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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Of the oxygen added to the atmosphere each year, only 30% comes from land plants. Plankton in the sea contributes the majority 70%.

Science Story

The stories in this regular section of *SER* may be used to enrich lessons and make them more interesting.

Eugenics in the United States

A consideration of morals and ethics should play an important role in science education. Being a human activity, science is strongly influenced by cultural and personal biases and, like all things humans do, can be used for good or bad.

Stories like the following, of how scientists and others can be morally blind in relation to ethical issues, and how political ideas contribute to science, can inform this discussion. In so doing, they can help us address contemporary questions such as who should make decisions about stem cell research, and upon what basis.

During the early 1900's, eugenics was popular in many countries, including the United States where 30 states eventually passed associated laws. Many believed that, in order to improve offspring, disabled persons and persons who were morally or socially deficient should not be allowed to reproduce, and such beliefs also led to laws in the U.S. banning interracial marriages.

In 1927, the state of Virginia began action to forcibly sterilize Carrie Buck, a rape victim who had been placed in an institution by her foster parents to hide her out-of-marriage pregnancy. The U.S. Supreme Court subsequently ruled in favour of the

Virginia law. Hitler's supporters used this court ruling to support their own atrocities.

Sterilization laws existed in the U.S. till the 1970's, facilitating over 60 000 forced procedures. May 2002 was the 75th anniversary of the Supreme Court ruling in the Carrie Buck case, and at that time the state of Virginia became the first state to apologize for the sterilizations it had forced.

Source: Moore, R., Jensen, M., Hsu, L., & Hatch, J. (2003). Lessons of history: Ethics & the public's views of science & society. *The American Biology Teacher, 65*, 85-89.

Students Enjoy Chemical Sensation

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Abstract

This exciting new way of teaching high school / college chemistry combines music, visual aids, and chemical experiments in multi-sensory lessons that motivate students and provide them with meaningful learning experiences in science. The method, known as the Chemical Sensation Project, acknowledges that some individuals learn by seeing or hearing, and others learn by actively performing activities, so it incorporates diverse learning styles to meet the needs of all students.

Introduction

Chemistry educators and researchers Dana Barry and Hideyuki Kanematsu have developed a multi-sensory approach for the teaching of chemistry (Barry, Kanematsu, Shimofuruya, & Kobayashi, 2003). Their method, known as the Chemical Sensation Project, combines music, visual aids, and chemical experiments into captivating and enjoyable science lessons (Barry, 2003). It also incorporates a variety of teaching styles to meet the needs of all students, including those with disabilities.

The project contains songs which address many topics in chemistry, a sketch / visual aid to accompany each song, two chemical experiments to complement each song, and evaluation forms, which provide both students' and instructors' reactions to the program and learning results. These materials were prepared by Dana Barry and translated into Japanese by Hideyuki Kanematsu. Tatsumasa Kobayashi and Hiroshi Shimofuruya, Suzuka National College of Technology, Japan also provided assistance. The program is sponsored by the Northern New York Section of the American Chemical Society and by Suzuka National College of Technology.

The program's chemistry songs (titled "Organic Chemistry," "Acid Verses Base," "Chemicals," "Matter and Energy," "Fission and Fusion," "Science Is," and "Periodic Table") (Barry, 1996) were included in the popular science education television series *Sensational Science*, which aired in New York State in 1996-1997. These songs and their complementary chemical experiments cover many topics in chemistry. Science activity titles include "Hydrocarbons," "Functional Groups," "pH and Indicators," "Acids and Bases," "Chemicals," "Bonds," "Half-Life," "Helium and other Gases," "Cooking," "Walking," "Mixtures," "Surface Tension," "The Human Atom," and "Periodic Table of Items" (Kanematsu, Shimofuruya, Barry, & Kobayashi, 2002). These activities will be included in a science book to be written by the authors of this article.

Participants begin the Chemical Sensation program by viewing a picture/visual aid and the words to a selected chemistry song, while listening to the song. The words to the songs are written on handouts and overhead transparencies. They then perform the exciting chemical experiments. Finally, they answer chemistry questions related to the activity and complete the evaluation forms.

An Example Lesson

The following multi-sensory lesson complements a high school chemistry unit on bonding. The students begin by singing the song "Chemical Bonds" to the tune of "My Bonnie." In addition, they view a three-dimensional model of sodium chloride or a picture displaying different bond types. The class then performs the enjoyable bonding activity, which provides concrete examples for the senses of seeing, touching, and so forth.

Chemical Bonds

Bonds hold things together.
They may be weak or strong.
Energy is released when they form.

The sharing of electrons,
forms bonds,
covalent bonds.

The attraction of ions forms bonds,
ionic bonds,
ionic bonds.

Oh, bonds hold things together.

Bonds

Question

How are chemicals held together?

Information

A chemical is held together by a bond. Covalent bonds are made by the sharing of electrons. Ionic bonds are made by the attraction of oppositely charged ions (charged atoms), such as in sodium chloride (table salt).

Activity

Simulate the stretching of bonds. You will need the following materials: a metric ruler, a cotton ball, a small rubber band, a caramel or gummy candy, a piece of gum, and any other items provided to test. Please record all data on a separate sheet of paper.

First measure and record the length of each item in its original form. Then stretch each item up to its breaking point (i.e., till it just breaks). Measure the length of each stretched item and record it. Identify the item that stretches the most.

Extension

1. Simulate an ionic bond using two magnets. Let the magnets represent oppositely charged ions. *Hint:* Opposite poles of a magnet attract and like poles repel.

Use a magnifying glass to closely examine some table salt (sodium chloride), a chemical with ionic bonds. In this chemical, the sodium is a positive ion and the chlorine is a negative ion. Record your observations. Next add one teaspoon of table salt to a paper cup filled with water and stir. What happens? Why?

2. Make models of compounds such as methane (CH_4) and ethene (C_2H_4). Refer to chemistry reference tables and books containing structure / bond information for assistance. Use chemistry model kits or gumdrop candy of different colors and toothpicks. Let black gumdrops represent carbon and white ones be hydrogen. Use the toothpicks to simulate covalent bonds. Keep in mind that methane (natural gas) has single covalent bonds whereas ethene (a gas also known as ethylene) has a double bond.

Evaluation

The Chemical Sensation Project has been successfully carried out at Clarkson University, Edwards-Knox High School, and Canton High School in the United States and at Suzuka National College of Technology, Takada High School, and Kanbe High School in Japan. Students using the multi-sensory approach learned chemistry. After each lesson, they were required to answer questions, which were developed to provide educational feedback about the program. For the student participants in the U.S., 94% of the Canton High School students, 100% of the Edwards-Knox High School students, and 100% of the Clarkson University students answered the questions correctly.

Students in the United States and Japan enjoyed learning chemistry through the project. They gave the program's theme (the combined use of chemical experiments / activities and songs) a good rating. The evaluation results of Table 1 show that students found the theme creative and pleasing. A "neutral reaction" in our study refers to one in which the student has a feeling of indifference. A "very positive reaction," for example, is one in which the student thinks the approach is great. The other possible extreme reaction is "very negative." This would indicate to us that the student did not like the song or activity.

Table 1
Student Reactions to the Combined use of Chemistry Activities and Songs

Organization	Number of students	Category of reaction			
		Creative		Positive	
		Very creative reactions (%)	Neutral reactions (%)	Very positive reactions (%)	Neutral responses (%)
Clarkson University (US)	28	89	4	82	14
Edwards-Knox High School (US)	20	95	0	95	5
Canton High School (US)	21	81	14	76	14
Total for three US organizations	69	88	6	85	11
Suzuka National College of Technology, Japan	47	72	14	71	23
Takada High School, Japan	56	84	16	82	11
Kanbe High School, Japan	39	72	23	79	13
Total for three Japanese organizations	142	76	18	77	16
Total for both US and Japanese organizations	211	82	12	81	13

In addition, of the high school student participants in the U.S. (Canton High School and Edwards-Knox High School), 86% had a neutral or very positive reaction to the songs and 93% of them had a neutral-very positive reaction to the activities. Of the Japanese high school student participants (Takada High School and Kanbe High School), 88% had a neutral-very positive reaction to the songs and 92% of them had a neutral-very positive reaction to the activities. Of all college student participants (Clarkson University, U.S. & Suzuka National College of Technology, Japan), 79% had a neutral-very positive reaction to the songs and 99% of them had a neutral-very positive reaction to the activities.

In addition to the students, the instructors and administrators hold this program in high esteem. The instructors said that the chemical experiments were exciting, useful, and meaningful to the students. They liked the music component and believed it to be educational, entertaining, and relaxing. Mr. Goto, Principal of Kanbe High School, Japan said that the music component of the program is a great idea. He believes that the songs relax the students and prepare them for the exciting activities in chemistry. Mr. Jeffrey Davis, Principal of Edwards-Knox High School (US) said the program works well and that its multi-sensory approach is a fascinating concept.

References

Barry, D. M. (Composer). (1996). *Chemical sensation with the Barry Tones* [CD]. New York: Author. (This CD may be purchased, for USD 8 plus handling and shipping, by contacting Dana Barry at dmbarry@clarkson.edu .)

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Demonstration

While the activities in this section of *SER* have been designated demonstrations, they might easily be structured as hands-on student learning experiences. While some sample lesson sequences have been included, the notes provided both here and in the following *Student Experiments* section are meant to act primarily as stimuli for classroom activities and to provide teachers with background information, so please modify any sample pedagogy as you see fit.

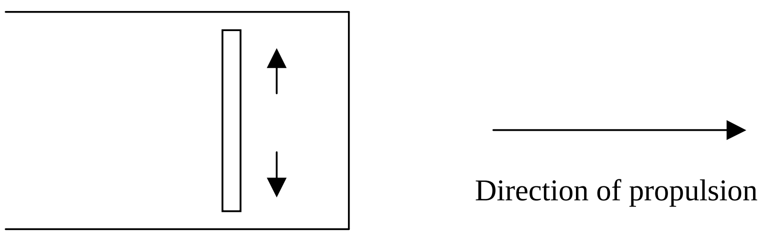
The Rocket Principle

Needed. Balloon, cardboard shoe box (the removable lid is not needed), scissors, and wooden dowel.

Inflate the balloon and release it. Invite students to explain why the balloon moves around in the air. After surveying their responses, ask if the balloon would be similarly propelled if it was released in a vacuum.

It is not uncommon for students to incorrectly think that the balloon, just like a rocket, moves because the gas expelled from it pushes on the air outside (the action) and that, in accord with Newton's Third Law of Motion, the outside air pushes back on the balloon (the reaction) and propels it forward. While it is true that the expelled gas does push on any air that may be outside, and that this air does push back on, and slows down, the expelled gas, this does not explain why a rocket moves forward, as evidenced by the fact that a rocket works fine in a vacuum. When released in a vacuum, the inflated balloon would also be propelled along.

Explanation. To prepare our model, place the shoe box on the desktop with its open top upwards. Cut a piece of dowel so its length is somewhat shorter than the width of the box, as shown.



Before the inflated balloon is released, the gas particles inside it are moving around quickly, colliding with the inside wall of the balloon and rebounding from it. These collisions cause the balloon to be pushed out equally in all directions, as simulated by oscillating the dowel backwards and forwards firstly across the box, and then along its length. The impacts of the dowel on opposite walls of the box balance, and there is no overall movement of the box.

To simulate rocket propulsion, cut the two vertical sides of the left-hand end of the box, and fold this end down so it lies flat along the desktop, thus giving the box three vertical walls only. Repeat both movements of the dowel inside the box. This time, with no wall on the left side, the collisions of the dowel with the right-side wall cause the box to move (be propelled) along the desktop.

Balloon propulsion does differ from rocket propulsion in that the air particles are pushed out of a balloon by the contracting balloon rubber, whereas in a rocket the gas is exhausted as a result of the rapid expansion of the very hot particles. Nevertheless, it is collisions of the gas particles inside with the front wall that provides the propulsive force in both cases. In terms of Newton's Third Law of Motion, the action is the front wall pushing backward on the gas particles, and the equal and opposite reaction is these gas particles pushing forward on the front wall. It is this latter force that we call the thrust of a rocket.

Student Experiment

Reminder: Appropriate risk assessment, supervision, and guidance are necessary.

Count a Million!!

Contributed by: Graeme Abbott, ABA Books Ltd http://www.ababooks.co.nz

Needed. Graph paper (1-mm squares), cardboard or hardboard, ballpoint or felt marker pen, and drop of water.

Introduction. Here is a simple exercise involving counting, estimation, and mathematical proportion that I have found appeals to students from Years 9-13. The aim of the exercise is to give students an appreciation of the enormity of some of the numbers that scientists have to grapple with, like the distances between objects in the universe or the number of water molecules in a drop of water.

What to do. Please follow these steps.

1. Paste some sheets of graph paper containing 1-mm squares onto a sheet of cardboard or hardboard, so that the whole pattern occupies 1 metre square (i.e., the board contains 1000 x 1-mm squares along each side and hence 1 million squares in total).
2. Isolate any 1-cm square on the board by drawing a line around its periphery, thus isolating 100 millimetre squares.
3. Time a student to place a dot, using a ballpoint or felt marker pen, into each of these 100 millimetre squares as fast as they can. (As a sideline, this could be turned into a group / class competition to find the fastest dot maker!) *Note:* Even though you have 10 000 x 1-cm squares to choose from, if you don't want the board to get marked, you could place some transparent plastic over the 1-cm square and use a felt marker pen.
4. Once the students have timed themselves to place 100 dots in the square, get them to guess how long it would take to place a dot in each of the million 1-mm squares on the board if they were "going dotty" at the same consistent rate.
5. Now get the students to repeat the previous step, but this time to use calculation to estimate how long it would actually take. Some students will find the answer to this quite amazing.

6. Extract one drop of water, on the end of your finger, from a beaker of water, the end of a water tap in the lab, or even the saliva in your mouth (which is mainly water and slightly dramatic!). Ask the students to guess how long they think it would take them to count the number of water molecules in that drop of water if they could count at the same rate as they put dots in the 100 x 1-mm squares. After being shown how to estimate this time, they will be astounded by the result. (More senior students will be able to do the calculation for themselves.)

Sample result and calculations. Time to place 100 dots in the 1-mm squares = 30 s. Time to place 1 000 000 dots on the board = (30 x 1 000 000/100)/(60 x 60 x 24) days = 3.5 days!

Take the volume of one drop of water to be 0.1 mL, having a mass of 0.1 g. One mole of water (18 g) contains approximately 6 x 10^{23} water molecules. Hence, one drop of water will contain (0.1/18) x (6 x 10^{23}) molecules = 3.3 x 10^{21} molecules. The time to count these molecules, at the rate of 100 molecules every 30 s, will be (3.3 x 10^{21}/100) x 30/(60 x 60 x 24 x 365) years = 31 million million years!!

Conclusions. Highlight the fact that one million is a large number. One million things is a lot of things, and especially if it is dollars! How often, if ever, have children appreciated one million of anything? The graph idea is a simple way to generate one million items that children can actually visualise.

So when students stand back far enough to see the whole board, they are looking at 1 million 1-mm squares, but can they identify any one particular square? Probably not. Similarly, imagine that there are 1000 rows of 1000 people (i.e., 1 million people) all standing huddled up in a square. If Peter is standing with a red hat on, and Jan travels up high enough in a helicopter so that she can see the whole mass, would she be able to pick out Peter? Once again, probably not.

Ask students what they can conclude from their final calculation. If it would take 31 million million years to count the number of water molecules in one drop of water, and there are millions of water molecules in one drop, then those molecules must be incredibly small!

To put this counting time for the water molecules in one drop of water into the context of the graph board, one would need 31 million 1-m square boards, covering an area of 31 km^2 (a rectangle more than 6 km long and 5 km wide)!

Developing Critical Thinking Skills Through the Use of Guided Laboratory Activities

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Abstract

In a study to evaluate an approach for improving the critical thinking skills of middle school science students, 60 students were given the assignment of completing three guided laboratory activities and writing a report for each. In writing their reports, students were expected to identify the manipulated variable, identify the responding variable, write a statement of the problem, make a prediction, display the data in a well-organized table, depict the data from the table in a graph, and write a conclusion that showed how the data supported or refuted the prediction. Higher level thinking skills demonstrated by such tasks included analysis, synthesis, and evaluation. The student laboratory reports were evaluated using a comprehensive rubric. It was found that repeated use of the guided laboratory activities produced remarkable improvements in students' higher-level thinking skills.

To read the full text of this article (13 pages), please **click here**.

Science Poetry

Reading and/or listening to poems that have been composed by other children their own age can inspire and reassure students as to their ability to understand, and write, poetry, and the science poems in this regular section of *SER* may be used for this purpose. Please find information about the *International Science Poetry Competition* at http://www.ScienceEducationReview.com/poetcomp.html .

Oxygen

With water oxygen gives us life,
Without it we would be in strife.

We depend on it to keep us living,
It comes from trees that are giving.

You can't see it, you can't taste it,
You can't touch it, you can't waste it.

Oxygen is in the air,
Oxygen is EVERYWHERE!!!!

Ashley Campbell, Year 5
Australia

Cells

Cells make living things,
From elephants to bee stings.
From monera to mammals, they all have cells,
Decomposers break them down and that's what smells.
Cells make organs, tissue and bones,
But not man-made things like mobile phones.
Cells divide and make things grow,
But they decide and we don't know.
Cells can't make a thing like a knife,
But they are important and needed for life.

Waide Cross, Year 7
Australia

Students' Alternative Conceptions

Students' alternative conceptions have been variously called misconceptions, prior conceptions, preconceptions, preinstructional beliefs, alternative frameworks, naive theories, intuitive ideas, untutored beliefs, and children's science. The tasks in this regular section of *SER* are based on the literature and may be used at the beginning of a constructivist learning segment to arouse the curiosity of students and to motivate them, while simultaneously eliciting their ideas or beliefs. They are designed to address areas about which students are likely to have an opinion, based on personal experiences and/or social interactions, prior to a specialist learning sequence, or areas that might be considered important for the development of scientific literacy.

1. For each of the following, please indicate whether you *agree*, *disagree*, or are *not sure*.

    a. When ice melts, the particles making up the resulting water have the same size and shape as those in the original ice.
    b. Most materials expand when heated. This is because the particles that make up these materials get larger.
    c. Water evaporates only from bodies of water like a lake or ocean.

Comment. Statement a is the only correct one. Students answering *true* to item b will include those who attribute macroscopic properties to the microscopic level. Textbook diagrams of the water cycle commonly show the evaporation arrow coming from a large body of water, and this may contribute to misconception c. Water can, of course, evaporate from many things, including the ground, animals, and plants.

Please send to *SER* any suggestions you may have, based on your own experience or the literature, for adding to or otherwise modifying the items in this task.

Cardiac Baseball: A Questioning Game

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Asking questions in science is a critically important skill (Goodman & Berntson, 2000). Questioning allows teachers to check for understanding, obtain information, and provide indirect cues (Columbia, 2001). Questioning provides a fairly effortless method of monitoring student progress on an ongoing basis and a means to detect problems at an early stage. Research suggests teachers in science may average as high as 150 questions per hour (Berliner, 1989). Teachers who average a high rate of questioning ask questions that are meaningful, assessable, short, and leading to the point (Goodman & Berntson, 2000). Many times teachers, especially beginning teachers, have trouble finding ways to incorporate an appropriate amount of questioning into a lesson while maintaining student interest. One way to incorporate a high rate of questioning into a lesson is through the use of a game.

Background

Cardiac Baseball is a classroom game that simulates real baseball. The author has used Cardiac Baseball in beginning university level undergraduate human anatomy and physiology classes to review the cardiovascular system. The name of the game and type of questions asked can easily be modified to accommodate any subject or level of schooling. A full nine-inning game can take up to two 50-minute class periods to complete.

Pre-Season Preparation

Before the game can be played, the teacher must write 120-150 questions on Microsoft PowerPoint or overheads to accommodate a nine-inning game. Questions in multiple-choice, true/false, and short answer format allow for quicker game play. Be sure not to write questions beyond the level of content mastery of the students. Bases can be cut out of construction paper or rubber bases can be borrowed from a cooperative physical education department for use during game play. Next, prepare small slips of paper with base hit numbers that can be folded and placed in a hat. For close simulation of real game statistics, four slips should be singles (1B), three should be doubles (2B), two should be triples (3B), and one should be a homerun (HR). Finally, alert the students to the fact that they will be playing a questioning game and that they all will be expected to participate for their team.

Game Day Set-Up

On game day, bases should be set up in a baseball diamond pattern, with home plate facing the projection screen. Be sure that the questions can be clearly projected against the screen so that all students can see them. Prepare a score card with spaces for team names, innings, runs, and hits. This can be done informally against a chalk or marker board, or on construction paper, and hung up on a wall. Place the slips of paper with base hit numbers in a baseball cap and mix them up. Divide the class into two even teams and have them pick team names.

Rules of the Game

The teams have been chosen and its time to play ball. The first student in seating row order for the team at bat must step-up to home plate and face the screen. The teacher projects the question onto the screen and the student must provide an answer without help from their teammates. If the students answer is incorrect, it is considered an out. If the student answers correctly, they have made contact with the ball. At this time, the opposing team must play defense. The next student in row order for the opposition must field a question. If the student answers correctly, they have fielded the ball cleanly and thrown the runner out. If they answer incorrectly, the team at bat gets a hit. The batter must close their eyes and choose a slip of paper from the baseball cap. They are allowed to advance to the base indicated on the slip and the next batter comes up to the plate. This continues until there are three outs in the inning, and then the teams switch.

Special Rules

Double Plays. In a double play situation, the team at bat has a runner at first base and the player at the plate has made contact with the ball. If the fielding team answers their first question correctly, they get to answer a second question to complete the double play, thus resulting in two outs for the team at bat.

Sacrifice Flies. If the team at bat has a player at third base with less than two outs and the player at bat makes contact with the ball, but is thrown out by the fielding team, the team at bat has the option of sending the runner to home plate. If this option is chosen, the fielding team must answer a question. If they answer correctly, the player is thrown out at the plate. If they answer incorrectly, the player is safe at the plate and it is a run for the team at bat.

Base Stealing. If the team at bat has a runner on first or second, they may chose to have the runner attempt to steal a base. If the fielding team answers a question correctly, the runner is thrown out attempting to steal. If the fielding team answers the question incorrectly, the runner has safely stolen the base.

Conclusions

Researchers have stressed the importance of asking students questions in science. Cardiac Baseball is a game that makes answering questions fun. It is a game that can be easily modified for use at any level and in any subject area. A teacher can add new rules and make modifications in order to add their own personal touch to the game. Overall, it is a game to have fun with as a teacher and as a student.

References

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Goodman, L., & Berntson, G. (2000). The art of asking questions: Using directed inquiry in the classroom. *The American Biology Teacher*, *62*(7), 473-476.

Teaching Techniques

This regular section of *SER* describes thinking, cooperative learning, and other teaching techniques.

Paired Interview

The paired interview is very useful for monitoring student progress on a task, such as preparing a library research report or writing an essay. At the same time, students gain practice in oral and written communication.

During the process of completing the task, students form pairs and interview each other about the progress the other has made to date. Questions might include: “What have you done so far?” “What problems are you experiencing?” “How do you plan to solve them?” “What do you plan to do next?” Students may be involved in designing the questions used for a particular task. Each interviewer takes notes during the interview and uses these to write a brief report about the progress of the other. The reports are then submitted to the teacher.

Tactile Tools in the Classroom

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We all know students who drive the teacher, or other students, crazy by fiddling in the classroom. These students are the pen clickers, those who tap pens or fingers on desks, tear up paper, doodle throughout the class, fiddle endlessly with equipment, and who are often without any conscious awareness that they are doing so. When we ask them to stop, they look at us in amazement and ask: "Stop what?" These students are tactile learners, and one excellent way to help them in the classroom is to provide tactile tools they can use, instead of resorting to some of the more irritating and noisier strategies they come up with on their own.

If the teacher has a bag, or basket, of small, squeezy balls of different shapes and textures, plastic tangles, koosh balls, balloons filled with grain or flour, rubber worms, or even small stuffed animals (yes, even high school students will use these)--anything that is small, maleable, and textured--it will stimulate the huge concentration of sensory nerve endings in the palms of the hands and fingers and enhance learning. When these sensory nerve endings are stimulated, information feeds into the cortex, waking up the brain and enabling these children to learn. Some students may find that all they need is a tactile tool to hold and play with in class for their learning and retention of material to increase enormously.

Naturally, you will need to provide parameters for the use of tactile tools in class. The first parameter is that it does not interfere with anyone else's learning, or disrupt the classroom (e.g., no throwing of objects high into the air, or at anyone else, to distract others). Also, the student's learning must improve, otherwise there is no point in continuing to use the tool.

Novelty may lead many students to experiment with the tactile tools when you first introduce them into the classroom. However, you will find that only those students who really need them for learning will continue to use them after the first week or so.

You may be surprised at the difference such a small thing can make in class. Teachers with whom I have worked all over the world have found that classroom learning has improved, that students are happier, and that they find teaching easier after simply introducing these tools into the classroom. They are cheap and easy to obtain, and often students will provide their own once they realize their value. Best of all, it works for any age group.

Ideas in Brief

Science and Religion: Is Conflict Necessary?

Derry (1999) acknowledges the conflicts that have existed, and continue to exist, between science and religion, citing as examples the banning of Copernicus' great work, Galileo's treatment by the Inquisition, the burning at the stake of Giordano Bruno, the denouncement of the use of lightning rods, the ridiculing of Darwin's work, and efforts to ban the teaching of evolutionary theory in some schools. However, he suggests that such conflicts are quite unnecessary, because science and religion have different purposes and methods, and that conflict arises only when one area inappropriately attempts to commentate in the realm of the other.

Science attempts to understand our experiences, and uses explanations that are always tentative. Religion, on the other hand, attempts to give meaning to our experiences, addresses more abstract questions and questions of ultimate significance, and often involves eternal truths that are not open to revision. Conflict arises when religious authorities make statements about nature (science) that have no spiritual content and which contradict scientific evidence, or when a scientist provides comments having a spiritual dimension, as in the case of the physicist who declared: "The more the universe seems incomprehensible, the more it seems pointless" (Derry, 1999, p. 127).

More than other cultures, the major conflicts have involved the Christian West, and Derry (1999) suggests two possible reasons. First, Christian churches needlessly adopted ideas such as geocentrism, whereas scientific ideas rarely arise in, for example, Zen Buddism. Second, European culture allowed for science and scientists to exist apart from religion whereas, in the 12th Century Islamic world, science was integrated into the culture.

Contrary to some accounts, faith, experience, and meaning all feature in both science and religion, but in very different ways. In science, there is faith that nature is in some way orderly and logical and subject to understanding, and that the scientific methodologies used are valid. In religion, the faith is in dogmas, writings of scripture, and the pronouncements of leaders. Both science and religion demand a faith in an overall world view.

Scientific experiences are based on perceptions of the senses, whereas religious experiences are more internal. Both kinds of experience are valid, although their relative validity is a matter for personal determination.

Meaning in science involves bringing order to our understanding, as in the case of understanding the cause of an epidemic and how it is spread. Religion would focus on bringing spiritual meaning, if there is one, to the associated deaths. It is a mistake to confuse these two types of meaning, as in the case of concluding, on the basis that the earth is the centre of the universe (the province of science), that humanity is central to the divine plan (religion).

Science can operate well without religion, but this does not imply that science somehow invalidates religion. Science cannot prove the existence or otherwise of God. Are science and religion therefore mutually exclusive, or do they share some common ground? One tradition supporting the latter, a position adopted by Galileo, is that "if nature is the embodiment of some spiritual divine presence, the study of nature (i.e., science) is a way to better know this divine presence" (Derry, 1999, p. 130).

Science and religion overlap in the area of values and ethics. They can also meet on the question of what it means to be human, although again each asks this question in a different way. It remains open as to whether science and religion might enrich each other in this area.

Reference

Derry, G. N. (1999). *What science is and how it works*. Princeton, New Jersey: Princeton University Press.

Using Anchor Activities

Providing for students who finish mandatory tasks before other students in the class can be a challenge, and Corlett (2003) has used an Anchor Activity Learning Station in her middle-school classroom with much success. The activities she provides to differentiate learning in this way may extend topics being studied in class, or address other useful concepts. Some activities are permanent, others are unit specific and rotated and, overall, they include multiple intelligences.

Students, working individually or in pairs, involve themselves in activities (e.g., puzzles, games, a weather station, and electrical circuits) that use a variety of items (e.g., a mineral set and science CD's), books (e.g., optical illusions, experiments, and magazines), and equipment (e.g., stereoscope, Magdeburg hemispheres, mirrors, and lenses). Pupils have been so interested in these activities that she does not assess performance on them, although this would be easy using a journal or bonus-point scheme. While students are asked to return materials to their original place, student monitors are sometimes assigned to tidy up. Materials are also made available for borrowing.

Reference

Corlett, C. (2003). Anchor activities. *Science Scope*, *26*(6), 40-42.

Students Monitor Their Writing

All teachers, including science teachers, are teachers of writing. Liftig (2002) uses students' analysis of their own writing portfolios to facilitate improved writing.

Student writing may take various forms, including projects, laboratory reports, responses to open-ended questions, and essays on science-based issues. At the beginning of the year, students receive a criteria sheet for written work that summarises the areas to be evaluated. Three criteria are specified: format, content, and writing. Format includes neatness, margins, sentence and paragraph structure, spelling, grammar, and punctuation. Content comprises items such as relevance and accuracy, appropriate vocabulary, and appropriate connections between information. Writing includes clarity of communication (could someone unfamiliar with the topic follow and understand what you are saying?), answering the question asked, logical sequencing and conclusion, provision of sufficient details, and absence of unnecessary information.

After being returned to students, all written assignments are added to individual student portfolios, which are kept in the classroom. At least once each term, students analyse the feedback by arranging the tasks in chronological order, using the above criteria to categorise the comments, and looking for trends, such as weaknesses and strengths. They then conclude by identifying those problem areas upon which they need to focus in order to improve their writing.

Reference

Liftig, I. F. (2002). Showing students how they write: Using writing portfolios in science. *Science Scope*, *26*(1), 36-38.

"Truth comes out of error more readily than out of confusion."
Francis Bacon

"There is nothing so unequal as the equal treatment of those who are unequally prepared." *P. F. Brandwein*

"The only way to have a friend is to be one." *Ralph Waldo Emerson*

Ecology at Work: The Biodome Challenge

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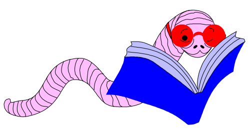
Abstract

This article describes a challenge given to students completing a senior high school biology course. The scenario described encourages students to apply their knowledge, understanding, and appreciation of scientific and commercial principles. It permits them the opportunity to develop skills in research, collaboration, cooperation, delegation, and reliability, as well as monitoring, evaluation, and reflection. The assessment strategy described ensures that the individual and the group understand the evaluation criteria being used and, by using peer evaluation protocols and independent reviewers, the overall project mark is seen to be fair and valid.

To read the full text of this article (8 pages), please **click here**.



Research in Brief

A Review of Middle School Programs

Commercial science education programs provide teachers with tools to do their best work. Previous reviews of such materials have typically had a narrow focus, such as topic coverage, level of reading difficulty, how they cater for student diversity, or the extent to which they focus on enquiry. To date, the findings of research on learning during the past 2 decades have not impacted the evaluation of curriculum materials.

Project 2061 aims to develop research-based review criteria and use them in reviewing curriculum materials. As part of this project, Kesidou and Roseman (2002) reviewed nine middle school programs used in the United States. Titles include Glencoe Physical Science/Life Science/Earth Science, Macmillan/McGraw Hill Science, BSCS Middle School Science & Technology (Levels A, B, C), Exploring Physical/Life/Earth Science, Prime Science (Levels A, B, C), Science 2000, Science Insights: Exploring Matter and Energy/Exploring Living Things/Exploring Earth and Space, Science Interactions (Courses 1, 2, 3), and Science Plus.

Some programs were better than others on particular criteria. However, overall, the programs were found to be deficient in supporting attainment of the scientific ideas specified in the US national science standards, as follows:

- While key ideas in the standards were generally included, the content of the materials typically did not focus on them. Rather, the key ideas were buried with peripheral or unrelated ideas, and addressed over several units without any attempt at linkage.
- A sense of purpose for studying a unit was rarely provided.
- The materials rarely took account of alternative conceptions that affect learning.
- Students were rarely engaged with everyday phenomena in an attempt to make abstract scientific concepts plausible.
- Key ideas were rarely used to explain everyday phenomena and promote transfer.
- Teacher's guides provided minimal guidance in scaffolding student learning, and no suggestions for best responding to students' responses to questions and activities in the programs.

There is a need for the development of new middle school science programs. This process needs to incorporate the findings of learning research (e.g., the role of prior knowledge and understanding), and may require new partnerships between curriculum developers and researchers. In the interim, teachers might continue with their current programs and seek professional development opportunities to compensate for shortcomings in those programs.

Reference

Kesidou, S., & Roseman, J. E. (2002). How well do middle school science programs measure up? Findings from Project 2061's curriculum review. *Journal of Research in Science Teaching*, *39*, 522-549.

Better History of Science Needed

Allchin (2003) analysed the typical textbook stories of five scientists--Gregor Mendel (pea plant inheritance), H. B. D. Kettlewell (peppered moths), Alexander Fleming (penicillin), Ignaz Semmelweis (handwashing), and William Harvey (circulation of blood)--and concludes that they do not portray history accurately and that they mislead students about the nature of science (NOS). He identifies four literary structural features, used to "tell a good story," that contribute to this problem: monumentality, idealization, affective drama, and explanatory and justificatory narrative.

The characters are portrayed as larger than life, having no character flaws and never erring. Their achievements are inflated, and discoveries that took time and involved several people are attributed to a single person at one instant in time. This attempt to impress the reader does not portray science as the human endeavour it is.

In a desire for a cosy story, the stories are sharpened (the gist of the message is emphasized) and levelled (less emphasis given to details considered less important).

Methods are depicted as flawless, historical webs become a simple timeline, black and white extremes emerge at the expense of qualifications, and blind alleys, errors, and “failures” are overshadowed or omitted. At times, the stories drift into what should have happened, as opposed to what actually happened.

This leads to misleading oversimplification, supporting the false notion that there is a scientific method that guarantees finding the truth, despite trial and error having a legitimate place in the ways science is done. It can also lead to people expecting too much of science.

Literary devices are used to entertain and persuade, producing an emotional effect that makes the story more memorable. Such techniques include the surprise of chance, the thrill of the moment of discovery, reward for integrity, tragic irony, vindication, and shame, such as challenging what is eventually found to be a correct idea. Truth always prevails. Finally, by coupling the process and product of science, the stories portray a right method-right idea or wrong method-wrong idea mentality, justifying the authority of the scientific conclusion on the basis that science leads surely to the truth.

The five selected stories are all biological, but Allchin (2003) suggests the same features can be found in stories about Antoine Lavoisier (oxygen), Alfred Wegener (continental drift), Galileo (Copernicanism), or Isaac Newton (optics). To rectify the situation, and contrary to recent calls for more history in science courses, Allchin suggests that what is needed is a different type of history that better conveys the NOS, including its limits. It is not necessary to remove traditional stories from texts. Rather, teachers should be equipped to recognise the above patterns and encouraged to use some stories that break convention and thereby foster deeper thinking. For example, even good scientists can use correct methods to reach incorrect conclusions, and there is much for students to gain from developing an understanding of how such conclusions were recognised and remedied.

Reference

Allchin, D. (2003). Scientific myth-conceptions. *Science Education*, *87*, 329-351.

Success Using Embedded Assessment

Assessment in middle school science is typically restricted to end-of-unit summative tests used to assign levels of achievement, and teachers rarely use assessment to guide their lesson planning. In contrast, embedded assessment (also called formative assessment) requires the teacher to probe for students’ understanding, reasoning, and use of learned material in an on-going way, and to use the information gained to respond to students’ needs.

Treagust, Jacobowitz, Gallagher, and Parker (2003) monitored the implementation of embedded assessment in an eighth-grade science curriculum. This required a change from a testing culture to an assessment one. The frequent, informal, yet well organised techniques used also blurred the distinction between teaching and assessment, because assessment items could be most effective teaching activities, and vice versa. They concluded that embedded assessment facilitated both improved cognitive and affective outcomes.

The following classroom techniques were employed:

1. *Pretests*. At the start of a unit, at least five open-ended questions were used to elicit students' prior ideas (e.g., explain how sound travels).
2. *Questions* were asked orally during lessons. The questions sought students' ideas and reasoning, and answers were recorded on the board or responded to by other students.
3. *Hands-On* and *other activities* challenged students' ideas, asking them to present their findings in writing and to share these with others.
4. *Individual writing tasks* monitored students' understanding (e.g., how can the pitch of a vibrating string be changed?)
5. *Diagrams* and *models* were created, individually or in small groups, to express students' understanding (e.g., draw a diagram to explain how an echo occurs).
6. *Group writing tasks* were assigned, such as summarising what ideas the experiments in a unit contributed to the topic.

Subsequent teaching was planned to address any incorrect or incomplete responses.

It was found that, by requiring students to express their personal ideas in this way, and to reconcile them with accepted scientific ideas, students' understanding of scientific ideas increased, as did their motivation, self-esteem, confidence, and classroom behaviour. The approach is also impacting positively on students' achievement on the Michigan Educational Assessment Program (MEAP) Science Test.

Reference

Treagust, D. F., Jacobowitz, J. J., Gallagher, J. J., & Parker, J. (2003). Embed assessment in your teaching. *Science Scope*, *26*(6), 36-39.

? ? ? ? ? Your Questions Answered ? ? ? ? ?

This section of *SER* responds to readers' queries, so please submit your question to The Editor at editor@ScienceEducationReview.com . Have that long-standing query resolved; hopefully!

Evolution is an example of historical science, as opposed to experimental science. However, I recall hearing something about evolution being demonstrated with microorganisms in the laboratory. Has evolution really been observed experimentally, or is it just one or more components of the theory that have been demonstrated in the laboratory?

Various people before Charles Darwin had proposed ideas to account for life's diversity. Some explanations, such as God did this or that, were not testable and therefore not scientific. Lamarck claimed that biodiversity resulted from acquired traits. His famous example was that giraffes have long necks because their ancestors stretched their necks to reach leaves in the tops of trees, and that they passed on these acquired traits to their offspring. This idea was testable, and a multitude of experiments provided evidence that caused scientists to quickly dismiss Lamarck's idea. For example, if I chop off my finger, my offspring will not be born missing a finger. If I dye my hair blond, my offspring will not be born with blond hair, and so on. We do not inherit acquired traits.

In contrast, Darwin's theory of evolution by natural selection is supported by an overwhelming amount of scientific evidence. Evolution by natural selection is based on the following tenets:

1. Populations have the potential to grow very rapidly, but the resources needed for their survival and reproduction are relatively constant and limited. This produces a competition in nature for survival and reproduction.

2. Organisms have differing abilities to obtain resources, escape predators, extract nutrients from food, intercept light for photosynthesis, and so on.

3. The competition among variable individuals results in the fact that, on average, better-adapted organisms survive and produce more offspring than do poorly adapted organisms. These offspring tend to inherit the traits of their better-adapted parents. Meanwhile, the traits of the poorly-adapted parents become less frequent (and sometimes disappear) in populations. The resulting changes in gene frequencies are evolution.

At the time Darwin proposed it, evolution was an historical science. Life on earth left much observable evidence of its history. This evidence now includes the fossil record, comparative anatomy (e.g., unrelated species such as penguins [which are birds] and seals [which are mammals] have similar fat-insulated shapes), vestigal structures (e.g., molar teeth in vampire bats, pelvic bones in some snakes and whales), homologous structures (e.g., the same bone arrangements used by different species for different functions), embryological similarities, and biochemical/genetic similarities (e.g., DNA as the genetic information). Together, this evidence provides overwhelming support for evolution by natural selection.

Evolution continues to be an historical science. However, there are many examples of evolution that can be observed experimentally. For example, a farmer's first use of a pesticide usually kills more than 99% of the pests that he/she has targeted. Subsequent applications of the pesticide are less effective because the survivors of the first application have genes that enable them to resist the pesticide. These survivors then produce offspring that are also resistant to the pesticide. This change in gene-frequency (i.e., the evolution of resistance) is why subsequent applications of the pesticide are less effective than the first. The evolution of antibiotic resistance among microbes provides similar examples of evolution that can be observed in nature and in labs. Other examples of evolution that have been observed experimentally include coloration, morphological traits, and biochemical changes. In conclusion, evolution is today very much both an experimental and historical science.

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Further Useful Resources

Paper Airplanes

http://www.paperairplanes.co.uk

Instructions for making a range of paper planes and gliders, categorised as easy, medium, and difficult. Includes advice and ideas for science fairs and further links.

Insultingly Stupid Movie Physics

http://www.intuitor.com/moviephysics/

Discusses where, and in what way, the physics is lacking in movies. Treats a number of generic issues such as flashing bullets, flaming cars, problems with windows, outerspace explosions, and visible laserbeams. Movies reviewed include The Matrix Reloaded, Spider-Man, Collateral Damage, Planet of the Apes, Pearl Harbor, and Star Wars: Episode I – The Phantom Menace.

The PISA Project

http://www.pisa.oecd.org

The Program for International Student Achievement (PISA) project was set up, in 1997, by the Organisation for Economic Co-operation and Development (OECD). This 3-yearly survey, of 15-year-old students (the end of compulsory schooling) in 32 countries, monitors reading, mathematical, and scientific literacy and focuses on knowledge and skills needed for full participation, in society, in adult life. The outcomes, which will include trends over time in each country and comparisons between countries, will inform policy development.

Optical Illusions

http://www.anomalies-unlimited.com/illusions.html

Use these optical illusions to shake your students (and perhaps even your own?) faith in empiricism. This Editor's favourites are the rotating gear rings and the left-brain/right-brain experiment.

The Why? Files

http://Whyfiles.org

Search the science behind the news of current events. Aims to portray science as a human enterprise and to explain the process, culture, and people that shape science.

WebElements Periodic Table

http://www.webelements.com/

The Professional Edition uses audio and text to describe each element, and includes history, properties, compounds, cartoons, and particular aspects such as the isolation of an element from compounds or mixtures. The Scholar Edition, which may be more suitable for high school students, contains much less detail.

Virtual Pig Dissection

http://www.whitman.edu/biology/vpd/main.html

Study each of the major organ systems of pig foetuses. Uses images of real preparations, and includes a series of quizzes.

DNA From the Beginning

http://www.dnaftb.org

Contains 41 animated experiments about DNA, genes, and heredity. The experiments contain videos, image galleries, biographies, problems, and links to further information.

Scientific Illiteracy

http://www.geoffdavis.net/dartmouth/policy/elites.html

An analysis of the consequences of a scientifically illiterate public.

Forensic Science

http://sample:discover@www.netlearn.discover.tased.edu.au:8900/SCRIPT/forensicscienceB/scripts/serve_home

Learn about fingerprints, ballistics, entomology, fibres, hairs, handwriting, footprints, blood samples, DNA, and odontology. Then use these skills to investigate a robbery and solve a crime.

Humour

In a previous issue, we had a smile about some scientific ideas expressed by students. Try these amusing comments made by teachers.

"Either what you said is deeply profound or completely trivial--I've yet to decide which."

[Thinking being interrupted by a mobile phone was a compliment] "Let it ring. A bit of music never hurt. Was that because you were excited by the proof? Wait until we get to the theorem. All the mobile phones will be singing."

Source: Luntz, S. (2002). *Australasian Science*, *23*(8), 48.

"[Struggling to find a lecture aid] "Transparencies tend to be invisible."

Source: Luntz, S. (2002). *Australasian Science*, *23*(9), 48.

[To a student who complained about his examination grading] "Well, this is an unjust world and education is intended to prepare you for it."

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The Science Education Review (*SER*) is an international, peer-reviewed periodical aiming to provide primary and high school teachers with the latest, and best, ideas in science education from around the world. *SER* also publishes original articles, including research articles, and much more.

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