>
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<tr>
<td>Use known procedures from long term memory</td>
<td>Findings ways out of darkness type approach</td>
</tr>
<tr>
<td>Abstract representation and qualitative</td>
<td>Formula driven</td>
</tr>
<tr>
<td>stimulation of scientific principles</td>
<td></td>
</tr>
<tr>
<td>before quantitative math application</td>
<td></td>
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</tbody>
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EXPERT NOVICE DIFFERENCES IN PLANNING AND TEACHING

1) Expert teachers have a better command of science content than novice teachers.
2) Expert teachers show more efficiency and autonomy in planning and teaching compared to novice teachers.
3) Expert teachers have a strong memory reservoir built up on experience; therefore they do not write down in their lesson plans what they are going to say and how they are going to say it.
4) Expert teachers are more effective in processing information compared to novice teachers.
5) Expert teachers are able to quickly recognize meaningful patterns compared to novice teachers.
6) Novice teachers write much more detailed lesson plans compared to expert teachers describing “what they were going to say and the actions that they intended to carry out, even noting what they would write on the blackboard” (P. 27)

PROBLEM-BASED LEARNING (PBL)

“Problem-based learning as a curricular area emerged over several decades from the design of a student-centered, small-group curriculum for medical students. PBL is based on real-world situations (7). It is the "learning which results from the process of working towards the understanding of, or resolution of, a problem" (8, p. 1). PBL is aimed at engaging students in a problem-solving activity that they can relate to and see as meaningful while emphasizing the authentic feature of learning in context. Research on the outcomes of problem-based learning in the training of future physicians indicate that medical students in PBL programs achieve as well as students in traditional programs on traditional exams (9). Hur and Kim (10) also demonstrated positive outcomes of PBL in medical education. Some of the advantages of problem-based learning include active learning, critical thinking, flexible reflections, and fruitful group cooperation (11).”

“The essential components of problem-based learning are loosely structured learning cases (e.g., news clips, teacher/custom-made materials), student-centered learning, and small-group cooperative learning (12). In PBL the role of the classroom teacher is mostly as a facilitator of discussion among students, leading to self-directed learning leading that culminates in meaningful comprehension (13, 14, 15). "Students pursue their own problem solutions by clarifying a problem, posing necessary questions, researching these questions, and producing a product that displays their thinking. These activities are generally conducted in collaborative learning groups that often solve the same problem in different ways and arrive at different answers" (13, p. 50).

“According to Schmidt (16) the cognitive psychology bases of PBL are as follows:

- It enables the activation of prior knowledge that is important to the processing of new information;
- As students engage in discussing a case, they are able to make multiple cognitive associations between new and old concepts; and
- Learning takes place in a context similar to real-world situations that help the learner receive cues in accessing prior knowledge when dealing with similar problem situations.

Similarly, The emerging idea is that the critical role of a reality-based context is to provide a rich array of information that facilitates better comprehension and meaningful connections between new, incoming, and existing information.”

“Alphabet-Soup” Curricula
- Developed in late 50’s and early 60’s
- Implemented in 60’s and 70’s
- Still around
- Now have achieved the classic status viewed science as both process and product
  emphasis on discovery learning and hands-on approaches

Common features
- Developed with funding
- Developed by teams of individuals
- Emphasis on active participation of learner
- Consisted of kits of materials and teacher’s guides
- Teacher’s role is that of a guide, facilitator, not teller

Differences
- Degree to which they stress process or content

ESS (Elementary Science Study)
- Utilizes “Messing About” philosophy
- Non-sequential science units
- Emphasis is neither on process nor content; emphasis is on manipulation of
  materials/phenomenon to produce self-directed learning
- Design own curriculum …or…supplement existing curriculum

SCIS (Science Curriculum Improvement Study)
- Is a total program K- 6
- Stresses content
- Learning strategy of exploration, invention, discovery
- Great source of ideas for lessons on a variety of topics

SAPA (Science- A Process Approach)
- Is a total program K-6
- Stresses processes of science
- Emphasis on guided discovery
- Source of process lessons for primary levels

NOTE: The Following OBIS is developed later than the above, but equally effective.

OBIS (Outdoor Biology Instructional Strategies)
- Emphasis on outdoor activity based learning in ecological environments
- Includes non-routine problem solving
TEACHER RESOURCE GUIDELINES FOR ACTIVITIES WITH MULTIMEDIA

1. The context must be readily available on videotape, videodisc, CD, virtual reality the Internet or WWW.
2. The context must be suitable for student viewing at the elementary levels.
3. The context must contain information needed to gain student interest and attention.
4. The information in the context must be in a language of communication familiar to students.
5. The science and language arts illustrated in the context must fall within a topic of instruction in the school curricula.
6. The teacher should be able to explicitly identify the science concepts and language skills embedded in the context.
7. The topic represented in the macrocontexts must be appropriate to the grade level.

CREATIVITY

What is Creativity?
A. One View - production of a new idea or entity not known to man or production of something
   unique to the individual
B. the ability to view the familiar in an unique way, to make a transformation, to see a multiple of
   things in a single object, to synthesize in new an original ways
C. to see the commonplace as strange
D. Paul Torrence: Creative thinking is a process of sensing gaps or sensing the disturbing missing
   elements, forming ideas or hypotheses, and communicating the results.

Creative Abilities
   Fluency - proposes many similar ideas for a problem
   Flexibility - produces many different classes of ideas for a problem
   Originality - gives uniquely different responses
   Elaboration - states many details related to a creative response
   Sensitivity - generates many problems in response to a situation

Unknown Quotes
- The capacity for creativity always exists in children, even though it may sometimes be dormant or
  latent.
- In order for creativity to be nurtured, it must have an environment to grow and survive.

Characteristics of Creative Individuals
1. Curiosity
2. Resourcefulness
3. Desire to discover
4. Preference for difficult tasks
5. Enjoyment in solving problems
6. Flexible thinking
7. Drive and dedication to work
8. Ability to synthesize and see new applications
9. Pronounced spirit of inquiry
10. Breath of reading background
11. Persistent and sustained concentration
12. Habit of giving more answers to questions than do most students
Summary of Research in Creativity

An accumulation of psychological research in the field of creativity has attracted the attention to the problem of improving the possibilities for manifestation of creative ability in schools. Findings of this research are summarized as follows:

1. All people of all ages and races are creative to some extent.
2. Individuals differ considerably in degrees of their creative ability.
3. Freedom to be creative has an effect on mental health.
4. Students learn more effectively in a creative situation.
5. Schools have been successful in helping to develop creative abilities.
6. Outstanding creative individuals in society often are not high academic achievers.
7. Overuse of positive reinforcement in class discussions may inhibit creative responses by students.
8. IQ and creative ability generally do not correlate highly.
SYNECTICS

Techniques developed by William J. J. Gordon for stimulating creative talents by using several types of metaphors and analogies.

Underlying Beliefs:

Creative processes of thought can be described, developed, and are generalizable to most subject areas.

The emotional, affective, irrational components of the creative enterprise are initially more important than the intellectual, rational components.

Activities should include non-rational group interplay.

Activities center around students being invited to form varied types of metaphors so as to “open their minds” and broaden their creative insights.

Metaphors help break mental "structural fixedness"; or "psychological set"; or "tunnel vision" in looking at a problem, thereby contributing to the stimulation of diverse, creative ideas.

End result could be:

   Rational solutions to problems

   Connections can be made between:
       Something strange to the familiar
       Something familiar to the strange
SYNECTICS TECHNIQUES

Warm-up Metaphor

Topic: Clouds
- What is a cloud?
- Snow, pillow, foam, giant animals

Direct Analogy

- How is a cloud like snow?
  o Fluffy, airy, sticky
- How is a cloud like giant animals?
  o Moving, large, hairy

Personal Analogy

- How would it feel to be a cloud?
  o Cold, wet, free

Compressed Conflict

- How is a cloud like snow but not like a pillow?
SYNTUS IN SCIENCE

Syntu poems may be used when you want students to express or describe their thoughts and feelings about an observation or activity in the class. They are quite suitable for introducing new terminologies. Syntus is a Japanese poem form consisting of five lines as follows:

Line 1 - One word name of an object, event, or phenomenon
Line 2 - An observation of the object using one of the five senses
Line 3 - A feeling about the object in Line 1
Line 4 - Another observation of Line I using one of the senses not used in Line 2
Line 5- A one-word synonym for Line I

Air
Cool, refreshing
Blowing, breezing by
Coolness in my face
Wind.

Trees
Lovely, free
Blows, dances, rocks
Happily housing a bird
Plants.

Rain
Wet and refreshing drops of water
Gloomy
Downpour, shower, rainfall
Precipitation
(Leigh, Kumar and Torres. (2015). FAST Journal, Spring, p. 8)

Have the students share their syntus with the class.

In the space below, write a Syntu
TEACHING INTEGRATED SCIENCE AND MATHEMATICS

Considerations and Recommendations

“In defining how to integrate math and science, White and Berlin (1992), and Sunal and Furner (1995) made the following recommendations.”

“• Base integration on how students experience, organize, and think about science and math.
• Take advantage of patterns as children from the day they are born are looking at patterns and trying to make sense of the world.
• Collect and use data in problem-based integrated activities that invoke process skills.
• Integrate where there is an overlapping content in math and science.
• Be sensitive to what students believe and feel about math and science, their involvement and the confidence in their ability to do science and math.
• Use instructional strategies that would bridge the gap between students’ classroom experiences and real-life experiences outside the classroom.”

“The integration of math and science encompasses a number of considerations, for example, teaching math entirely as a part of science, math as a language and tool for teaching science, or teaching science entirely as a part of math. Also, teachers' confidence level in teaching math and science needs to be addressed. In some instances, a math teacher may not feel prepared to teach science or vice versa. Also science teachers may not feel confident teaching all science disciplines. Beane (1995) defines curriculum integration as a way of thinking about the purpose of schools, the sources of curriculum, and the basis of knowledge. Beane believes in order to define curriculum integration; there must be a reference to knowledge.”

“According to Jacobs (1989) and the Association for Supervision and Curriculum Development (1989), planning and teaching interdisciplinary lessons involve two or more teachers, common planning time, the same students, teachers skilled in professional collaboration, consensus building, and curriculum development. As Robinson (1994) pointed out, the following considerations are necessary for the preparation of interdisciplinary instruction.”

“• An understanding of the nature of subject field and the need for teachers, for example, single subject field/single teacher; single subject field/multiple teachers; multiple subject fields/single teacher; or multiple subject fields/multiple teachers.
• A deeper knowledge of methods of interdisciplinary subject matter correlation (unified subject field, theme, topic, problem-based, etc.)
• Strategies for motivating students to use process skills, such as reading, writing, reporting, research, problem solving, mathematical application, data collection, data analysis, an drawing conclusions.”

“The following set of conditions is essential for interdisciplinary instruction (Robinson, 1994).
• The lesson or unit should complement or support some aspect of instruction in the subject area.
The lesson or unit should complement or support the content and/or learning skills in at least one other subject field.

The lesson or unit should be constructed in a manner that encourages students to integrate and use the new knowledge and skills from several areas of competence.”

“Zemelman, Daniels, and Hyde (2005), have arrived at the following research-based list of “best practices” for teaching math and science: (a) use manipulatives/hands-on (make learning concrete and active); (b) use cooperative group work; (c) use discussion and inquiry; (d) use questioning and making conjectures; (e) use justification of thinking; (f) use writing for thinking, feelings, and problem solving; (g) use problem-solving approach to instruction, making content integration a part of instruction; (h) use technologies such as calculators and personal computers; (i) promote the role of the teacher to that of a facilitator of learning; and (j) use assessment as a part of instruction. As noted above, problem solving is an area where frequently math and science are integrated, and problem-based learning might be a successful instructional strategy for integration.”

“Problem-based learning invoking process skills instead of rote learning must become a classroom norm in integrated science and mathematics. Teachers should be able to incorporate more problem solving/inquiry approaches to instruction as well as assessment rubrics that take into account processes. NCTM (2000, 1995, & 1989) and NRC (1996) suggest that the methods and tasks for assessing students learning should be aligned with the curriculum's goals, math and science content, instructional approaches, and hands-on activities including manipulatives. Also, appropriate assessment must be practiced based on the type of information sought, how the information will be used, and the developmental level and maturity of each student. Teachers need to employ alternative forms of assessment such as observations, interviews, and performance tasks, self-assessments of students, portfolios, and standardized tests. Students must be given multiple opportunities to demonstrate their understanding of mathematics and science aligning assessment with curriculum and instruction. Teachers benefit children most when they encourage them to share their thinking process and justify their answers out-loud as they engage on problem-based learning.”

PENDULUMS

SCIENCE CONCEPTS- Factors influencing periodic motion

SCIENCE SKILLS- Identifying, Controlling and defining variables.

MATH SKILLS- Graphing, Averaging, Rounding, Range, Number line.

MATERIALS- Washers, String, Masking Tape, Seconds Clock.

BASIC PROCEDURES:
1. Distribute washers and string (10 to 50 CM).
2. Students tie string to washer.
3. Students tie knot in end of string for reference point.
4. Students practice swinging pendulum and counting swings which are completed in 10 seconds.
   Do this as a group using a demonstration, then by individual teams of 2 to 3 students.
5. Students and teacher identify and define variables.
7. Students conduct the experiment 3 times.
8. Students average the three-trials (using a calculator) and record to the nearest whole number.
9. Teacher determines range of results and draws a number line on the chalk board.
10. Students come to chalk board and hang their strings on the number line in the position corresponding to the number of swings for their pendulum.

APPLICATION
- Clock and/or timer. Have all students start their pendulums at the same time and instruct them to call out “Ten” at the end of ten seconds according to their “clocks”.

EXTENSION
- Other variables such as number of washers (mass) and size of arc for swing can be explored. Student groups could be encouraged to conduct individual experiments.

SUGAR CUBE EXPERIMENT

SCIENCE CONCEPTS: Surface area. Solution rate.


MATH SKILLS: Volume. Surface area.


BASIC PROCEDURES:
1. Teacher gives each student 8 sugar cubes.
2. Students arrange the cubes in as many different ways as they can think of and determine the surface area for each way.
3. Record data as follows:

<table>
<thead>
<tr>
<th>Volume (cubes)</th>
<th>Surface area (cube faces)</th>
<th>Shape (Drawing)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

4. Students glue the cubes together in shapes that result in a broad range of surface areas.
5. Students arrange shapes in order from the one which they think will dissolve first to the one they think will dissolve last.
6. Students suspend the shapes in about 400ML of water. Use netting and wooden splint to support shapes in the container.

BOTTLE CURVES


BASIC PROCEDURES:
1. Obtain 3 bottles of varying shapes and sizes (less than 250 ml total volume).
2. Draw the shapes of the bottles.
3. Fill each bottle by adding small measured amounts of water (10-15 ml units).
4. Record the total amount of water and the height of the water in the bottle at each step.

Sample data table:

<table>
<thead>
<tr>
<th>Volume of water (cm³)</th>
<th>Height of water (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Graph the results comparing the volume of water to the height of water in the bottle.
6. Describe the relationships between the shape of the graphs and the shape of the bottles.
7. Write mathematical equations for the relationship between the height and volume of water for bottles with straight sides
   \[ V/H = \text{cm}^3/\text{cm} \].

REVIEW OF SCIENCE CONTENTS

MATTER

Matter is made of atoms and molecules. Matter has mass and takes up space (has volume).

MASS AND WEIGHT

**MASS** is the amount of matter an object contains

Mass of an object does not change unless matter is added to the object or matter is removed from the object.

Mass is measured by comparing against a known amount of matter. Unit Grams.

At the Sea Level mass of an object is same as its weight.

**WEIGHT** is a measure of gravitation pull on an object

Weight of an object changes from elevation to elevation (depends on the distance from the center of the earth)

Weight is measured using a spring balance/scale
**Volume** is the amount of space occupied by an object.

**Volume** of a Regularly shaped Object = Length (cm) X Width (cm) X Height (cm). Unit CC; mL

**Volume** of an Irregularly shaped object is determined by Displacement.

**Volume of an Irregular Object**

*by Displacement*

*Water Level After immersing the object*

*Water Level Before immersing the object*

*Volume of the irregular object = Amount of water Displaced by the object*

*Example: 35 mL - 25 mL = 10 mL*
Density is a measure of amount of matter in an unit area. It is a ratio of Mass to Volume.

Density = Mass (grams) / Volume (cc). Unit grams/cc.

Density Problem:

Calculate the density of an object with mass 90 grams and volume 1000 cc.

\[
\text{Density} = \frac{90 \text{ grams}}{1000 \text{ cc}} = 0.90 \text{ grams/cc}
\]

**DENSITIES OF SELECTED SUBSTANCES**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density (gm/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond</td>
<td>3.51</td>
</tr>
<tr>
<td>Gold</td>
<td>19.32</td>
</tr>
<tr>
<td>Sapphire</td>
<td>3.49</td>
</tr>
<tr>
<td>Quart</td>
<td>2.65</td>
</tr>
<tr>
<td>Table salt (Sodium Chloride)</td>
<td>2.16</td>
</tr>
<tr>
<td>Balsa wood</td>
<td>0.16</td>
</tr>
<tr>
<td>Iron</td>
<td>7.87</td>
</tr>
<tr>
<td>Air</td>
<td>0.001</td>
</tr>
<tr>
<td>Water</td>
<td>0.999</td>
</tr>
</tbody>
</table>
COHESIVE AND ADHESIVE FORCES

- Cohesive Force- forces between like molecules
- Adhesive Force- forces between unlike molecules
- Capillary rise- as liquids adheres to the walls of a tube, the liquid is pulled up the tube
- Meniscus- curved surface on a liquid
SURFACE TENSION

- Surface tension is caused by an imbalance of forces at the surface of liquids

The *net inward pull* on the molecules on the surface contracts the surface and makes it behave like stretched skin.
OSMOSIS

- Osmosis is caused by the movement of solvent molecules through a semipermeable membrane from a dilute solution to a concentrated solution

Shrinking/Expanding Grapes in Sugar Solution by Osmosis
HEAT
Heat is a form of energy.
Heat is generated by chemical reactions, by the conversion of electrical energy or mechanical energy.
Heat is measured in Calories (Cal)

TEMPERATURE
Temperature is a relative measure of how hot or cold an object is.
It is the property of an object which determines the direction of the flow of heat energy when it is brought in contact with another object.
Temperature is measured in degree Celsius °C or degree Fahrenheit °F.

HEAT TRANSFER
Heat energy is transferred by Conduction, Convection and Radiation.

Conduction

Convection

Radiation (from Sun)
(SOURCE: NASA; http://virtualskies.arc.nasa.gov/weather/2.html)
PHYSICAL AND CHEMICAL CHANGES

Physical change – ice melting into water. The chemical nature of water (H₂O) does not change. Only physical state changes so as physical properties like, density, shape, refractive index, etc.

Chemical changes are caused by creating and/or destroying bonds between atoms. When Water (H₂O) changes into Hydrogen peroxide (H₂O₂) by addition of one more Oxygen atom the new substance is no longer water.

Chemical Properties are only observed by changing the identity of a substance. When you burn a piece of paper it changes into a black substance which cannot be burned further after the flame goes out. This is chemical change.

Churning of milk is another example of a chemical change.
### PHASE CHANGES

<table>
<thead>
<tr>
<th>Temperature:</th>
<th>Melting Temperature</th>
<th>Boiling Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>Melting</td>
<td>Boiling/Evaporation</td>
</tr>
<tr>
<td></td>
<td><strong>Heating</strong></td>
<td></td>
</tr>
<tr>
<td>SOLID</td>
<td>LIQUID</td>
<td>GAS</td>
</tr>
<tr>
<td>Cooling</td>
<td>Cooling</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process:</th>
<th>Freezing</th>
<th>Condensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature:</td>
<td>Freezing Temperature</td>
<td>Condensation temperature</td>
</tr>
</tbody>
</table>

- No two different substances have the same melting and boiling temperatures.
- Melting temperature and freezing temperature of a substance are the same.
  (E.g. ice melts at 32°F and water freezes at 32°F). Only the direction of flow of heat is changed. Similarly
  the boiling/evaporation temperature and condensation temperature of a substance are the same. (e.g. water
  boils at 212°F and water vapor condenses at 212°F). Only the direction of flow of heat is changed.
CURRENT ELECTRICITY

- Moving electrons generate electrical current (approx. 1 million electrons every 5 seconds)
- Electrical current- rate of flow of electrical charge through any section of an electrical conductor
- Current (I) is measured in Amperes
- Battery- storage tank of electrons
- Potential differences- the force necessary to get the electrons out of the battery
- No potential differences, means dead battery
- Potential difference (V) is measured in volts
- Resistance- ability of materials to oppose the flow of electrical current
- Electrical conductors- low resistance materials and facilitate the flow of electric current
- Electrical non-conductors- high resistance materials and obstruct the flow of electric current
- Resistance (R) is measured in Ohms
- Ohm’s law- the current flowing through a conductor is proportion to the potential difference, at constant temperature
- Corroded wire terminals raise the resistance and lower the current, if the voltage remains the constant
**Types of Circuits**

- Opened circuit- no electrical current (switch off = 0)
- Closed circuit- yes electrical current (switch on = 1)

- **Electrical conductors**- low resistance materials that facilitate the flow of electric current (e.g., copper, aluminum)

- **Electrical non-conductors**- high resistance materials that obstruct the flow of electric current (e.g., rubber, dry wood, plastic)
ELECTRICAL CONDUCTORS AND NON-CONDUCTORS LABORATORY

Objective: To Classify objects as Electrical Conductors and Electrical Non-Conductors

Materials: One Simple Electrical Circuit with one opening (two leads)
5-10 common objects in the immediate environment

Procedure: Identify five objects in your immediate environment (e.g., keys, pencil, pen)
Make a list of each object
Predict each object whether it is an electrical conductor or electrical non-conductor
and record your prediction
Place each object between the two open leads and notice of the circuit is completed or not.
(If the bulb lights or not)
Record your observation
Repeat
Report your results

Data:

<table>
<thead>
<tr>
<th>Item</th>
<th>Object Description</th>
<th>Prediction (Electrical Conductor/Electrical Non-Conductor)</th>
<th>Observation (Electrical Conductor/Electrical Non-Conductor)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>5</td>
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</tbody>
</table>

Results:

Safety Tips: Make sure wire leads don’t hurt your fingers, do not play with wall power outlets, etc.
ELECTRICAL ENERGY PROBLEM

One 75-Watts light bulb in a living room is used 10 hours per day for 30 days. Calculate the amount of electrical energy consumed in units.

75 Watts x 10 hr x 30 days

22,500 Watts-Hr

22.5 Kilowatts-Hr

(1 unit = 1 Kilowatt-Hour)
LIGHT

- Light is a part of electromagnetic radiation (wave) spectrum.

- Light travels in a straight-line path within one medium.

- Light reflects, that changes in direction at the interface between two media so that the wave returns to the original medium.

- In a mirror like reflection the angle at which the light wave hits (incident) the surface is equal to the angle at which it is reflected.

- Light refracts when it travels from one medium to another medium due to a change in speed, and this causes the light wave to bend at the intersection.

- Speed of light (estimated in vacuum) is approximately 186,000 miles per second OR approximately 300,000 kilometers per second.

Demonstration to show Light Travels in a Straight Line Path
Angle of Incidence $A_1 = \text{Angle of Reflection } A_2$
REFRACTION

Angle of Incidence $A_1 >$ Angle of Refraction $A_2$
MAGNETISM

- Magnet or magnetic material is an object that generated a magnetic field, and has the ability to attract iron.
- Magnetism is the force of attraction or repulsion due to arrangement of atoms in a magnetic material.
- Magnets have 2 poles- NORTH POLE and SOUTH POLE
- North Pole of a magnet attracts the South Pole of another magnet and vice versa.
- North Pole of a magnet repels the North Pole of another magnet and vice versa.

MAGNETS

-A material with the ability to attract iron (field of force)

<table>
<thead>
<tr>
<th>North Pole</th>
<th>S</th>
<th>South Pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on Magnetism there are two classes of materials:

**Magnetic Materials** – materials that are attracted by magnets (e.g., iron nail, iron door hinge)

**Non-Magnetic Materials** – materials that are not attracted by magnets (e.g., glass, plastic, wood)
MAGNETIC AND NON-MAGNETIC MATERIALS LABORATORY

Objective: To Classify objects into Magnetic and Non-Magnetic materials

Materials: Magnet
5-10 common objects in the immediate environment

Procedure: Identify five objects in your immediate environment (e.g., coin, note, pen)
Make a list of each object
Predict each object whether it is made of magnetic or non-magnetic material and record your prediction
Place the magnet near the object and see if the magnet attracts the object or not
Record your observation
Repeat
Report your results

Data:

<table>
<thead>
<tr>
<th>Item</th>
<th>Object Description</th>
<th>Prediction (Magnetic/Non-Magnetic)</th>
<th>Observation (Magnetic/Non-Magnetic)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2</td>
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<td>4</td>
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<tr>
<td>5</td>
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</tr>
</tbody>
</table>

Results:

Safety Tips: Please keep the magnet away from credit cards, cellphones, computers, electronic watches, electronic devices, etc.
- Vibrating objects produce sound and it is a pressure vibration or “traveling wave”
- Speed of sound in dry air (at 20°C) is 343 meters per second (1,236 kilometers per hour)
- Sound cannot travel in vacuum.
- Sound travels faster in a denser medium. That means sound travels faster in solids than liquids, and faster in liquids than gases.
ACIDS, BASES AND INDICATORS

**Acid** is any substance that can provide Hydrogen Ion (H\(^+\)) in water, turn blue Litmus to red, sour in taste and can react with base to form salt and water.

**Base** is any substance that can donate Hydroxyl Ion (OH\(^-\)) in water, soapy slippery in feeling, turns red Litmus to blue, and react with acid to form salt and water.

<table>
<thead>
<tr>
<th>ACIDS</th>
<th>BASES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROPERTIES OF ACIDS:</strong></td>
<td><strong>PROPERTIES OF BASES:</strong></td>
</tr>
<tr>
<td>Corrosive</td>
<td>Corrosive</td>
</tr>
<tr>
<td>Sour Taste (e.g., lemon juice)</td>
<td>Soapy slippery feeling</td>
</tr>
<tr>
<td>Supplies Hydrogen Ion (H(^+)) in water</td>
<td>Most bases in water contain Hydroxyl Ion (OH(^-))</td>
</tr>
<tr>
<td>pH less than 7</td>
<td>pH more than 7</td>
</tr>
<tr>
<td>Changes blue Litmus to red</td>
<td>Changes red Litmus to blue</td>
</tr>
<tr>
<td>Reacts with bases to form salt and water</td>
<td>Reacts with acids to form salt and water</td>
</tr>
<tr>
<td>Reacts with carbonates to form carbon dioxide, salt and water (e.g., acid rain destroys marble monuments)</td>
<td>EXAMPLES OF BASES:</td>
</tr>
<tr>
<td></td>
<td>Sodium Hydroxide (Caustic Soda) (NaOH) (pH 14 )</td>
</tr>
<tr>
<td></td>
<td>Human Blood (pH 7.4)</td>
</tr>
<tr>
<td></td>
<td>Sea Water (pH 7.9)</td>
</tr>
<tr>
<td></td>
<td>Ammonia water (pH 11.6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXAMPLES OF ACIDS:</th>
<th>EXAMPLES OF BASES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric Acid (HCl) (pH 0.1)</td>
<td>Sodium Hydroxide (Caustic Soda) (NaOH) (pH 14 )</td>
</tr>
<tr>
<td>Stomach Acid (pH 1-3)</td>
<td>Human Blood (pH 7.4)</td>
</tr>
<tr>
<td>Vinegar (pH 2.9)</td>
<td>Sea Water (pH 7.9)</td>
</tr>
<tr>
<td>Fresh Milk (pH 6.5)</td>
<td>Ammonia water (pH 11.6)</td>
</tr>
<tr>
<td>Sour Milk (pH 4.4)</td>
<td></td>
</tr>
</tbody>
</table>

(Note: pH of water is 7, neutral)

**INDICATOR** is a substance when it reacts with acids and bases forms different colors.

Example: Litmus (purple in neutral solution) when added to acid turns red in color, and when added to base turns blue in color.

Bromothymol Blue (bluish in neutral solution) turns yellowish in acid and turns bluish-green in base.

Neutralization Reaction (This is a Chemical Reaction.)

When equal strengths of an acid and base react they neutralize each other producing salt and water.

\[
\text{Acid} + \text{Base} \rightarrow \text{Salt} + \text{Water}
\]

\[
\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}
\]
LEVERS

Levers are simple machines, tools for moving or tackling physical resistance), e.g., straight iron rod

Levers have three centers of action:

- Effort (the point of strenuous attempt, exertion)
- Fulcrum (the point of support of a lever)
- Resistance (the point of stopping power, weight)

Based on how the three centers of action are arranged levers are divided into three classes: First Class Lever; Second Class Lever; Third Class Lever

First Class Lever:

<table>
<thead>
<tr>
<th>Effort</th>
<th>Fulcrum</th>
<th>Resistance</th>
</tr>
</thead>
</table>

Examples: Seesaw, Scissors, Crowbar

Second Class Lever:

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>△</td>
<td></td>
</tr>
</tbody>
</table>

Fulcrum

Examples: Nutcracker, Wheelbarrow, Door on a hinge

Third Class Lever:

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>△</td>
</tr>
</tbody>
</table>

Fulcrum

Example: Tennis Racket, Pen
**REQUIRED READINGS AND ACTIVITIES FROM THE TEXTBOOK**

“Activities for teaching science as inquiry”


**Will be part of Tests**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grouping- Buttons</td>
<td>A-17</td>
</tr>
<tr>
<td>Properties of liquids- How much water can you heap up in a cup?</td>
<td>A-20</td>
</tr>
<tr>
<td>How many paper clips can you add to a cup of H2O?</td>
<td>A-21</td>
</tr>
<tr>
<td>Floating a paper clip on top of water</td>
<td>A-22</td>
</tr>
<tr>
<td>Soap and surface tension</td>
<td>A-23</td>
</tr>
<tr>
<td>Water drops on different surfaces</td>
<td>A23-A-24</td>
</tr>
<tr>
<td>Properties of Oobleck</td>
<td>A-27</td>
</tr>
<tr>
<td>Is air a real material substance like solids and liquids?</td>
<td>A-34</td>
</tr>
<tr>
<td>Does air take up space?</td>
<td>A-35-A-36</td>
</tr>
<tr>
<td>Factors affecting the equilibrium of equal-arm balance</td>
<td>A-41-A-42</td>
</tr>
<tr>
<td>Levers</td>
<td>A-44-A-45</td>
</tr>
<tr>
<td>Bernoulli’s Principle</td>
<td>A-50-A-51</td>
</tr>
<tr>
<td>Pendulums-Rate of swinging- Factors</td>
<td>A-53-A-55</td>
</tr>
<tr>
<td>Drinking Straw Flute</td>
<td>A-62</td>
</tr>
<tr>
<td>Bottle Pipe Organ</td>
<td>A-63</td>
</tr>
<tr>
<td>Light travels in a straight-line path</td>
<td>A-81</td>
</tr>
<tr>
<td>Pinhole camera</td>
<td>A-82</td>
</tr>
<tr>
<td>How do Seed Pods vary?</td>
<td>A-127</td>
</tr>
<tr>
<td>Lungs model</td>
<td>A-173</td>
</tr>
<tr>
<td>Starch-test</td>
<td>A-179</td>
</tr>
<tr>
<td>Fats- Tests</td>
<td>A-181</td>
</tr>
<tr>
<td>Which soda has more sugars?</td>
<td>A-186</td>
</tr>
<tr>
<td>Vitamin-C test</td>
<td>A-191</td>
</tr>
<tr>
<td>Core sampling</td>
<td>A-217</td>
</tr>
<tr>
<td>What is in soil?</td>
<td>A-215-A-216</td>
</tr>
<tr>
<td>How fast does water in a wet sponge evaporate?</td>
<td>A-223</td>
</tr>
<tr>
<td>Desalination of salt water</td>
<td>A-226-A-227</td>
</tr>
<tr>
<td>Wind Vane-Making a Vane</td>
<td>A-231-A-232</td>
</tr>
<tr>
<td>Measuring how fast wind blows</td>
<td>A-233</td>
</tr>
<tr>
<td>(Wind speed varying by time and location)</td>
<td></td>
</tr>
<tr>
<td>Salt water and fresh water-objects floating differently</td>
<td>A-241</td>
</tr>
<tr>
<td>Pressure and depth/height</td>
<td>A-242-A-243</td>
</tr>
<tr>
<td>Changing shadows</td>
<td>A-250</td>
</tr>
<tr>
<td>Static electric forces (comb, flour, balloons)</td>
<td>A-107-A-108</td>
</tr>
<tr>
<td>What is an electromagnet, and how can you make one?</td>
<td>A-119-20</td>
</tr>
</tbody>
</table>
Why can we see clearly through some materials and not others?-------------------A-79-80
Is the air we breathe in the same as the air we breathe out?----------------------A-170-71
How much of each nutrient does your body need, and how can you find out what is in each food?-----------------------------------------------A-193-195
SITUATED COGNITION IN SECOND GRADE SCIENCE: LITERATURE BOOKS FOR AUTHENTIC CONTEXTS

By David Kumar & John F. Voldrich

Abstract
A report of how literature books can be used to create authentic contexts for teaching science at the second grade level is presented. Since, from a cognitive psychology perspective, language helps to mediate social actions and cognitive functions, at lower grade levels it is possible to use literature books to situate science learning in macro-contexts. This paper points out that instead of relying on expensive technologies, such as intelligent tutors and interactive videos, teachers could use carefully selected reading materials to provide students with meaningful contexts for science learning activities.

Introduction
This paper will explore how "literature books" are used to situate science learning by providing authentic contexts in a second grade science classroom in the United States. As Vygotsky (1978) said, "[k]nowledge acquisition and cognitive functions in general are internalization of social actions." According to Brown, Collins, and Duguid (1989), knowledge is situated as a part of the context (culture) from which it is acquired, which forms the basis of situated cognition. Thus, the context of the social action is a crucial factor in learning.
For example, when problem-based learning is situated in a real-world event, the learner has the opportunity to develop an understanding of the concept under study and facilitate the internalization of the information through meaningful semantic network in order to overcome inert knowledge (Lockhart, Lamon, & Gick, 1988). [The term "inert knowledge," according to Whitehead (1929), represents the knowledge often unable to be recalled and applied spontaneously in problem-based learning due to a lack of meaningful contexts. Semantic network represents how knowledge is "organized by associative structures" for example, the "vocabulary of a language along with general facts about the world" (Dunlop & Fetzer, 1993, p. 115).] Brown and co-workers (1989) call for creating apprenticeships for students to situate their learning in practices that are representative of experiences in ordinary life.

Numerous studies suggest that situated cognition provides a meaningful learning context for students and helps them develop an understanding of how to use subject-specific knowledge in practical problem solving (Brown, Collins & Duguid, 1989; Kotovsky, Hayes & Simon, 1985; Lajoie & Lesgold, 1989; Cognition & Technology Group, 1990). Kotovsky, Hayes and Simon (1985) have shown that real world representations of problems yield significant improvements in problem solving and learning abilities of students.

In science education, expensive technologies such as intelligent computer models and interactive video systems, are often used to facilitate situated cognition (Merrill, 1988; Kumar, Smith, Helgeson & White, (in press); Cognition & Technology Group, 1990). Lajoie and Lesgold (1989) pointed out that the performance of Air Force trainees who used a computer tutoring system (SHERLOCK) mastered trouble-shooting as well as their colleagues with more years of in-service experience. The Cognition and Technology Group described the effect of contexts provided by videos of movies such as "The Young Sherlock Holmes" on student learning. For example, one student after viewing "Sherlock Holmes" recognized a pattern in the strange murders where the victims are always hit by poison darts in the neck. This spontaneous recognition of a pattern triggered a series
of discussions ranging from movies to human biology. In another project, adventures of a character named Jasper are presented to students via an interactive video system. Each adventure of Jasper is embedded with carefully structured data in a rich context. Thus, students are able to generate their own problems to solve. Findings showed that students who used the interactive video system became better problem solvers than those who did not.

On the other hand, how to provide similar meaningful learning experiences without the aid of these expensive technologies is a question that challenges educators. One should not be led to believe that expensive technologies are essential for providing enriched contexts for learning. For example, Gragg (1940) proposed the use of "case based instruction" to enable learning in a real-world context. According to Rosenblatt (1978), from an educational point of view, reading could help the learner focus the "concepts to be retained, ideas to be tested, actions to be performed" (p. 24). Wallace-Jones (1991), in a research study with 11 to 16 year old students, found that student response to reading poetry had not only emotional implications as conventionally held, but also cognitive implications. As previously stated, since cognitive functions are internalization of social actions, an argument could be made that teachers at primary grade levels could create authentic contexts for meaningful learning for their students using literature books. Accepting this premise, a report of how literature books are used to create enriched contexts for teaching science concepts in a second grade classroom in the United States is presented.

**Weather Unit in Second Grade**

An example of how techniques of situated cognition can be utilized in a second grade science curriculum can be seen in a unit on weather from a public elementary school in Columbus, Ohio. The teacher's primary objectives of the unit are:

1. To develop "awareness" of and "interest" in the weather phenomena that affect both the students and the people around them. For example,
as the students work through the unit, they will hopefully be asking themselves questions such as: What experiences have I had with weather? What experiences have I shared vicariously with characters in books? etc.

2. To add to the students' understanding of the physical properties of air, water, light, and heat, all of which are shown to contribute to various weather phenomena.

3. To give a practical context to the use of math computation and measurement skills.

4. To develop an attitude of inquiry in each student, by asking questions such as: What do I want to find out about weather? How can I go about answering questions I have about weather? etc.

Materials

The materials needed for the unit are fairly simple: student journals, student weather folders (a manila folder containing a calendar and temperature graph), indoor and outdoor thermometers, class "Clock-In" chart, library books at appropriate grade levels on various weather subjects, and literature relating to various aspects of the weather (to be read aloud by the teacher and discussed with the class).

Activities

Over the span of the school year, the teacher reads Laura Ingalls Wilder's *Little House* books to his class. Three 10-minute periods each day are set aside to read aloud to the students. Because children seem much more interested in science, math, health, and social studies concepts when placed in a meaningful context, (i.e. the personal experiences of a pioneer family as they face a variety of physical and social conditions) much of the teaching of science concepts spins off from the experiences of the Ingalls' family. Though the class may discuss different aspects of weather and seasonal change presented in particular chapters of Wilder's series throughout the year, a more focused study of weather and its causes usually occurs when the teacher begins reading *The Long Winter* in January and February. Weather-
related topics in this book include: weather forecasting (animal signs, Indian predictions, weather patterns), effects of extremely high and low temperature, effects of wind speed and direction, snow cover, sunshine, and cloud cover on human survival, and seasonal norms.

Along with letting the students vicariously experience the effects of blizzards, droughts, floods, tornadoes, and more normal prairie weather presented in the readings, the teacher and students will often spend journal time brainstorming ideas and writing about experiences that students have encountered related to weather topics. For example, after reading the chapter in *On the Banks of Plum Creek* in which Laura almost drowns in a flood-swollen creek, the teacher could write his/her own flood experiences on the chalkboard or newsprint and encourage students to share their own experiences in their journals. Further exploration into the subject of floods and their causes can be encouraged as the teacher shares or reviews other non-fiction books on floods with students. Though the experiences related may not be as dramatic or life-threatening as the ones presented in the *Little House*, students are eager to share what they do know from their own experiences.

A third activity that develops a sense of weather changes, cycles, and seasonal trends is the use of individual weather calendars. Each month the students is given a new calendar, showing five-day school-weeks. Space is provided in each day's square to paste one of six weather pictures kept in a zip-lock bag stapled to the inside of the folder depicting sunny, cloudy, rainy, snowy, windy, or foggy weather. Space is also provided to record the low and high temperatures for each day. A grid to record the daily highs and lows as a line graph is stapled to the other side of the folder. With each succeeding month, students will hopefully notice not only the weather extremes possible within each month, but the temperature trends (either up or down) as the months pass from season to season. Graphing activities involving temperature measurements could also be used to further compare the weather conditions and trends from month to month, or over the course of several months.
A fourth ongoing weather activity involves a daily check of the time and indoor/outdoor temperatures. The teacher introduces the task at the beginning of the year by showing the students how to read the thermometers and clocks. When each student reaches the "Clock-In" task each day, s/he signs in, and fills in boxes on a chart labeled "Analog time," "Digital time," "Inside temperature," and "Outside temperature." Later in the school year, when all students have been exposed to two digit subtraction, another column is added to the chart, "Difference (High - Low Temp)." To support the routine of monitoring temperature and weather conditions, students will listen to weather information and forecasts on a weather radio each day and discuss how the forecasts will affect their plans for the next day, as well as how accurate the weather forecasts have been in days previous.

Evaluation

At the second grade level, the primary focus of evaluation is not on how well students gain and retain a knowledge of science facts and concepts, but on how much each student's awareness of and interest in weather phenomena has been increased. If and when the need does arise to gather "hard data" on understandings of science concepts and facts, students will function best if they do not sense they are being tested on their knowledge of facts presented in the literature books, or science concepts learned in conjunction with the extension activities and centers. The natural enthusiasm of students and teachers is diminished when both sense that the ultimate purpose of their reading, investigations, and activities is to prepare for a paper and pencil test, or to earn a grade.

In order to evaluate the affective elements of "awareness," and "interest" of students, individual work on projects and activities can provide much insight into the students' awareness, interest, and new understandings of weather phenomena. In addition, anecdotal records can reveal an individual student's interest by noting frequency of weather-related choices of books, magazine articles, and "show and tell" items for silent reading or sharing times, as well as by
references to weather topics in class discussions and daily journal entries.

To evaluate a student's understanding of specific facts and concepts encountered in a study of weather, (e.g., properties of air, water, light, and heat) as well as the student's capabilities in using math and measurement skills the teacher can employ hands-on activities demonstrating the properties of air, water, etc., and check the student's understandings using an activity sheet or response journal. An individual conference with the students can add further insight into the depth of student understanding of particular science concepts.

Another example of evaluation of the student's grasp of math and science concepts can be seen in the use of the weather folder. At the end of a given month, students can use information recorded on their weather folders to construct a bar or picture graph to compare the numbers of sunny, cloudy, rainy, and snowy days. The students' understandings of "greater than," "less than," and "equal to," can be evaluated and reinforced as the students are asked to show the comparisons using mathematical language and symbols. Similarly, if students have recorded daily temperatures on their calendars, the information can be used to construct line graphs. Based on their understandings of seasonal changes and the trends they see represented on the graphs, students can be asked to predict future trends and characteristics of seasons and climates, showing their degree of understanding of these concepts.

Evaluating the student's "attitude of inquiry" can be approached in several ways. Before investigating a specific science topic -- air, for instance, the class as a group will list on a wall chart titled, "What I know About Air," all of the facts, ideas, and concepts relating to air with which they are already familiar. After exhausting the student's reservoir of facts about air, the teacher will list on another wall chart titled, "What I Want to Find Out About Air," all of the questions for which students want answers. In the following weeks, students can refer to the questions on the chart as they read during free-reading or project time. When a student finds an answer to one of the class' questions, s/he brings the book to his/her teacher and shares the
discovery, which is then recorded on a notecard and taped to the chart next to the question. The notecard not only shares the answer to the question, but the name of the person who found the answer and the book in which the answer was found.

For students who are less-able readers, or more suited to hands-on activities, a science center can be an effective means of not only introducing a student to science concepts and facts, but also evaluating an "attitude of inquiry." The teacher's anecdotal records of how often and to what degree a student involves himself with explorations and applications of activities in a science center can also reveal the depth of a student's "attitude of inquiry."

Discussion and Implications

Many other examples could be given to relate situated cognition with the teaching of science concepts about weather in authentic contexts. In teaching primary age children, the technique of situating science instruction in the student's "frame of reference," (personal experiences, of events in literature, and hands-on activities) is crucial in helping students understand science concepts, as well as initiating and developing an interest in the process of scientific investigation. In a study of teachers' uses and beliefs of text materials in the context of science reading at the elementary grades, Shymansky, Yore and Good (1991) stated that "[u]nderstanding science ideas requires purposeful action where the learner brings all forms of activity to bear on the task of making meaning of the ideas" (p. 452).

Even though terms like situated cognition appear strange at first, upon close examination they seem to represent learning strategies familiar to most classroom teachers. The basic premise of situated cognition lies in enriched context-based learning reflective of ordinary events in order to overcome inert knowledge. There is no genuine substitute for situated cognition focused on learning experiences in authentic context, as illustrated by the four examples of science activities on weather presented in this paper. It is hoped that teachers will continue to value and provide such learning opportunities for
their students. Generally, cognitive theories which call for apprenticeship in authentic contexts, help to reinforce the importance of memorable, real-world practical learning experiences. Certainly, there are many teachers who are providing much experiences for their students without even realizing the support their practices have from those in educational research, and the long-range positive implications of their actions on learner outcomes.

References


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Science literacy strategies anchored in nanotechnology

David Devraj Kumar, Susanne I. Lapp, Philomena Marinaccio and Kimberly K. Scardala

A modern context such as nanotechnology brings new excitement to learning basic science knowledge

This article is about teaching science using literacy (reading, writing, speaking, listening and viewing) strategies anchored in nanotechnology. Motivating students to learn science remains a challenge in the United Kingdom and throughout the world. Using the nano world of science and technology can help provide motivation:

*It brings a new excitement to many subjects... Students see amazing applications that result from nanoscience, and learn that an understanding of basic science is necessary to make them happen. For example, CDs wouldn't exist without nanotechnology; neither would the new colour-changing paints on luxury cars and motorbikes; transparent sunscreens and many new cosmetics use nanoparticles; the technology behind stay-clean chinos (and even new school uniforms) is nanotechnology. These developments depend on a fundamental knowledge of chemistry, physics and biology. (Anon, undated).*

*Figure 1 Compact discs wouldn't exist without nanotechnology (used with permission, © 2006, Kimberly Scardala).*

**ABSTRACT**

This article addresses teaching science using literacy (reading, writing, speaking, listening and viewing) strategies anchored in nanotechnology. Motivating students to learn complex scientific concepts such as atomic structure can be challenging, but using a modern context such as nanotechnology brings new excitement to learning the basic science knowledge. Nanoscience pedagogy presents unique literacy challenges because of the technical vocabulary and abstract concepts involved. Encouraging students to use effective literacy strategies to help them gain a better understanding of scientific concepts has been helpful in our own contexts in the United States and we offer these suggestions to others in an adapted format. This approach provides students with scaffolded reading experience. Metacomprehension strategies are suggested for use before, during and after reading nanotechnology core texts to provide instructional scaffolding especially relevant to the needs of this content area. Exploratory, response and essay writing are highlighted as useful informal tools.

*Figure 2 Textiles, supplements, sunscreens – just some of the many products dependent on nanotechnology (used with permission, Project on Emerging Nanotechnologies, © 2006, David Howxhurst, Woodrow Wilson Center).*

School Science Review, June 2008, 89(329)
Nanotechnology

The prefix 'nano' refers to sizes of the order of one-billionth of a metre or one-millionth of a millimetre, so nanotechnology refers to the various technologies used to produce materials at this scale (see Figure 3 for examples). Nanotechnology is one of the fastest growing technologies of the twenty-first century, as indicated by, for example, a 50 times increase in the number of publications on the subject between 1995 and 2004 (Kumar, 2006a). Nanotechnology 'implies the ability to generate and utilize structures, components, and devices with a size range from about 0.1 nm (atomic and molecular scale) to about 100 nm (or larger in some situations) by control at atomic, molecular, and macromolecular levels' (Roco, 1999: 131). A combination of developments in scanning tunnelling microscopy, solid-state physics and chemistry, molecular biology, molecular engineering, and synthetic chemistry form a major part of nanotechnology. For example, nano-sized indium melts at a much lower temperature than the bulk metal (Allen, 2002). Copper in extremely thin layers, in the presence of a magnetic field, becomes a poor conductor of electricity (Loder, 2005).

Figure 4 shows nanoscale writing of a passage from the Encyclopaedia Britannica on a plastic slide or biochip, using a scanning electron microscope at the Nanoscience Centre at Cambridge University: 'Each letter is 250 nm tall. If one letter is considered to be equivalent to 8 bits then the storage density achieved here is around 1000 Gbit in². Or you would be able to write the whole Oxford poetry dictionary on the area of one letter on this page' University of Cambridge, 2004: 1). As Siegel (1999) said:

Nanostructure science and technology is a broad and interdisciplinary area of research and development activity that has been growing explosively worldwide in the past few years. It has the potential for revolutionizing the ways in which materials and products are created and the range and nature of functionalities that can be accessed. (p. xvii)

The Scale of Things – Nanometers and More

![Image of the Scale of Things diagram](Image)

Figure 3 'The scale of things' (used with permission, Office of Basic Energy Sciences, United States Department of Energy. http://www.science.doe.gov/bes/scale_of_things.html).

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Scaffolded reading

When teaching areas of factual content, it is insufficient to teach solely academic content: teachers need to be responsible for content literacy as well. Nanotechnological pedagogy presents literacy challenges as unique to this discipline as the technical vocabulary and abstract concepts. Imagine the vocabulary and comprehension demands of defining nanotechnology as the controlled manipulation of matter at the nanometre scale (0.000 000 001 m). Therefore, nanoscience education needs to provide students with a scaffolded reading experience (SRE). We will suggest metacommprehension strategies for use before, during and after reading nanotechnology core texts to provide instructional scaffolding specific to the needs of this content area (Figure 5).

The pre-reading phase of an SRE for teaching expository text is when the reader needs to activate their prior knowledge, set a purpose for reading, make predictions and learn new vocabulary. For example, to activate schema prior to reading about

<table>
<thead>
<tr>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanotechnology is research and technology development only at the macromolecular level.</td>
<td></td>
</tr>
<tr>
<td>Nanotechnology is in the length scale of 1–100 nanometre range.</td>
<td></td>
</tr>
<tr>
<td>Nanotechnology is the ability to control or manipulate on the atomic scale.</td>
<td></td>
</tr>
<tr>
<td>A nanometre is one-billionth of a metre.</td>
<td></td>
</tr>
<tr>
<td>The width of a human hair is approximately 1 nanometre.</td>
<td></td>
</tr>
<tr>
<td>Federal funding for nanotechnology has increased substantially in the past few years.</td>
<td></td>
</tr>
<tr>
<td>The United States is the only country to recognise the economic potential of nanotechnology.</td>
<td></td>
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<tr>
<td>Nanotechnology has the potential to change our economy.</td>
<td></td>
</tr>
<tr>
<td>Major applications for nanotechnology are years away.</td>
<td></td>
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</tbody>
</table>
transmission electron microscopy (TEM), students should brainstorm prior knowledge about light microscopes. Similarly, the teacher could divide the class into small groups and get students to brainstorm and write a list of as many words as they can that are associated with the concept. To encourage reading for meaning, teachers need to raise the curiosity of students and encourage them to set a purpose for reading. This ‘purpose for reading’ can be set by having students predict whether statements taken from the actual text to be read are true or false (see Table 1). Encouraging students to make predictions on information (Knop, 2005) activates their prior knowledge and helps them to establish a purpose for reading.

Innovations on this strategy include adding a Reaction Guide, where students confirm whether their predictions were correct and provide the page in the text where they found the information or use a combination of their background knowledge and the author’s message to defend their reasoning.

The vocabulary used in nanotechnology texts is often not part of students’ everyday reading and listening activities. Technical words often do not have specific concrete frames of reference. Vacca and Vacca (2005) suggest teaching content-area vocabulary by teaching technical vocabulary in relation to other related terms. In a Semantic Feature Analysis graphic organisers, students list the technical vocabulary words down the left side of a table and list characteristics of these words or concepts along the top. For example, students could list different kinds of microscopes in the first column and include characteristics such as ‘uses magnetic lenses’, ‘uses light’, ‘uses glass lenses’ and ‘allows visualisation of thin slices of materials’ in the top row (see Table 2). When the content contained in intersecting columns and rows is correct, students place a plus sign. If the information is not accurate they place a minus sign. By investigating likenesses and differences between content-related vocabulary students learn new words and refine previously held conceptions. This multi-phase strategy can be used before, during or after reading.

During reading, students need to be active readers and learn to interact with the core text. The Reciprocal Teaching and Reciprocal Questioning (RTIQ) strategies of Palincsar and Brown (1984) involve teachers and students in reciprocal questioning, predicting and summarising techniques while reading sections of a text. The RTIQ strategy begins with the teacher assigning a section of text to be read by students and then, together, the teacher and students proceed through the RTIQ questioning stages, addressing key components of the strategy. An example is given in Tables 3 and 4. Here, the teacher sets the stage for the RTIQ strategy by asking students to read a portion of a newspaper article. The

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Semantic Feature Analysis graphic organiser for teaching technical vocabulary for studying nanostructure properties (Nanotech Facts, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Allows direct mapping of surface features</td>
</tr>
<tr>
<td>Transmission electron microscopy</td>
<td></td>
</tr>
<tr>
<td>Scanning electron microscopy</td>
<td></td>
</tr>
<tr>
<td>Scanning probe microscopy</td>
<td></td>
</tr>
<tr>
<td>Atomic force microscopy</td>
<td></td>
</tr>
<tr>
<td>Conventional microscope</td>
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</table>
teacher then poses the question, 'Why do you think the government should fund nanotechnology research?' Students respond to the teacher's query by offering predictions and clarifying these predictions as they continue to read and respond to the text. At the end of the activity students summarise the reading section to confirm or disconfirm their predictions.

Once this portion of the activity is complete, roles are reversed and students have the opportunity to initiate a new follow-up question based on further reading of the same text. For example, students might ask, 'What is the worldwide government funding for nanotechnology?' The teacher and students continue to take turns making predictions and summarising different sections of text. Although this strategy works well with struggling readers, it is equally useful when reading difficult text at the secondary level. Teacher-modelling of questioning, predicting and summarising techniques provides the necessary scaffolding that these challenging texts demand.

During reading, students also need to determine what information is important to remember, and to organise this information in a meaningful way. The use of a 'study guide', as illustrated in Box 1, helps secondary students to comprehend difficult text selections by providing instructional support and direction in developing effective reading strategies. This study guide was developed for an excerpt from an American nanotechnology core text (Clinton, 2000) and based on a speech by Dr Baltimore from the Science Foundation as he shares his views on the future impact of nanotechnology research.

**Writing activities**

To create additional opportunities for students to demonstrate their understanding of content-area reading, it is essential for teachers to integrate writing activities in their classrooms. Students who are encouraged to write about content-area topics and integrate writing and reading activities are more likely to learn additional content, to understand it better and to remember it longer (Vacca and Vacca, 2005).

There are a range of science-content writing activities, from exploratory to essay writing, which

| Table 3 Reciprocal Teaching and Reciprocal Questioning strategy chart (teacher version) |
| Teacher initiating activity | Reading material: Newspaper article [XYZ Times, 2007] Parliament agrees to increase funding for scientific research. [paragraphs 1-4] Date: 30.3.2007 |
| Question | Why do you think the government should fund nanotechnology research? |
| Prediction | British researchers have convinced members of Parliament to spend additional funds to research nanotechnology. |
| Clarification | Nanotechnology is a cost-effective way to produce newer and better products for British consumers. |
| Summary statement | British researchers have identified cost-effective ways to produce materials for public consumption. |
| Was the prediction confirmed? | Yes [x] No |
| Details | After reading and discussing aspects of the article, we believe that Parliament has made the correct decision to increase funding for scientific research. According to the article, British researchers are exploring the potential impact of nanotechnology applications for public consumption. Preliminary research suggests that increased use of nanotechnology research will decrease the final costs of producing a product and consumers will witness savings of 20–30% on personal consumer items. |
### Table 4 Reciprocal Teaching and Reciprocal Questioning strategy (student version)

<table>
<thead>
<tr>
<th>Student initiating activity</th>
<th>Reading material: Newspaper article (XYZ Times, 2007) Parliament agrees to increase funding for scientific research. (paragraphs 5-9) Date: 3.4.2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction</td>
<td>Other countries are beginning to invest huge amounts of money in nanotechnology research.</td>
</tr>
<tr>
<td>Question</td>
<td>What is the worldwide government funding for nanotechnology?</td>
</tr>
<tr>
<td>Clarification</td>
<td>British researchers want to remain competitive with other international researchers.</td>
</tr>
<tr>
<td>Summary statement</td>
<td>For British researchers to remain competitive in the growing worldwide field of nanotechnology research, it is imperative that Parliament agrees to spend additional money to fund future nanotechnology research.</td>
</tr>
<tr>
<td></td>
<td>See results from chart based on international scientific research funding (Japan, China, United States, and European Union).</td>
</tr>
<tr>
<td>Was the prediction confirmed?</td>
<td>Yes [x]  No</td>
</tr>
<tr>
<td>Details</td>
<td>Nanotechnology research is beginning to dominate research interest among scientists worldwide. These researchers are constantly learning about new and better products that will benefit consumers; however, additional funding is needed to determine the most productive and cost-effective means of producing these products. British researchers realise that additional funding will help British industries remain competitive with other world markets as they begin to produce these new materials.</td>
</tr>
</tbody>
</table>

### BOX 1 Example of use of a ‘study guide’

‘My budget supports a major new national nanotechnology initiative worth $500 million. Cal Tech [California Institute of Technology] is no stranger to the idea of nanotechnology, the ability to manipulate matter at the atomic and molecular level, ... you will find more enduring uses for nanotechnology. Just imagine, materials with 10 times the strength of steel and only a fraction of the weight; shrinking all the information at the Library of Congress into a device the size of a sugar cube; detecting cancerous tumors that are only a few cells in size. Some of these research goals will take 20 or more years to achieve. But that is why – precisely why – there is such a critical role for the federal government in funding nanotechnology research.’ (Clinton, 2000)

Study guide

- The main idea introduced is ---
- It can be defined as ---
- An example is ---

The author elaborates on the idea by discussing the differences between --- and ---
teachers may incorporate into their courses. Teachers may wish to engage students in exploratory or first-draft writing before or after the students read and consent material. Exploratory writing helps students to collect together what they already know and connect it to what they will be reading. Essay writing, by contrast, is a more formal type of writing and requires that the students think more deeply about the subject that they are studying. Essays are usually longer and effectively integrate content information with accurate written form.

Exploratory writing

Brainstorming and clustering are exploratory strategies for pre-reading and pre-writing because they help students establish a purpose as they think about ideas and concepts they are about to study. Although brainstorming and clustering can easily be implemented at the primary level, students at the secondary levels can also benefit from these techniques.

Brainstorming activities usually involve the entire class and the teacher models the activity for the students. Brainstorming begins as the teacher presents a new topic, idea or concept to students. For example, the teacher might ask the students to suggest as many ideas as possible about the topic. As students share ideas, the teacher records them on a whiteboard, so that all students see the ideas generated. Figure 6 illustrates the response when a teacher encouraged students to list issues associated with nanoscience technology in a 5-minute brainstorming session.

Once students have listed their ideas, they can begin to organise and extend their lists into groups or clusters of related ideas. Key words or ‘nucleus’ words or concepts are identified from the brainstorming lists and are then surrounded with other associated words (Figure 7). This technique allows students to gather ideas for writing and helps them connect the ideas within categories of information.

Teacher-led clustering activities provide students with opportunities to practise pre-writing strategies. Students should be encouraged to create their own clusters for writing as soon as they understand how to use this strategy effectively.

| The impact of nanoscience affects our daily lives in numerous ways. |
| Two significant factors include personal enjoyment and personal safety. |

- Personal enjoyment
  - Music & videos
  - CDs & DVDs
- Personal safety
  - Protection against harmful ultraviolet rays (sunscreen & cosmetics)

**Figure 7 Using the clustering exploratory strategy after brainstorming ideas.**

Letter-writing campaign

Another useful exploratory strategy that can be used in content-area writing is the ‘Letter-writing campaign’. This role-playing strategy involves getting students to write letters in response to the material that they are studying. Students frequently discover that they incorporate a great deal of imaginative, interpretive and evaluative thinking as they compose their letters for a real audience. The example in Box 2 (overleaf) demonstrates how UK students used the above brainstorming/clustering pre-writing activity as a catalyst for writing a letter to the Prime Minister. In their letter, students request additional research funding to study the use of nanoscience technology in the prevention of skin cancer in the United Kingdom. Once students have completed and carefully edited the letter, it is sent off by the teacher and a reply awaited.

Response writing

Writing in response to any learning event, such as reading, a lecture or an experiment, is an important technique with real-life purposes. Response writing allows students to develop their thinking and encourages them to think about new information based upon personal reflection (Fisher et al., 2007). Professionals from all walks of life have used response writing to record everyday events in their lives and the issues that concern them (Tompkins, 1990). Response writing can be easily incorporated into science-content courses at the secondary level.
BOX 2  Example of letter writing as an exploratory strategy

Dear Mr Prime Minister

Greetings from Middleton Secondary School. We are students in Mrs Mitchell’s year 8 science course. We are studying the effects of nanoscience technology in our daily lives. We were all very excited to learn how nanoscience technology makes our lives much better. In fact, this technology improves the quality of CDs, paint on cars, cosmetics but, most importantly, creates sunscreens to protect people from the effects of harmful ultraviolet rays (UV) rays. Too many people die each year in the United Kingdom and abroad from skin cancer that develops when people are exposed to harmful UV rays. We would like to ask you, as Prime Minister of the United Kingdom, to consider spending additional money to further explore this very important link between sunscreen protection and nanoscience technology. Thank you very much for your consideration and we look forward to hearing from you very soon.

Very sincerely,

Mrs Mitchell’s year 8 science course

Middleton Secondary School

as students begin to generate ideas, create a record of thoughts in response to what they are reading and learning, and clarify ideas and issues that they are studying.

Teachers may create useful prompts to encourage students to explore a range of ideas by creating scenarios to stimulate thinking. An example of a scientific scenario builds on our previous discussion related to nanoscience technology. In this example, the science teacher assigns students with a prompt in which they assume the role of a science researcher studying the impact of nanoscience technology on the negative effects of the sun’s UV rays on humans. Students must think about ways in which they might use some of the money awarded to them (£5 million) from the Prime Minister’s Nanoscience Grant. Response-writing prompts might include the following:

- What research would science researchers need to conduct?
- What materials would they need to purchase for their labs?
- What type of support staff would they need to conduct their research?

Students may require more guided development of their response-writing efforts and can elect to incorporate free-writing guidelines or prompts (Hancock, 1993). Free-writing prompts can be easily adapted to informational texts and can include several writing suggestions.

Students who complete informational response-writing prompts have the opportunity to carefully monitor their ability to grasp complex aspects of their reading. Students are encouraged to express freely their ideas and personal responses to the readings. They can include connections to other ideas that they have previously encountered in class discussions or other readings. Students are encouraged to actively critique and monitor their own understanding of material. Informational writing responses can frequently be used to help initiate further classroom discussion or debate on a topic (Table 5).

Teachers can use student response writing as a gauge to determine whether students have a firm grasp of the content material or whether some form of remediation is necessary. Teachers can also use student response writing as a way of developing and enhancing students’ understanding of a topic through metacognitive discussions and classroom demonstrations.

Essay writing

Exploratory and response writing are useful informal tools to assist students as they explore science content that they are reading and learning about in class. Essay writing, however, is a more formal and finished production of students’ written understanding of the content. In essay writing, students are required to think more deeply about the subject matter, integrate their new knowledge with prior knowledge and express their thoughts in an organised and synthesised manner. Teachers should carefully scaffold essay-writing experiences for students by designing good essay assignments, which contain prompts that are explicit yet maintain students’ interest and curiosity.

One effective technique for encouraging writing in upper secondary science courses is the Role, Audience, Form and Topic (RAFT) essay (Holst and Santa, 1985). The RAFT writing activity is a creative way for students to demonstrate their understanding of content. RAFT assignments allow students to communicate content-related details by choosing a viewpoint other than their own, an audience other than the teacher and a form other than the standard essay. Three possible sets of roles,
Table 5: Informational response-writing prompts

<table>
<thead>
<tr>
<th>Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are my predictions while reading?</td>
</tr>
<tr>
<td>What questions come to mind while I am reading?</td>
</tr>
<tr>
<td>What are my feelings, thoughts and opinions about the reading?</td>
</tr>
<tr>
<td>What am I thinking about as I read this section?</td>
</tr>
<tr>
<td>How can I relate this reading to my own experiences?</td>
</tr>
<tr>
<td>Is this information easy or difficult to understand?</td>
</tr>
<tr>
<td>Do I want to learn more about this topic?</td>
</tr>
</tbody>
</table>

audiences, formats and topics for a RAFT based on the reading of a nanotechnology core text are suggested in Box 3 (overleaf).

Discussion and summary

Nanoscience is clearly one of the most exciting scientific concepts to date and its impact on our daily lives is significant. It should be the goal of all science educators to introduce students to the possibilities of this new and cutting-edge scientific application. In order to create this learning opportunity for students, it is imperative that curriculum materials be effectively designed so that this cognitively demanding information can be easily adapted for primary and secondary classrooms.

Currently, it is very difficult for teachers to implement reading and writing activities based on nanoscience and nanotechnology in science classrooms since curricula do not specifically address it. Curriculum materials addressing nanoscience have not yet been developed. Although curriculum developers scramble to introduce more challenging terminology and concepts in younger and younger grades, currently, there are no (widely available) science materials for primary and secondary levels that specifically address nanoscience and nanotechnology topics.

Curriculum designers must also consider the academic needs of the growing non-native speaking (NNS) students of English and adapt scientific materials and curriculum materials to meet their needs. Scientific topics geared to NNS students must be incorporated effectively into science curriculum standards. It behooves curriculum designers to incorporate effective reading and writing literacy strategies to facilitate student learning. One example of integrating effective reading strategies in an NNS science-content course would be to introduce NNS students to Closed Captioned Videos, which encourage the student to read the text captions while listening to the material. Combining reading and listening skills may prove to be useful for teaching scientific information to NNS students.

Finally, the role of adequately prepared classroom science teachers in the United States cannot be ignored (National Research Council, 1996). Teachers are the key to improving school science (National Commission on Teaching and America's Future, 1996) and their familiarity with, and knowledge of, scientific concepts is crucial in motivating and engaging students to learn more about science. Results from a nano quiz demonstrated an overall correct score of 57.3 per cent among prospective primary and secondary teachers, indicating teachers'
BOX 3 Possible scenarios for Role, Audience, Form and Topic (RAFT) essays

Composition 1

Write a set of instructions from a red blood cell (that is in the 2.5 nanometres range) to a nanotechnologist who is doing his job for the first time. Make sure the instructions tell the new nanotechnologist how to perform his job effectively (Medical News Today, 2004).

Role: A red blood cell.

Audience: A new ‘inexperienced’ nanotechnologist.

Format: A set of instructions.

Topic: How to perform the duties of a nanotechnologist effectively.

Composition 2

Write a letter of apology from a ‘jumbatron lamp’, a nanotube-based light source that uses field-emitted electrons to bombard a phosphor (Jumbatron lamps light many athletic stadia), to Sumio Iijima, who discovered a new form of carbon in 1991 – the nanotube. In 1995, it was recognised that carbon nanotubes are excellent sources of field-emitted electrons. By 2000, the jumbatron was a commercial product. As a jumbatron lamp, you will be describing possible reasons why you are not working (Nanotech Facts, 2005).

Role: A jumbatron lamp.

Audience: Sumio Iijima.

Format: A letter of apology.

Topic: Possible reasons why the lamp is not working.

Composition 3

Write a newspaper editorial from a cancer patient to the general public describing the underappreciation of the vital work done in discovering a revolutionary new form of non-invasive cancer therapy. The non-invasive cancer treatment uses a combination of harmless near-infrared light and benign gold nanoshells to destroy tumours with heat (Medical News Today, 2004).

Role: Cancer patient.

Audience: The general public.

Format: A newspaper editorial.

Topic: The underappreciation of the development of a new form of cancer treatment at Nanospectra Biosciences Inc.

lack of familiarity with some basic scientific concepts related to nanoscience (Kumar, 2006b). Without the participation of teachers in early and ongoing science literacy pedagogy, addressing nanoscience and nanotechnology information in the school science curriculum would be difficult.

Science teachers and teacher educators must spearhead efforts to introduce nanoscience and nanotechnology within their science methods classes. If prospective science teachers see how nanoscience technology is effectively integrated into the school science curriculum, they will be
more inclined to motivate and interest their students in these innovative scientific applications. This article has sought to encourage readers to apply literacy (reading and writing) strategies as one way of introducing students to the possibilities of nanoscience and nanoscience technology.

References


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David Devraj Kumar, Susanne L. Lapp, Philomena Marinaccio and Kimberly K. Scarola all work at Florida Atlantic University, College of Education, Davie, Florida.
Inducing Structure to Promote Science Literacy
Steidle, Leigh; Kumar, David Devraj; Torres, Lisette

Introduction

This paper presents a classroom based approach to inducing structure to the promotion of science literacy through integrating science and language arts with concept definition word maps supplemented with structured poetry writing (e.g., syntus) at the elementary grades. Science literacy is a national priority in developed nations as economic development of a nation depends largely on the strength of its scientifically literate workforce (President’s Council of Advisors on Science and Technology, 2010) and science, technology, engineering and mathematics (STEM) focused elementary schools “provide a unique opportunity to better connect science learning and literacy” (p. 98). However, “currently, reading and science are generally taught as distinct subject areas, and the potential for synergies between the two areas of learning are often overlooked” (p. 98). Let us explore how to resolve this oversight.

Science and language arts have many things in common. They share most thinking processes (e.g., inference, prediction, analysis). Science needs the medium of a language to be conveyed externally to another person or internally to one’s thoughts. Integrating science and language arts in classroom activities benefits students’ development, scientific thinking, and literacy skills (Kumar, 1994; Kumar, Lapp, Marinaccio, & Scarola, 2008). Creative literacy activities such as composing poetry and writing essays can supplement traditional science teaching in elementary grades. In this context vocabulary is an important factor in science literacy development for school age children. Students are introduced to many new vocabulary words and concepts at an early age. It is important that students understand what these words/concepts mean in order to comprehend what they are reading in text. Concept definition (CD) word mapping “provides a framework for organizing conceptual information in terms of three types of relationships - categories, properties, and illustrations” (Schwartz, 1988, p. 109) paving the way for a more meaningful understanding of terminologies. In science education CD word mapping has its roots going all the way back to concept mapping developed and tested by Joseph Novak and co-workers (Novak & Canas, 2009, 2008; Novak & Gowin, 1984).

Concept Mapping

and related knowledge already known. When learning meaningfully, the integration of new concepts into our cognitive knowledge structure takes place through linking this new knowledge to concepts we already understand. Thus a concept map is a graphical representation of these relationships between concepts in our cognitive structure” (n.p.) A concept map includes “concepts usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts” (Canas & Novak, 2009, n.p.) and are adaptable to a variety of subject matter content and instructional strategies. As noted earlier, for example, concept development (CD) word maps play a supportive role in helping students understand the meanings of the terminologies in science (Schwartz, 1988; Schwartz & Raphael, 1985) and help them express their understanding through creative writing activities such as composing poetry.

**Concept Definition Word Map**

Concept definition (CD) word maps (Novak & Canas, 2008; Novak & Gowin, 1984; Schwartz & Raphael, 1985; Vacca & Vacca, 2010) are an effective strategy that enables students to think about, clarify, and make meaning of new and unfamiliar concepts by providing a structure that helps individuals organize information and define, or make sense, of new information creatively. Inducing structure to develop creativity is nothing new and found in the works of William J. J. Gordon (1961) on synectics. Research has shown that when students link concepts, make connections, and see relationships between ideas, higher order thinking and comprehension take place (Oliver, 2009; Novak & Canas, 2009, 2008; Novak & Gowin, 1984; Schwartz & Raphael, 1985; Butzow & Butzow, 2000; Gordon, 1961). The CD word map allows students to brainstorm ideas and broaden their repertoire of vocabulary and concepts (Schwartz & Raphael, 1985; Smith, 2003). This advanced organizer is a tool that supports vocabulary and concept development and enhances critical thinking in the classroom. CD word maps are organized into four categories: What is it? (Meaning), What is it like? (Feeling), comparisons (Similarity), and examples (Pictorial Representations). Besides enhancing comprehension of the content and subject matter, this tool enables students to activate and build on their prior knowledge. One such CD word map developed during a class discussion on the topic “rain” by following the overall framework of Novak and Canas (2009; 2008) and Schwartz and Raphael (1985) is shown in Figure 1 (Steidle, 2013.) For example, by mapping out the words, the students are be able to see the definition of the word, examples, characteristics, as well as illustrations while exploring scientific terminologies through language arts activities such as a writing syntus, a structured form for composing poems.
Syntus

Syntus are a structured poem format that allows students to expand on vocabulary. Syntus contain five steps. Line 1-One word name of an object, event, or phenomena; Line 2-An observation of the object using one of the five senses; Line 3-A feeling about the word in line 1; Line 4-Another observation of Line 1 using one of the senses not used in Line 1; Line 5-A one-word synonym for Line 1. A sample syntu follows.

Rain
Wet and refreshing drops of water
Gloomy
Downpour, shower, rainfall
Precipitation

Activity

A lesson integrating science and language arts was taught to second graders in a local school. As students participated in the structured science and language arts integrated lesson by creating their own syntu poems, they were excited and engaged. They were able to do word association and exploration using metaphors as part of creating their own Syntus. Students brainstormed by mapping key vocabulary words (Figure 1) and applied to their poetry creation. Since the poem is individualized and student-created, it is an example of authentic work. After students created their poems, they read them to the class. As an extension, each student typed their poem in their iPads and extended it with pictures to create a keynote presentation. This allowed for the integration of technology in the curriculum. Students then shared their keynote presentations. The classroom teacher was able to assess their knowledge based on their keynote presentations. Each student received a beautiful certificate of completion which became part of their individual journals. The overall atmosphere was engaging and student-centered.

Discussion

Bringing structure to activities integrating science and language arts with CD word maps, for example in writing syntus provides students with an advanced graphic organizer that enables them to enlarge their understanding of the scientific concept, improve vocabulary and develop creativity by composing their poetry. CD word mapping is especially useful in a science and language arts integrated lesson to describe new terminologies. In light of the Florida State Standards the teaching plan may emphasize introduction of vocabulary, reinforcement of vocabulary, introduction of challenge, experiment, and presenting findings/conclusions. A comprehensive teaching plan incorporating CD word maps should help students grasp the information presented to them. The concept definition word map along with syntus is helpful by providing a structure for organizing integrated science and language arts instruction and to promoting science literacy among students.
Summary and Final Thoughts

Inducing structure to science and language arts integration with concept development word maps supplemented with syntus is one way to promoting science literacy among children. However, in an already overcrowded standardized test driven curriculum it is unfair to expect classroom teachers to buy into every teaching strategy out there on face value. The strategy discussed in this paper is easy to implement, time efficient and does not cost any additional resources other than that are commonly available in ordinary classrooms. We strongly suggest that teacher preparation programs include such strategies as part of their curriculum. Also, we suggest that despite the push for improving standardized test scores, school administrators encourage and facilitate more structure-induced integration of science and language arts strategies. We hope such efforts to promoting science literacy become a part of classroom practices in schools across the nation.

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Figure 1 Concept Definition Word Map


International Center for Leadership in Education. (n.d.) *Concept definition map* Available at: http://www.hammond.k12.in.us/article_reading/5%20CTE%20Reading%20Strategies/4%20CTE%20Reading%20Con...


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Effect of a Problem Based Simulation on the Conceptual Understanding of Undergraduate Science Education Students

David Devraj Kumar,1,3 and Robert D. Sherwood2

A study of the effect of science teaching with a multimedia simulation on water quality, the “River of Life,” on the science conceptual understanding of students (N = 83) in an undergraduate science education (K-9) course is reported. Teaching reality-based meaningful science is strongly recommended by the National Science Education Standards (National Research Council, 1996). Water quality provides an information-rich context for relating classroom science to real-world situations impacting the environment, and will help to improve student understanding of science (Kumar, 2005a; Kumar and Chubin, 2000). The topics addressed were classes of organisms that form river ecosystem, dissolved oxygen, macroinvertebrates, composition of air, and graph reading skills. Paired t-test of pre- and post-tests, and pre- and delayed post-tests showed significant (p < 0.05) gains. The simulation had a significant effect on the conceptual understanding of students enrolled in a K-9 science education course for prospective teachers in the following areas: composition of air, macroinvertebrates, dissolved oxygen, classes of organisms that form a river ecosystem, and graph reading skills. The gain was more in the former four areas than the latter one. A paired t-test of pre- and delayed post-tests showed significant (p < 0.05) gains in the water quality and near transfer subsets than the dissolved oxygen subset. Additionally students were able to transfer knowledge acquired from the multimedia simulation on more than one concept into teachable stand-alone lesson plans.

KEY WORDS: simulation; problem solving; science; conceptual understanding.

INTRODUCTION

Science and technology are areas of national interest in the United States, although international comparison studies show that American students are lagging behind other industrialized countries in science and mathematics achievements. As the National Commission on Teaching and America’s Future (1996) stated, the teachers’ knowledge and their teaching are the most significant factors that affect student learning. Therefore, to accomplish systemic reform in science education, it is imperative that classroom teachers are equipped with the knowledge and skills to teach science meaningfully to students (Kumar and Altschuld, 2003; Kumar and Crippen, 2005; Kumar, 2003). The National Science Education Standards (National Research Council, 1996) calls for giving practicing teachers the “same opportunities as their students will have to develop understanding” (p. 60) of science, and recommends professional development with more emphasis on “inquiry into teaching and learning; learning science through investigation and inquiry; integration of science and teaching knowledge; etc.” (p. 72). The Standards further recommend, “courses that are heavily based on investigations, where current and future teachers gather and interpret data using appropriate technology and are involved in groups working on real,
open-ended problems” (p. 61). In terms of technology, the Standards call for “the use of computers for the collection, summary, and display of evidence” (p. 145). An analysis of laptop computers in science learning indicates that they are used more often in secondary than middle and elementary school classrooms for presenting student work, data management, inquiry learning and problem solving activities (Kumar, 2004). A national report titled “Will New Teachers be Prepared to Teach in a Digital Age?” commissioned by the Milken Exchange on Education Technology (1999) and based on a study conducted by the International Society for Technology in Education strongly recommended the integration of information technology instruction into teacher education. From these key teacher education and science education reform documents, the following needs emerge for teacher education in science: real-world based science content and integration of technology in science teaching and learning. In this context the study attempted to answer the following question.

Does teaching science anchored in a water quality theme using a multimedia simulation effect the conceptual understanding of students in an undergraduate science education (K-9) course in the following areas; Organisms that form a river ecosystem, dissolved oxygen, macroinvertebrates, composition of air, and graph reading skills? Also, are students after using the simulation able to develop stand-alone plans useful for teaching these concepts?

DESCRIPTION OF THE SIMULATION (“RIVER OF LIFE”)

The simulation software, the “River of Life” (Sherwood, 2002, Used with permission) was developed based on contemporary cognitive research on learning, the STAR.Legacy Cycle format created by cognitive psychologists (Schwartz, Brophy, Lin and Bransford, 1999), and the National Science Education Standards. Sherwood (2002) provided the following description of the STAR.Legacy Cycle River of Life simulation. The River of Life involves the “Legacy League” characters, a multiethnic group of “twenty-somethings” whose mission is to help students tackle real-world problems and develop better attitudes toward learning. The software contains six phases. See Fig. 1 for the introductory screen.

The first phase, the “Challenge Quest,” is a video presentation of a challenge centered on a “teachable agent,” a character named “Billy Bashinal.” During a discussion on data collected on water quality, Billy’s lab partner Suzie is concerned with his conclusions and realizes his “just enough to get by” attitude towards the project. The “Legacy League” senses Billy’s attitude and convinces him to do more

![River of life introductory screen](Source: Sherwood, 2001, used with permission).
research on water quality. The software has three challenges; Macroinvertebrates and Water Quality Index, Dissolved Oxygen and Water Pollution, and the Source of the Pollution and How to Clean Up a River. In addition, factors such as pH and Temperature are part of the data based simulations incorporated into the River of Life software.

In the second phase, “Generate Ideas,” students are invited to respond to some questions the Legacy League asked Billy, and are given an opportunity to generate their own questions and ideas. Sample questions are as follows: “What’s another measure of water quality you could use to check your conclusions, a measure other than macroinvertebrates?” “How would you decide where the river is being polluted?” and “What needs to be done to clean up the pollution?”

The third phase, titled “Multiple Perspectives,” provides an opportunity to listen to the League on some of the questions. The perspectives are short “hints.” For example, “Given how little oxygen is dissolved in water, could there be any water breathing mammals?” “Keep in mind that fish are not macroinvertebrates and they are mobile. So, even if one is captured in your sampling net, it is not counted in the water quality index.” “It takes awhile for changes in water quality to appear, make sure to look at data over several months.” and “I, like most people, used to think a river was polluted if it had a lot of trash in it. Scientists don’t see it that way. A river can look beautiful but still be polluted. It is important to understand what pollution means.”

The fourth phase, “Research Resources,” involves background information about the challenge, simulations, and links to related web sites (e.g., the Walton League of America). The simulations include a sampling for benthic macroinvertebrates, the Issac Walton method of analyzing the number of macroinvertebrates and calculating water quality index (Fig. 2 and 3), and water quality measures (Fig. 4 and 5). The simulations include data based activities such as graphing data, analyzing data and making predictions and arriving at conclusions based on data involving pH, dissolved oxygen, temperature, etc. [e.g., “Which site (A, B, or C) has the lowest WQI and which has the highest for the samples you just took?” “Take a look at the graphs from previous years for sites A and B. What is the general trend for site A? Site B?”]

During the fifth phase, “Test your Mettle” students help Billy by testing themselves about their knowledge of water quality. The activities include selecting the best tool for “sampling macroinvertebrates,” “testing dissolved oxygen,” “analyzing the data from his river monitoring project for his report,” “making graphs for his report using data provided,” and “figuring out where his river is being polluted,” etc.
In the sixth and the last phase, “Go Public,” Billy's interactions with the Legacy Team, his responses to the challenges, and his analysis of data are taken into account by the classroom teacher to evaluate Billy’s progress on understanding water quality.

**THEORETICAL BACKGROUND**

The foundational principles of River of Life are as follows: (1) The use of multimedia as anchors helps to provide students with an authentic
environment for presenting information for problem solving in the form of challenges; (2) the availability of multimedia reference resources as technology-based tools for deeply exploring the problem context; and (3) the flexibility of the learner to view the problem from multiple perspectives (Cognition and Technology Group at Vanderbilt, 1992, 1993; Kumar and Sherwood, 1997; Kumar, 2005b. The pedagogical aspects of the River of Life problem solving in science are as follows. Students are posed with challenges several times over the course of the episode that enables them to be a part of the process of problem solving. The cognitive mechanisms responsible for improving problem solving are tied to the ability of the video-based simulations to provide “anchors” that can serve as “macrocontexts” (CTGV, 1993). Macrocontexts are realistic contexts that encourage the active construction of knowledge by learners. (These contrast with traditional “microcontexts” found in educational technologies of the past. Microcontexts offer students’ disconnected contexts or situations that assume that the student is simply learning from the experts.) From this perspective the River of Life simulations provide a meaningful macrocontext for students to actively construct their own knowledge.

METHOD

The study investigated the effect of science instruction anchored in water quality using the River of Life simulation software on the conceptual understanding of students in a science teacher education course.

Sample: The participants were undergraduate students \((N = 83)\) enrolled in a K-9 science education course in an ethnically diverse urban distributed public university in the southeastern United States.

The Outcome Measures: Pre-, post- and delayed post-tests were administered to the study participants. The pre-test was administered a week before students were introduced to the River of Life software. The test developed by Sherwood (2002) contained multiple choice and written response questions to evaluate knowledge in the following five topics: classes of organisms that form a river ecosystem (item #1), dissolved oxygen (items #2, 4), macroinvertebrates (item #5), composition of air (item #3), and graph reading skills (item #6). Immediately completing all three challenges students were given the post-test followed by a delayed post-test after two weeks. The delayed post-test originally developed by Vye, et al. (1998) contained 13 multiple-choice items that had been developed to measure both under-
standing of some of the basic concepts under study (water quality and dissolved oxygen) but also some items that might be considered “near transfer”. These items used multiple concepts and asked the prospective teachers to predict and outcome from a situation, not just recall an answer. An example of a near transfer item was Item 11.

“11. Imagine that you did the following experiment: You filled a small jar to the top with water. Next you put a goldfish in the jar and sealed it. Once every hour for 12 hours, you watched the fish for a minute. During this minute you counted the number of times the goldfish flapped its gills to breathe. Predict what will happen over time. Billy said that the number of times the fish flaps its gills would increase because the fish will get hungry.

(a) I agree with Billy.
(b) The number of times the fish flaps its gills will decrease because the fish does to sleep. Fish do not breathe much when they sleep.
(c) The number of times the fish flaps its gills will increase over time because there is less oxygen and the fish is gasping for breath.
(d) The number of times the fish flaps its gills will not change over time.”

The subsets of the delayed post-test follow: water quality (items #1, 2, 3, 4, 5, 6), dissolved oxygen (items #7, 8, 9, 12), and near transfer (items #10, 11, 13). The pre- and post-test data, and pre- and delayed post-test data were analyzed using paired t-test.

Lesson Plans: The participants in this study were asked to develop stand alone lesson plans on topics addressed by the simulation. Lesson plan topics included the following: Water may appear clean, but still be polluted; Macroinvertebrates are classified into three groups for water quality testing – pollution tolerant, somewhat tolerant and pollution intolerant; pH levels are an indication of water quality; Water quality must be maintained to sustain all living organisms. Behavioral objectives included identifying different types of macroinvertebrates, determining the water quality of a sample through chemical means (test kits), and calculating water quality using Isaac Walton Method and Water Quality Index.

RESULTS

The results indicate a significant gain in score from pre- to post-tests ($t = -13.44; df = 82; p < 0.05$). Also, there was a significant difference between pre- and delayed post-tests ($t = -17.72; df = 82; p < 0.05$). See Table I.

Further examination of pre- post-test item means showed significant ($p < 0.05$) gains in all areas with considerable gain item 3 (composition of air), moderate gains in items 5, 4, 1, and 2 (macroinvertebrates, dissolved oxygen, and classes organisms that form a river ecosystem), and a mild gain in item 6 (graph reading skills). See Table II.

The results also showed a significant gain from pre-test to delayed post-test ($t = -17.72; df = 82; p < 0.05$). Analysis by subsets showed that pre-test to delayed post-test gain was significantly higher for the water quality subset ($t = 18.04, df = 82$) followed by near transfer subset ($t = 16.08; df = 82$) and dissolved oxygen ($t = 12.33; df = 82$). A closer examination of delayed post-test means grouped by subset revealed that students mean scores on the water quality and near transfer subsets were the highest followed by the dissolved oxygen subset. See Table III.

Student lesson plans on various topics addressed by the simulation were evaluated by two faculty members (science and science education). Overall the lesson plans showed originality, ability to transfer knowledge acquired from the simulation to K-9 classrooms with no access to the simulation, and strategies for including students with disabilities and students with limited English proficiency. In several lesson plans, students made connections to local resources and websites on water quality related topics.

An analysis of lesson plans using the National Science Education Standards found that about 55–70% of the lesson plans addressed Content Standards A (Science as Inquiry), C (Life Science) and F (Science in Personal and Societal Perspectives), 20–35% addressed Content Standards E (Science and Technology) and B (Physical Science), and G (History and Nature of Science).

Table I. Pre-Test, Post-Test and Delayed Post-Test Means as Percentage of Total Points Possible ($N = 83$)

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>38.86 (16.73)</td>
</tr>
<tr>
<td>Post-test</td>
<td>75.30 (19.14)</td>
</tr>
<tr>
<td>Delayed post-test</td>
<td>83.97 (17.87)</td>
</tr>
</tbody>
</table>
DISCUSSION AND SUMMARY

The results of this study must be interpreted with caution due to limited sample size. There was a significant gain in student performance from pre-test to post-test using the water quality simulation River of Life. More specifically, teaching science anchored in a water quality theme using a multimedia simulation significantly affected the conceptual understanding of students in an undergraduate science education (K-9) course in the following areas: composition of air, macroinvertebrates, dissolved oxygen, classes of organism that form a river ecosystem, and graph reading skills. Especially, a considerable gain was noted in the conceptual understanding more in the former four topics than the latter one. The gain from pre-test to post-test was more significant in the conceptual understanding of composition of air than the rest of the items. In the delayed post-test water quality and near transfer items were found more significant than dissolved oxygen. Students were able to do near transfer problems involving more than one concept on the delayed posttest successfully. Additionally, students were able to transfer knowledge acquired from the multimedia simulation on more than one concept into teachable stand-alone lesson plans useful for teaching without the simulation.

Multiple studies and reports have raised concern in regard to the level of science and mathematics needed by elementary teachers to successfully teach these topics in elementary school (e.g., Allen, 2003; Kumar and Morris, 2005 for a review) and the need for all teachers to be “high qualified” by the NCLB act has raised the stakes for many teachers and school systems. Ecological concepts are a staple of elementary science and are prominent in the NSES document. As a vehicle to develop prospective teachers’ understanding of some of the core principles of water quality and allowing them to see technological applications, computer simulations such as the River of Life appear to be effective. Time limitations often prevent instructors of science methods courses from taking students to field settings where data can be collected, just as time considerations are an issue for classroom teachers in their science instruction. Using simulations allows for data analysis and concept development in an environment that makes maximum use of available time.

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Nanoscale Science and Technology in Teaching

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Abstract

A study of prospective teachers' general knowledge of nanoscale science and technology is reported. A voluntary sample of 109 prospective teachers in an undergraduate science education course participated in the study by responding to a ten-item questionnaire. The items demanded various types of knowledge of nanoscale science and technology such as etymology, chemical ingredients of materials such as sunscreens, and an understanding of physical scale. The average score for all ten items was 6.13 (SD = 1.34). The study revealed a lack of understanding of the underlying physical scale of nanoscience and nanotechnology, and the etymology of the term "nano" among prospective teachers.

Nanoscience and Nanotechnology

A study of the nanoscale science and technology knowledge of students (prospective teachers) in several sections of an undergraduate science education course is reported in this paper. Nano refers to dwarf, sizes of the order of one-billionth of a meter. Nanoscience refers to the scientific study of materials one billionth of a meter in size, and nanotechnology refers to various technologies to produce materials of extra high precision and dimensions on the scale of one-billionth of a meter (The Royal Society, 1994; National Science and Technology Council (NSTC Committee on Technology, 1999)). Nanotechnology is of great interest to researchers, business and governments around the world, and its impact is felt in almost all areas of life. For example, in 1971 it cost 10 cents to manufacture a computer chip containing 2,300 transistors with clock speed 0.8 million cycles/second (Semiconductor Industry Association, 2003). By 2003 the cost of manufacturing a computer chip (e.g., Pentium) containing 108 million transistors with clock speed 3,000 million cycles/second was 1/1000 cents thanks to developments in nanotechnology. The number of articles (registered by Institute for Scientific Information) with "nano" as a topic increased from approximately 60 in year 1995 to over 3000 by year 2004 (Kumar, 2006). Nanoscience and nanotechnology are areas of great interest in developed as well as developing nations.

Relevance to Science Teaching

The field of nanoscience and technology provides teachers the opportunity to develop motivating and engaging interdisciplinary learning experiences for students. "It brings a new excitement to many subjects. Students see amazing applications that result from nanoscience, and learn that an understanding of basic science is necessary to make them happen. For example, CD's wouldn't exist without nanotechnology; neither would the new color changing paints on luxury cars and motorbikes; transparent sunscreens and many new cosmetics use nanoparticles; the technology behind stay-clean chinos (and even now school uniforms) is nanotechnology. These developments depend on a fundamental knowledge of chemistry, physics and biology." (How is the Nanotechnology Relevant to the Scottish School Curriculum? n.d., p. 1).

Yet, as the National Commission on Teaching and America's Future (1996) stated, the teachers' knowledge and their teaching are the most significant factors that affect student learning. Therefore, to accomplish systemic reform in science education, it is imperative that classroom teachers are equipped with contemporary knowledge to teach science meaningfully to students (National Research Council, 1996). In this context the study attempted to answer the following question: What general knowledge do undergraduate science education (K-9) students have about nanoscale science and technology?

Method

The study implemented the Nano Quiz (Appendix 1) containing ten multiple-choice items used with permission from the National Institute of Standards and Technology (U.S. Department of Commerce, n.d.). The purpose here was to gauge the general knowledge level of study participants about nanoscale science and technology. No discussion on nanoscience and nanotechnology took place prior to administering the quiz.

Nano Quiz item 1 deals with the etymology of the prefix "nano" which means dwarf and has both Greek and Latin roots (NSTCCT, 1999). Item 2 requires an abstract understanding of perception of distance and an ability to make logical comparisons. One billion millimeters equals 1,000 kilometers or about 620 miles. Item 3 requires an understanding of sizes of atoms and especially an abstract understanding of the perception of width. For example, a hydrogen atom has a diameter of 1/10 nanometer (NSTCCT, 1999). A general knowledge of the chemical composition of day-to-day materials such as sunscreens is required for answering item 4. Other related information includes stain resistant nanowhiskers coated on khaki pants, nanoparticles used to seal certain tennis balls, and nano films used on read heads in computer hard drives. It should be noted that for items 5, 6, 7, 9, and 10 the respective terms “nanonewton,” “qubit,” “flying qubit,” “self-assembled monolayer,” and “spintronics” are not often addressed in the science content courses taken by prospective teachers. According to the National Science and Technology Council Committee on Technology (NSTCCT, 1999) a nanonewton is one billionth of the force needed to hold 20 nickels against the force of gravity. Qubits in quantum information processing represent bits at nanoscale capable of holding large amounts of information spanning from 0 and 1. Photons used to...
process quantum information represent flying qubits. Self-assembled monolayers are uniform single layers formed as a result of atoms or molecules spontaneously attaching to specific surfaces. Spintronics represent the use of pattern (up or down) electronic spins to process information. Item 8 demands knowledge of a collection of atoms doing the same thing the same time and the Nobel Prize winning history behind the Bose-Einstein Condensate.

**Sample**

The participants were student volunteers (prospective teachers, $N = 109$) enrolled in several sections of an undergraduate science education course in an ethnically diverse urban university in the southeastern United States.

**Results**

The average score for all ten items was 6.13 ($SD = 1.34$). Scores for items 5, 6, 7, 8, 9 and 10 were above 60%. For item 4 the respective score was below 60% but above 40%. The scores for items 1 and 2 were between 25% and 40%. The score for item 3 was far below 25%. See Table 1 for a summary of Item Response Distribution, Item Difficulty, and Point Biserial Item Discrimination results.

**Discussion and Recommendation**

The findings must be interpreted with caution. Some of the items require an abstract knowledge of the underlying physical scale of nanoscience and nanotechnology. Though most of the items on the quiz required knowledge of the etymology of the terminology used in nanoscale science and technology, item 1 registered an item difficulty of 0.275. See Sarma (2006) for details on etymology. Items 2 and 3 dealt with physical scale and had item difficulty values 0.257 and 0.073 respectively. Especially item 3 required knowledge of the diameter of hydrogen atom. The distracter in item 5 “a miniature pop singer,” “a tiny lizard,” and item 7 “a prehistoric bird,” seem rather easy to eliminate.

It is recommended that science teacher education programs provide prospective teachers indepth opportunities to discuss and develop cognitively engaging and motivating ways of teaching nanoscale science and technology. Particular attention must be paid to the etymology of science and technology terms and the physical scale upon which the field of nanoscience and nanotechnology is developed.

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**References**


Appendix 1: Nano Quiz Items and Multiple Choice Responses

1. The prefix “nano” comes from a Greek word meaning ________________
   a) billion;  
   b) dwarf  
   c) invisible  
   d) infinite

2. If a nanometer were about as big as the width of a pinhead, about how long would a meter be?
   a) as long as the pin shaft  
   b) as long as a ladder  
   c) as long as a blue whale  
   d) as long as a trip between Washington, D.C., and Atlanta, Georgia

3. How many hydrogen atoms lined up “shoulder to shoulder” would fit in a one nanometer space?
   a) less than one  
   b) ten  
   c) 1 thousand  
   d) 1 billion

4. Which of the following products contain nanoscale manufactured parts or materials?
   a) sunscreen  
   b) khaki pants  
   c) tennis balls  
   d) devices that read computer hard drives  
   e) all of the above

5. What is a nanonewton?
   a) a new kind of cookie  
   b) a miniature pop singer  
   c) approx. amount of force required to break a single chemical bond between two atoms  
   d) a tiny lizard

6. What is a qubit?
   a) a unit of measure used in ancient Egypt  
   b) a cover for the tip of the stick used in billiards  
   c) a unit of information that takes advantage of the laws of quantum mechanics  
   d) a pair of atoms used to store digital information

7. What is a flying qubit?
   a) a prehistoric bird  
   b) a muon  
   c) a photon used to transport quantum information  
   d) a gluon

8. What is a Bose-Einstein Condensate?
   a) a new type of “smart” speaker that works under water  
   b) a collection of atoms doing exactly the same things at exactly the same time  
   c) a lumpy gray substance invented by Bose and Einstein  
   d) a physics “Holy Grail,” achieved in 1995, leading to a Nobel Prize in 2001  
   e) b and/or d

9. What is a “self-assembled monolayer”?
   a) atoms or molecules that spontaneously form uniform single layers  
   b) a type of clothing that gets thicker in response to colder temperatures  
   c) an optical device that puts itself together  
   d) a fuzzy logic circuit

10. What is spintronics?
    a) using the spins of electrons to carry information  
    b) electronics made of textiles  
    c) a rock group  
    d) a type of dance music

(Correct Responses: 1 b, 2 d, 3 b, 4 e, 5 c, 6 c, 7 c, 8 e, 9 b and/or d, 10 a.)

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