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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Science "Happened" Only Once

Different societies around the world have developed varying traditions in music, art, literature, politics, religion, and so on. However, modern science was developed only once, and in only one area (Western Europe, and primarily Britain, France, Germany, and Italy) and during only one period of time (the 16^{th} Century).

Until relatively recently, nearly all scientists were white, male Christians. Science has been practiced in institutions characterized by strong discrimination. For example, during a substantial period of time, faculty membership at Oxford and Cambridge Universities was restricted to ordained ministers of the Church of England. With time, faculty appointments first became open to laymen and Catholics and then to non-Christians, women, and non-whites.

Source: Ben-Ari, M. (2005). *Just a theory: Exploring the nature of science*. New York: Prometheus Books.

Teaching Ideas

Techniques, demonstrations, activities, alternative conceptions, critical incidents, stories, and other ideas

Science Story: Mesmerism and Magnetism

Being a somewhat mysterious phenomenon, magnetism is attractive to pseudoscientists who can be quick to endow it with mystical powers. The 18^{th}-Century doctor Franz Anton Mesmer claimed to be able to cure diseases by manipulating animal magnetism, or mesmerism. Although fashionable and trendy, his treatments attracted scrutiny, and an investigative committee was established. The committee included diplomat and scientist Benjamin Franklin, pioneering chemist Antoine Lavoisier, and doctor Joseph-Ignace Guillotin. Their well-designed study (Franklin & Lavoisier, 2002) totally debunked Mesmer's claims. How unfair it seems, though, that Mesmer's name lives on in the word mesmerize, while Lavoiser's head was removed by a machine named after Dr Guillotin.

Reference

Franklin, B., & Lavoisier, A. (2002). Report of the Commissioners charged by the King to examine animal magnetism. In M. Shermer (Ed.), *The skeptic encyclopedia of pseudoscience* (pp. 797-821). Santa Barbara, CA: ABC-CLIO.

Adapted from: Ben-Ari, M. (2005). *Just a theory: Exploring the nature of science*. New York: Prometheus Books.

The Internet-Telephone Interview

An in-class telephone interview can bring the enthusiasm of a professional or other person (e.g., a scientist, newsmaker, or zoo animal-keeper) into the classroom without major time sacrifices, travel issues, or funding (Lotter, 2009). The interviewee's voice is amplified while his or her photograph, web pages, and/or other documents are projected on a screen and discussed. There is no need to provide for the interviewee's "talking head" to be seen, thus also relieving the interviewee of the burden associated with setting up for such.

For small classes, students can gather around a speakerphone connected to the standard telephone system. Alternatively, a high-speed internet connection enables an internet telephone (or Voice over Internet Protocol [VoIP]) service, such as *Skype* (2009), to be used. One may use either the free computer-to-computer talk mode or pay the typically quite cheap rate to call a telephone. Your computer needs to be connected to the internet, a projector, and speakers. Also, a microphone needs to be plugged into your computer. Lotter (2009) cradles the microphone in his hand to minimize it picking up sound from the speaker.

Another possible alternative would be to use a cell (mobile) phone. Here, a microphone and amplifier could project the audio from the phone on speakerphone mode. However, the audio quality may be reduced. In any case, and with the consent of students, taking a photo of the class and emailing it to the interviewee adds a nice touch, as it allows the interviewee to see who he or she is speaking with.

References

Lotter, D. (2009). The internet-telephone interview as a classroom teaching tool. *Journal of College Science Teaching*, *38*(4), 48-49.

Skype. (2009). Retrieved April 2, 2009, from http://www.skype.com/intl/en/ .

Colourful Aprons

Recognizing that students learn better when information is presented in a variety of ways and that colour (e.g., a coloured worksheet) increases student interest, Bibi (2008) summarizes the main ideas of particularly topics that students find difficult by painting colourful diagrams and text on aprons. Different aprons are used for different topics, and the aprons are worn during every lesson on the topic. Attention is drawn to the apron at the start of the topic and it is used as a summary at the end.

The aprons are those used in the catering industry, extending from just below the neck to below the knee and held up by a loop of fabric around the neck. Cotton is the best fabric to use, as it works well with paint and is easy to wash. Fabric paints are available from the art section of any school catalogue.

Students might be invited to produce their own revision apron or T-shirt, perhaps during Science Club. Lab coats can also be decorated in this way.

Reference

Bibi, K. (2008). Teaching and learning aids: Colourful props promoting students’ progress. *School Science Review*, *90*(331), 20-23.

Energizers

The attention span of a student brain is about 15 minutes, after which time it needs a break. In addition, the brain can process only three to four “chunks” of information at a given time, where a chunk refers to a selection of content such as Newton’s second law of motion or mitosis.

An energizer is a 1- to 3-minute activity that, according to Almarode and Almarode (2008), can provide the brain with a neurological jump-start while adding novelty and excitement to the classroom. The breaks provided by energizers increase dopamine and norepinehrine levels, blood flow, oxygen levels, and glucose, stimulate the brain’s attentional system, and provide off-task time for the brain’s input system.

An energizer might be based on content or be a complete break from classroom topics. The following are examples of energizers. They can be readily modified, and students might even be invited to select the energizer to be used.

Spell It Out. Students spell out key terms (e.g., inertia) using different parts of their bodies, such as using their elbows or ears to spell a word in the air. This activity is also very entertaining to watch.

Ball Toss. With all students standing, a soft ball is carefully tossed around the class. Each time the ball is caught, the catcher either shares a piece of content just covered or asks a question about it.

Snowball Fight. Each student writes his or her name, together with one or two questions about the topic being addressed, on a sheet of paper and crumples the sheet to form a “snowball.” Students then divide themselves into two equal groups on opposite sides of the room and throw their snowballs to those on the other side. After picking up a snowball, a student answers the question(s) on it and returns the sheet to the question-asker.

Relocate. Students stand, gather their notes, and move to a new seat in the classroom. They then review their notes with 1 or 2 of their new neighbors. New content can be taught before students return to their original seats and again review, with a neighbor, what they learned while they were away. The use of music while students are finding a new seat can increase the energy in the room.

Stretch Break. Students stand, stretch, take a deep breath, hold it for 3 seconds, and exhale. They then turn to 1 or 2 neighbors and summarize content, verbally solve a problem, or respond to a question.

Reference

Almarode, J., & Almarode, D. (2008). Energizing students: Maximizing student attention and engagement in the science classroom. *The Science Teacher*, *75*(9), 32-35.

Appreciating Deep Time

Needed: Sheet of blank paper, pencil, and a timer that measures seconds.

Invitation. What is the age of our solar system (and hence Earth) in years? (Make a guess, if necessary.) For how many years has life existed on Earth? The answers to these questions are very large, and understanding, and accepting the scientific basis of, evolution requires a comprehension of such very large numbers associated with what is called deep time. This activity will help you to appreciate such vast amounts of time.

Exploration. How many dots do you think you could put on a sheet of paper in 1 year? Guess. Write the number down. Let's now investigate to answer this question.

Time yourself as you try to put as many dots as possible on a sheet of paper in 10 seconds. Count the dots. Using this result, how many dots do you estimate you could make in 1 minute? In 1 hour? In 1 day? In 1 year? How does this answer compare with your earlier guess?

Concept introduction. The evidence suggests that life first appeared on Earth about 3.5 to 3.9 billion years ago. How long do you think it would take you to put 3.9 billion dots on a sheet of paper? Again, guess (and write it down).

Using your earlier estimate for the number of dots you could put on a sheet of paper in 1 year, estimate how many dots you could make in 20 years. In 30 years? About how many years does it appear it would take you to make 3.9 million dots? (Older students could use proportion to arrive at this answer more directly.)

Now, a dot takes only a fraction of a second to make. If you assume, instead, that each dot represents 1 entire year, and that you did nothing else with your time than make dots, it would take about one-third of a life-time to make sufficient dots to represent 3.9 billion years. Using your own words, how would you now describe the length of time represented by 3.9 billion years? Compare your description with the descriptions of other students.

For your interest, our solar system (and hence Earth) appears to be about 4.5 million years old, there are presently about 5 billion people living on Earth, and the age of our universe is estimated to be about 13 billion years.

Concept application. Assuming a sporting field is 100 m long, and that 1 mm on the field represents 1 year, how many sporting fields would it take to represent the time that life has been present on Earth? Can you think of other ways to represent 3.9 million years?

Adapted from: Leonard, W. H. (2009). Addressing evolutionary concerns [Editorial]. *The American Biology Teacher*, *71*, 198 and Leonard, W. H. (2009). How many years is five billion? *The American Biology Teacher*, *71*, 199.

Shaking a Can of Soft Drink

Needed: Eight cans of soft drink (soda).

Invitation. Does shaking a can of soft drink change the pressure in the can? Take a class vote.

> *Most, if not all, students will answer "yes."*

Exploration. Design an experiment to answer this question, and then conduct the experiment. What do you conclude?

> *Guide the discussion towards the following experimental design. Mark the bottom of four of the eight cans with an "X." Invite a student to hold one of the unmarked cans in one hand, a marked can in the other, shake the marked can only for 5 s, say, and then feel which can has the most pressure inside. Repeat for 3 further students, using a different pair of cans for each student. Typically, most students (and especially younger students) will say that the shaken can has a greater pressure.*

Do you think this is a fair test? If not, please explain and suggest a better test. Discuss possible tests and perform a suitable one. What do you conclude? Take another vote on the original question: "Does shaking a can of soft drink change the pressure in the can?"

> *This is not a good test. Rather than actually feeling a difference in pressure, students may be influenced by their everyday experience that opening a can after shaking it produces a spray, and answer in accord with their expectations. A blind test would be better. Invite a student to be the tester and, with him or her looking away, have other students shake the four marked cans for 5 s, place them back on the table, and mix them with the unshaken cans. Invite the tester to now feel the cans and try to identify which have been shaken. Check for accuracy. Repeat with 1 or more different testers. It will be a very, very rare occurrence indeed if a student can pick the four shaken cans. Indeed, some students may even suggest that it is difficult to distinguish between cans. Students should conclude that shaking a can does not increase the pressure inside.*

Concept introduction. When a can is shaken, some of the gas (carbon dioxide) above the liquid dissolves in the liquid, but an equal amount of gas comes out of solution. Overall, the amount of gas above the liquid is unchanged. Shaking a can does not increase the pressure inside.

If this is the case, then why does shaking a can and then opening it cause a spray? In an unopened can of soft drink, carbon dioxide gas is dissolved under pressure. If you open the can without first shaking it, the gas will bubble out of the liquid quite slowly and the drink will eventually go "flat." However, if you shake the can before opening it, the situation is different. Shaking produces millions of microscopic bubbles in the liquid. If the can is then opened, any small, sharp, or rough places inside the bottle (and the microscopic bubbles fit this description) speed up the bubbling by providing a place for the dissolved carbon dioxide particles to come together and form bubbles. Such small, sharp, or rough places are called nucleation sites. In addition, when the bottle is opened and the pressure is released, the bubbles in the liquid expand to about three times the size they were before the can was opened. (The pressure inside a typical soft drink can at room temperature is about three times atmospheric pressure.) The result of both these effects is the production of froth and spray.

Concept application. Can you think of other ways whereby nucleation sites (i.e., small, sharp, or rough places) might be introduced to a container of soft drink and cause increased bubbling when the container is opened?

1. *One or more scratches on the inside of a plastic soft drink bottle would have this effect, so soft drink bottle manufacturers aim to ensure that the inside surface of such bottles are smooth so the soft drink doesn't go flat very quickly after a bottle is opened.*
2. *Menthos mints have a relatively rough surface. So, opening a 2-L soft drink bottle, say, and adding Menthos mints (even a full roll!) will cause much froth and possibly even a fountain. Fruit-flavored and sugar-free Mentos have a much smoother and shinier surface and don't have the same effect.*

Imagine shaking a can of soft drink and then allowing it to sit for 20-30 s. What do you predict will be observed when the can is opened?

Having the can sit for this period allows the bubbles time to float to the surface. So, when the can is then opened, it is just like opening a can that has not been shaken (i.e., there is no increased bubbling and frothing.

Finally, it is often said that tapping a can after it has been shaken will reduce frothing when it is then opened. Do you think this is true or false? Explain.

The act of tapping itself has no effect on reducing frothing. Rather, tapping simply gives the bubbles in the liquid time to rise to the surface. So, when the can is opened, it is just like opening the can in the previous situation (i.e., where the can was shaken and allowed to sit for a while).

Sources: Becker, B. (2007). Question from the classroom. *ChemMatters*, *25*(1), 2-3, Becker, B. (2007). Question from the classroom. *ChemMatters*, *25*(4), 2-3, and Becker, B. (2008). Question from the classroom, Part II. *ChemMatters*, *26*(1), 2-3.

Science Poetry

Reading and/or listening to poems 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 .

Famous Scientists

There once was a man named Einstein
A hero of his day
He liked to think about many things
In the most amazing way.

"$E = mc^2$," he said
Thinking with all his might
E for energy, m for mass
And C for the speed of light.

They found polonium and radium
And won a Nobel Prize
But in the end the substances
Led to her demise.

Sir Alexander Fleming
Went to war at age 19,
And when he returned
A rising star was seen,

Sir Isaac Newton, an Englishmen
Discovered gravitational laws
When an apple fell down from his tree
He just had to know the cause.

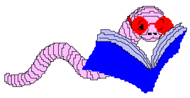
He later discovered that gravity
Stretched beyond the stars
And all across the universe
Even on Pluto and Mars.

Fascinated with radioactivity
Pierre and Marie Curie
Studied, and together, made a
Scientific discovery,

He became a doctor
Won a Nobel Peace Prize
For discovering penicillin
That reduced bacteria's size.

All of these great scientists
Advanced in a different way
The wonderful world of science
From which we benefit every day.

Lachlan Pickering, 10 years
Australia



Research in Brief

Research findings from key articles in reviewed publications

Context-Based and STS Approaches

During the past 20 years, there has been a trend towards the implementation of context-based and science-technology-society (STS) approaches in high school science courses. In a context-based approach, contexts and applications are used as the starting point for the development of scientific ideas, in contrast with the conventional approach of science first, followed by applications. STS approaches are characterized by a focus on links between science, technology, and society. The earliest examples of such approaches were with two groups of students for whom science appealed little; non-science students in tertiary institutions in the United States and less academic secondary students in the United Kingdom.

The rationale for implementing context-based/STS approaches was that they may impact positively on students in the affective domain, motivating them and increasing their interest in science as a result of helping them to appreciate the importance of what they are studying, while at the same time providing students with a sound understanding of scientific ideas. Indeed, more engaged students might even learn better. On the other hand, the development of scientific ideas in context-based or STS approaches does pose the challenge of needing to introduce ideas as they arise (i.e., on a "need to know" basis), as opposed to the conventional approach of introducing and developing a concept area in full, thus leaving open the possibility that such approaches will actually result in poorer learning.

Based on a review of 17 experimental studies from eight countries, Bennett, Lubben, and Hogarth (2007) conclude that context-based/STS approaches improve the attitudes of both girls and boys to school science considerably compared with conventional approaches, while also reducing the gender gap in attitudes. There is more limited evidence to suggest that the approaches positively impact students' attitudes to science more generally, and mixed evidence as to how these approaches affect subject and career choices. In addition, context-based/STS approaches facilitate a level of understanding of scientific ideas comparable with that resulting from conventional approaches.

There are some challenges, though, associated with trying to assess the impact of such interventions, given that some of their aims overlap with those of conventional approaches yet others differ significantly. Students taking different types of courses are likely to perform better on assessment items that reflect the course style, so it should not be a surprise to find that students taking a context-based/STS course might perform better on context-based questions than students taking a more conventional course. Similarly, students following a conventional course will likely perform better on traditional-style questions than those following a context-based/STS course. The best approach to course evaluation appears to be to evaluate not by comparing the old with the new, but by evaluating an intervention against its declared aims.

Reference

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*, 347-370.

Student Response Technology

With student response technology (SRT), students use “clickers” to respond to questions during class. Nagy-Shadman and Desrochers (2008) used a 33-question survey of 350 university science students in the classes of 5 different instructors to conclude that, when used correctly, the benefits to be gained from the use of SRT far outweigh the disadvantages.

Students enjoyed using the SRT, with 90% agreeing that it helped them learn. The majority (>50%) of students reported that the SRT impacted positively on student engagement, content understanding, student-student interactions, classroom participation, alertness, attendance, and examination preparation. Students appreciated the immediate feedback and the anonymity, which allowed them to engage without being judged.

In particular, the think-pair-share and classroom competitions were popular activities. In a think-pair-share, the class responses to a multiple-choice question were displayed, students briefly discussed with neighbours the reasoning for their choice of correct answer, and the class then used their clickers to vote again. The classroom competitions involved 2-student teams. While each team received points for a correct answer, additional points were given to the team that answered a question first. A competition typically comprised eight rounds.

Teachers need to prepare clear, substantive questions, review both the correct answer and distractors with students, and adjust their teaching on the basis of the student responses. Limitations associated with SRT include the time required to both prepare questions and to use the technology in class, as well as potential hardware and software problems.

Reference

Nagy-Shadman, E., & Desrochers, C. (2008). Student response technology: Empirically grounded or just a gimmick? *International Journal of Science Education*, *30*, 2023-2066.

Solving Contextual Physics Problems

Numerous studies have demonstrated that students prefer to learn science or physics through everyday contexts. However, learning physics in a conceptual context differs from solving everyday contextual physics problems (E-problems), because the latter requires considerations that are not found in the former, and there are few studies that examine students' preferences for everyday contexts in solving physics problems.

Park and Lee (2004) used 93 Korean high school teachers, 36 physics teachers, and 9 university physics educators, together with contexts related to auto safety and the safe use of electricity, to explore aspects of solving E-problems. Many students, teachers, and university educators wanted to learn or teach E-problem solving. While there was no difference between the performance of students on E-problems and decontextualized problems (D-problems), students felt that E-problems were more difficult to solve. The subjects generally preferred E-problems on school physics tests because they thought they were the better problems, although the preference for E-problems was higher among teachers and university educators than students.

Observation of the processes students used to solve E-problems, together with interviews, identified the following six factors that can impede the solution of E-problems:

1. Trying to import personal/subjective judgments that are not presented in the problem.
2. Failing to grasp the situation or context of the problem.
3. Not making sense of the given information, because the numerical value of information has an undefined range or is not in a simple format such as that of an integer.
4. Missing some important descriptive information in long sentences.
5. Being concerned about information that is irrelevant to solving a problem.
6. Experiencing difficulty in solving a problem because the form of the problem is different from that usually used in school tests.

However, teachers generally thought that students should be able to deal with such factors rather than needing to be taught them, possibly because many teachers may not have the skills or methods required to teach how to solve E-problems. Also, although a context may be an everyday one, students may not show an interest in, or curiosity with, it unless it is also a familiar context. In fact, an unfamiliar, everyday context such as a mirage may be no different in its effects on students than a purely scientific context. The authors therefore conclude that there is a need for in-service training to provide teachers with experience in developing various types of E-problems and to improve their ability to teach strategies for successfully solving E-problems.

Reference

Park, J., & Lee, L. (2004). Analysing cognitive or non-cognitive factors involved in the process of physics problem-solving in an everyday context. *International Journal of Science Education*, *26*, 1577-1595.

Readers' Forum

Use of the Terms Proof *and* Truth *in Science*

I have some reservations about the article "What's in a Word?" that appeared in *Science Scope* (Schwartz, 2007). First, a hypothesis is defined as "a statement that answers a posed question" (p. 46), but I think this is insufficient, because it does not make clear that a hypothesis needs to have an explanatory element (Eastwell, 2002). For example, one might ask if copper is a conductor of electricity, but the answer to this question is not a hypothesis. Rather, a hypothesis is better defined as a possible explanation for the observed facts and laws, with a theory being an explanation that has stood the test of time and in which we therefore show much faith. Also, a hypothesis is distinguished from a prediction by defining the latter to be an educated guess about the expected outcome of a test.

Second, it is written that "we can never have 100% proof of any claim in science" (p. 44) and suggested that terms like proof, prove, truth, and true should be removed from our vocabulary. While I agree that this is appropriate in the case of explanations (i.e., hypotheses and theories), I think it fails to acknowledge that there are different kinds of scientific knowledge, and that we are more certain about some kinds of knowledge than others. For example, isn't it true that copper is an electrical conductor? Indeed, I find it useful to define a scientific fact as a phenomenon that can be observed repeatedly, with an observation in turn being defined as a descriptive statement about a natural phenomenon that is accessible to our senses, or extensions of them, and about which several observers can reach consensus with relative ease. So, while we can never be certain about an explanation (i.e., a hypothesis or theory), I suggest that there is still a place for terms like truth and true in science. Indeed, doesn't writing that conveys the impression that all science is uncertain promote the misconception that science is less reliable and trustworthy than can be the case? Also, if one considers a proof to be evidence that serves to establish a scientific fact, then I'd suggest that banning terms like proof and prove appears similarly unwarranted.

Reference

Eastwell, P. H. (2002). The nature of science. *The Science Education Review*, *1*, 43-48.
Schwartz, R. (2007). What's in a word? *Science Scope*, *31*(2), 42-47.

Peter Eastwell, Science Time Education, Queensland, Australia

The Central Dogma of Professional Development

In 1962, Maurice Wilkins, James Watson, and Francis Crick were awarded the Nobel Prize in Physiology or Medicine for their determination, in 1953, of the structure of deoxyribonucleic acid, better known as DNA. Their discovery is undoubtedly one of the most important scientific discoveries of the 20th century. More than 50 years later, DNA plays a vital role in all aspects of our lives. Five years after their discovery of DNA, Francis Crick published a paper introducing two pivotal ideas in biology: The Sequence Hypothesis and the Central Dogma (Crick, 1958). In short, the Sequence Hypothesis posited that the sequence of residues in DNA informs the synthesis of proteins (i.e., information flows from DNA to RNA to protein). In that same paper he wrote "once information has passed into protein, it cannot get out again" (p. 153) and coined these words as the Central Dogma. Although it remains unclear, it appears that James Watson, his co-Nobel Laureate, confused Crick's two ideas and in his book *The Molecular Biology of the Gene* (Watson, 1965) used the term Central Dogma to refer to Crick's Sequence Hypothesis. And the rest is history. A controversy was born. The Central Dogma has since been under intense scrutiny and attacks from scientists. In an attempt to set the record straight, in 1970 Crick published a note in the prestigious journal *Nature* restating his Central Dogma as he originally conceived it (Crick, 1970).

At the center of the controversy was Crick's choice of the word *dogma* (n.d.), defined in the Merriam-Webster dictionary as "1 a: something held as an established opinion; especially : a definite authoritative tenet . . . c: a point of view or tenet put forth as authoritative without adequate grounds." In a religious context, dogma is a doctrine that must be accepted without disputation by followers. Clearly, the scientific community took these meanings literally and attacked Crick's (or should we say Watson's) Central Dogma relentlessly. Interestingly, Crick's Sequence Hypothesis has since been challenged and overthrown when exceptions were found to deviate from the standard theory; most notably the discoveries of retrovirus and the enzyme reverse transcriptase. However, his original Central Dogma has endured the test of time and scientific scrutiny.

Notwithstanding, even Crick second-guessed his choice of the word. In his autobiography entitled *What Mad Pursuit: A Personal View of Scientific Discovery* (Crick, 1988), he wrote:

> I called this idea the central dogma, for two reasons, I suspect. I had already used the obvious word hypothesis in the sequence hypothesis, and in addition I wanted to suggest that this new assumption was more central and more powerful. . . . As it turned out, the use of the word dogma caused almost more trouble than it was worth. . . . Many years later Jacques Monod pointed out to me that I did not appear to understand the correct use of the word dogma, which is a belief that cannot be doubted. I did apprehend this in a vague sort of way but since I thought that all religious beliefs were without foundation, I used the word the way I myself thought about it, not as most of the world does, and simply applied it to a grand hypothesis that, however plausible, had little direct experimental support. (p. 109)

And while many people may think there is little room in the science education lexicon for the word dogma, and at the risk of committing heresy, Crick's idea of the word dogma applied to a hypothesis with limited direct experimental support appears, more than 50 years later, to accurately describe the daunting task of demonstrating empirically the relationship between professional development and student learning (see Figure 1). Notably, a recent meta-analysis of more than 1,300 studies identified as potentially addressing the effect of teacher professional development on student achievement, across the three content areas of mathematics, science, and reading and English/language arts, revealed that only 9 of those studies met the U.S. Department of Education's *What Works Clearinghouse* evidence standards and therefore rigorously examined such an impact (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). So, based on the scarcity of rigorous data to demonstrate the connection between professional development and student achievement, it seems appropriate to apply the term Central Dogma to professional development.

The spirit of this *central dogma of professional development* reflects the well-accepted premise that places the classroom teacher at the center of education reform (Bybee, 1993). This idea stems from the notion that many science teachers, especially in early grade levels, lack the content knowledge and the pedagogical skills necessary to perform their job (Nelson, Weiss, & Capper, 1990). Therefore, professional development for teachers serves as the natural vehicle to improve classroom instruction (National Commission on Teaching and America's Future, 1996). However, there are two fundamental flaws with this seemingly logical idea. First, it depicts an oversimplification of the problem. Each step in Figure 1 represents a profound outcome that needs to be assessed by itself as well as in connection to the other steps in the chain. In addition, intermediate links must be added to the chain in order to obtain a complete picture of the process. For example, it is essential to include steps that assess how an increase in teacher content knowledge and improved pedagogical skills actually translates into the classroom practice and ultimately affects student learning.

The second fundamental flaw with the oversimplified professional development process is the difficulty in measuring the impact of the different steps due to the dearth of valid and reliable evaluation instruments. The development of these instruments, the analysis of their psychometric characteristics, and the subsequent testing of these instruments in the field require substantial human and financial resources. Fortunately, in the U.S. for example, the National Science Foundation (NSF) has acknowledged and acted on this challenge by providing funding under its Research, Evaluation, and Technical Assistance (RETA) program for two exemplary projects that show it is possible to rigorously measure changes on teacher and student learning. The Assessing Teacher Learning About Science Teaching (ATLAST) project (Horizon Research, 2004) has developed instruments that measure changes in both student and teacher knowledge, in the middle grades, in the areas of Forces and Motion, Plate Tectonics, and Flow of Matter and Energy in Living Systems. In addition, Phil Sadler's group at Harvard University has developed a set of instruments, in the Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART) project, for K-12 Physical Science and Earth Science topics (*MOSART*, 2006). These isolated examples attest to the fact that this formidable challenge is not insurmountable. However, these examples need to be the norm rather than the exception.

Participation in Professional Development

↓

Increased Teacher Content Knowledge and Improved Pedagogical Skills

↓

Increased Student Achievement

Figure 1. Relationship between professional development and teacher and student learning.

Taken together, the fundamental flaws in professional development described above (oversimplification of the problem and the lack of valid and reliable instruments) lead one to conclude that, despite decades of significant federal investment in STEM (Science, Technology, Engineering, and Mathematics) programs, there is almost no evidence demonstrating the impact of effective professional development on student achievement. Interestingly, a publication titled *How to Conduct Rigorous Evaluations of Mathematics and Science Partnerships (MSP) Programs* (National Opinion Research Center, 2005), and funded by the U.S. Department of Education, advises MSP projects and evaluators "to conduct rigorous impact evaluations that (i) are low in cost, and (ii) produce valid, actionable knowledge about what works within 1-3 years" (p. 3). This type of advice forces projects to develop their own instruments that are often poorly aligned with the professional development content or are developmentally inappropriate. It also pressures the researchers to operate under the premise that "if we torture numbers long enough they will confess to anything," hoping to report, against conventional wisdom, robust teacher and student gains even during the year of implementation of professional development. In the end, federal agencies report those spectacular gains to their legislators and school boards boast of their success to the stakeholders. It is a vicious cycle that acts against commendable projects with rigorous plans that are more likely to find modest gains over a longer period of time.

In conclusion, it is imperative for researchers and funding agencies to increase their efforts to develop high-quality assessment instruments that objectively and accurately measure growth in the content knowledge of teachers as a result of their participation in professional development programs. It is only then that we can ensure that the knowledge transferred to the classroom is genuine, accurate, and free from misconceptions. Furthermore, improved instruction will undoubtedly result in true student learning in the classroom. However, if we fail to show rigorous empirical evidence for the effectiveness of professional development programs, funding from the federal agencies will surely decrease or cease. Shortly thereafter, the schools and their shrinking budgets may not hesitate to cut professional development programs outright in preference to cutting other activities. Such actions could be devastating to the state of science education in the world and that is a risk citizens cannot afford, particularly during this time of economic uncertainty.

Perhaps dogmas, by definition, are always meant to be challenged. So what if, by using the term central dogma of professional development, it attracts additional controversy to this issue and helps bring the core principles of professional development to the forefront of the discussions? As it stands right now, the central dogma of professional development is just, using the adapted words of Crick (1988) quoted earlier, a grand hypothesis that, however plausible, has little direct experimental support. We must prove to ourselves something that we already know. We know that good professional development is essential for teachers and their students. And we know what features are essential to make professional development effective (i.e., to produce growth in the content knowledge and pedagogical skills of teachers) (Kennedy, 1998). Let us rigorously measure its effects and transform this central dogma into an evidence-based principle that can be used to strengthen professional development.

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Prayer Study

As a part of the *National Center for Case Study Teaching in Science* (2008) project, Kathy Gallucci presents the case titled "Prayer Study: Science or Not?" that focuses on the effect of intercessory prayer on patients. The case itself, which was made up by the author but based on a real news story, may be found at Gallucci (2009b) and associated teaching notes at Gallucci (2009a). This case was also featured in the *Journal of College Science Teaching* (Gallucci, 2004).

Question 10 asks students: "Do you think this study is an example of pseudoscience? Explain." The author's suggested response, which can be accessed online by applying for passwords, is as follows:

> Yes, because in pseudoscience, a hypothesis is either not testable or not falsifiable. In this study, the researchers propose that the effects of prayer can be objectively measured in a scientific manner. Furthermore, they do not consider that this hypothesis cannot be falsified but others might argue that the will of God cannot be predicted.

I am having difficulty with this, and wish to suggest that such a study is indeed scientific. Can't science play a role in testing claims like this? The evidence is empirical. Ok, such a study might not be easy to do well (e.g., controlling variables and measuring the dependent variable), but this is not a reason for a test to be regarded as not being scientific. Sure, if the researchers tried to propose a hypothesis (i.e., a possible explanation) involving God, they would be operating outside the bounds of science. But they were very careful in pointing out that they were simply wanting to do the test rather than propose any explanation. I cannot see what it is about this study that precludes it from being science.

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National center for case study teaching in science. (2008). Retrieved March 19, 2009, from http://ublib.buffalo.edu/libraries/projects/cases/case.html .

Peter Eastwell, Science Time Education, Queensland, Australia

Reply by the Author

From my understanding, a hypothesis (i.e., a possible explanation) must be falsifiable *and* testable to be considered scientific. If it is not, it is considered to be pseudoscientific. Falsifiability is a necessary condition for testability, but a hypothesis may be falsifiable (the opposite may be logically possible) even if it is not testable.

Testability means that evidence can be collected in support or rejection of the hypothesis. A hypothesis can be falsifiable and not testable, for example, because of lack of technology or a timeframe that makes it impossible to collect evidence. Examples of these two situations are that life exists in other solar systems, and that in 100 years there will be no humans on earth, respectively.

In this case, perhaps, the investigators may be able to disprove (falsify) that prayer helps a patient's recovery. But they cannot test the hypothesis because they cannot collect evidence that directly points to the mechanism of how prayer works. They can observe a correlation between prayer and recovery, but no causation, or explanation.

Prayer cannot be controlled with regard to length, type, or sincerity. We have no guarantee that the prayers were in fact even offered. Prayer is not a drug or a treatment that can be doled out in discrete dosages with additive value; it is a means for connecting with the sacred. Furthermore, the instructions were open-ended and the praying was done by volunteers (why not professionals?). Since no timetable was assumed, complications experienced in the short term do not necessarily point to prayer as ineffective in the long run. (I use these comments to claim that the study can also be considered junk science. Junk science uses data that is faulty, insufficient, unreliable, twisted, dredged, or selected in order to support or reject a hypothesis.)

If indeed one wanted to study the effects of prayer on outcomes, perhaps a more basic study would look at the effects of prayer on non-human subjects or processes, thus eliminating some of the confounding variables of human studies. But those who accept prayer studies as scientific would perhaps object to those types of studies as beyond the realm of science, questioning their reliability and validity.

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Laboratory Safety Guidelines

This section presents a series of 40 laboratory safety guidelines kindly provided by Dr James A. Kaufman, President, The Laboratory Safety Institute (LSI), USA. Please visit http://www.labsafety.org for further information, products, services, and publications.

#8 of 40. *Conduct periodic, unannounced laboratory inspections to identify and correct hazardous conditions and unsafe practices. Involve students and employees in simulated OSHA inspections.*

Inspections get people involved in thinking about hazards and unsafe practices in the workplace. These should be done at least four times a year (monthly is better). Perhaps, one of these can be done by people from outside your institution or company. This brings in fresh eyes to see the things you've grown accustomed to. Let everyone have a chance on some rotating basis to help conduct the inspection.

At Dow, we did it every month! It would be a good idea to consider having at least one inspection each year done by "outsiders." Ask the people from another department, another of your locations, another institution, or a consultant to conduct an inspection. LSI discussed the merits of this approach in one of our newsletter (*Speaking of Safety*) editorials titled “Safe Eye for the Lab Guy.”

Inspections are an integral part of a good safety program. This is your time to step back a little from your day-to-day involvement and look for problems and opportunities for improvement, as well as things that are well done. Don't hesitate to praise good work, safe practice, improvements, and good ideas.

People need to feel that the inspections are being done to make the working and learning environment safer and healthier for all. They are not to blame or to “get” someone. At the same time, it may be necessary to note some unsafe practices.

Keep a written record of the inspection. Share the results with the department members. Let each person be responsible for making the necessary changes in their area, except where outside assistance is needed. Use the inspection report as a check list to see that the situations are corrected in a reasonable period of time.

Regular inspections are one of the cornerstones of a good safety program. They are a great opportunity to take a good hard look at your working/learning environment to try to spot potential problems.

You need to be sure that the emergency equipment is in place, unobstructed, properly designated with signs, and properly functioning. Check electrical receptacles for correct wiring with a ground monitor. Check the hoods for proper air flow. Check the stockroom for security and overcrowding. See that benches and aisles are kept clear and free of materials that should have been put away. And so on . . . .

As you conduct your inspection, make a written list of those opportunities that you identify for improving lab safety. When you're done, prioritize the list to identify the more serious issues. Give copies of the list to department members, the maintenance department, and the management and administrators. Now you need to work diligently at trying to make those improvements that are within your ability and resources. Seek assistance for the rest. Having everyone participate in the inspection process is a great way to get them involved in the safety program and to teach them about hazards and how to recognize them.

Lastly, make lab inspections part of the college and university curriculum. Have the faculty member and his or her students do the inspection during a regular lab period. If more than one class uses the lab, the responsibility can be rotated among the various classes.

A six-page "Laboratory Safety Inspection Checklist" is available from LSI for $5.00. See order form in back of this booklet or online at our website. LSI also performs facilities inspections and audits facilities, safety programs, and regulatory compliance. Training programs are available in all these areas.

Further Useful Resources

Science in Industry (http://www.scienceinindustry.co.uk) Articles about the latest scientific developments, emerging industrial technologies, and the lives of practicing scientists.

A Short History of Nearly Everything

Austin, Menasco, and Vannette (2008) recommend use of the popular, non-fiction book *A Short History of Nearly Everything* (Bryson, 2003) to increase students’ interest in science and to authentically portray the nature of science, as well as to enhance students’ comprehension skills.

The content is interesting and accessible, and covers all science disciplines. In particular, the human drama associated with the development of scientific knowledge motivated their 10th-grade students to learn the associated science concepts. These authors also recommend Greene (2006) and Hellman (1998) for achieving similar goals.

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Powers of Ten (http://www.youtube.com/watch?v=A2cmlhfdxuY) A computerized simulation that helps students appreciate scale and powers of ten (both very small and very large numbers).

TeacherTube (http://teachertube.com) Following in the steps of YouTube, hundreds of short, vetted videos for use by teachers. Click on "Channels" to find the videos grouped by subject and grade level. Useful companion software is a video downloader such as TeacherTube Video Downloader, available from http://www.softpedia.com/get/Internet/Download-Managers/Teachertube-Video-Downloader.shtml . Upload your own videos, as well as accompanying lesson plans and worksheets, to share with others. Registered uses can interact with other members.

ScienceHack (http://www.sciencehack.com) Indexed science-related videos, some of which have been culled from YouTube and similar sources, that include experiments, projects, movies, and news. Videos are reviewed by a team of specialists before being posted online.

The Periodic Table of Videos (http://www.periodicvideos.com) Short videos describing each element of the periodic table.

Conceptual Physics: Next Time Questions (http://www.arborsci.com/Labs/CP_NTQ.aspx) Paul Hewitt's popular questions, embellished with cartoons and designed to elicit student thinking, are now available on the web.

Science-Related, Web-Based Videos

Wired Science http://www.pbs.org/kcet/wiredscience
YouTube http://www.youtube.com
Nova http://www.pbs.org/wgbh/nova
Discovery Channel http://dsc.discovery.com
Mediafestival (http://www.mediafestival.org/old_site/downloads.html) A copyright and fair use PDF file.

Enquiring Minds (http://www.enquiringminds.org.uk/) A four-stage approach to teaching and learning that takes students' ideas, interests, and experiences as its starting point and provides them with more responsibility for the direction and content of their learning.

Science Photo Library (http://sciencephoto.com) Search for science photos using keywords and/or the subject index.

Physclips (http://www.physclips.unsw.edu.au/) A multilevel, multimedia introduction to mechanics and other areas of introductory physics for high school and university. Included are film clips of experiments with animations, diagrams, and explanations in both voice-over and text.

Electronic Quality of Inquiry Protocol (EQUIP) (http://iim-web.clemson.edu/?page_id=166) Provides both a benchmark and a guide to improving the quality of inquiry in classrooms.

Papier-Mâché Animals: An Integrating Theme for Elementary Classrooms

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Abstract

One of the biggest present challenges for teachers, especially in primary classrooms, is the need to address the content standards in all subject areas with the same amount of instructional time. While curriculum integration continues to be a powerful strategy to meet this challenge, teachers often find it difficult to bridge the gap between theoretical models of integration and classroom implementation. In this article, we describe how to implement an integrated science lesson founded upon four guiding principles: (a) Use of the 5-E instructional model, (b) adherence to the National Science Education Content Standards, (c) utilization of developmentally appropriate practices for young children, and (d) incorporation of the project approach to motivate learning and integrate different subjects. Specifically, this article describes how to employ papier-mâché animals as a unifying theme in primary classrooms to integrate science, language arts, and visual arts to allow for overlapping adherence to content standards.

Traditionally, many teachers have popularized the inclusion of papier-mâché art projects in their classrooms (Farris, 2003; Hammond, 1983; Shaw & Pruitt, 1990; Sievert, 1979). However, the craft aspects of papier-mâché frequently overshadow the academic purpose for the project. As a craft, it is a wonderful activity, but to make it into a content-oriented lesson, connections to the subject areas need to be developed and emphasized. To address this problem, this article provides a set of activities that can be organized into a unit using papier-mâché animal representations as a thematic context in which to engage children in standards-based, developmentally appropriate inquiry projects that seamlessly integrate science, language arts, and visual arts. Enrichment activities are also provided to integrate social studies and mathematics.

Why Integrate?

A common thread that permeates national reform efforts stresses the need to integrate, or make connections among, the different areas of the curriculum (International Reading Association and National Council of Teachers of English, 1996; National Art Education Association, 1994; National Council of Social Studies, 1992; National Council of Teachers of Mathematics, 2000; National Research Council [NRC], 1996; National Science Teachers Association, 1998). Specifically, Program Standard B of the National Science Education Standards states: “The program of study in science should connect to other subjects” (NRC, 1996, p. 214).

Researchers of curriculum integration have identified many benefits, including that it (a) allows children to make connections among the disciplines (Shoemaker, 1989), (b) adds a sense of relevancy and significance to what is being learned (Beane, 1995; Hargreaves & Moore, 2000), (c) prepares children to transfer knowledge later in life (Caine & Caine, 1991), and (d) leads to academic gains in the content areas (McBee, 2000). Integration is also supported by brain research, which has revealed that individuals process information through patterns and connections rather than through fragments of information (Beane, 1996; Burton, 2001; Caufield, Kidd, & Kocher, 2000; Cohen, 1995; Diamond & Hopson, 1998).

Theoretical Framework

Curricula can be integrated via a number of different approaches, ranging from a fragmented model in which the teacher within a single discipline emphasizes concepts that may carry over into other disciplines to a networked model in which the learner directs the integration process by linking resources (human, experiential, textual, etc.) from different disciplines within and outside the school (Fogarty, 1991). The thematic learning cycle lesson and accompanying enrichment activities described below follows the connected model of curriculum integration. In this model of integration, a theme is used (e.g., papier-mâché) to link concepts and topics between disciplines, such as fictional descriptions of animals, sculptural representations of animals using papier-mâché, nonfictional descriptions of animals, historical uses of papier-mâché, and mathematical descriptions of papier-mâché creations.

The development of this integrated lesson was founded upon four guiding principles. The science lesson should:

- Follow the 5-E learning cycle to enhance scientific reasoning and foster conceptual understanding of scientific concepts (Bybee, 1997);
- Address specific National Science Education Content Standards (NRC, 1996);
- Employ developmentally appropriate practices for young children (Bredekamp & Copple, 1997); and
- Incorporate the project approach to motivate learning and integrate different domains of knowing (Helm & Katz, 2001).

The 5-E learning cycle model is an inquiry strategy whose origins can be traced to John Dewey and the Progressive Movement (Bybee, 1997). There is ample research to indicate the learning cycle model produces superior gains in children’s content knowledge and scientific reasoning compared to teacher-centered instruction (Guzzetti, Taylor, Glass, & Gamas, 1993; Lawson, 1995; Lawson, Abraham, & Renner, 1989). The model is comprised of five different phases that all start with the letter *E*: Engagement, exploration, explanation, elaboration, and evaluation (see Table 1). The first phase, engagement, stimulates curiosity, taps into children’s prior knowledge, and motivates the learner. In the exploration phase, the teacher invites children to investigate a problem by manipulating materials or brainstorming solutions. The explanation phase allows the teacher to uncover the children’s thinking about the problem and to help move children’s misconceptions toward scientifically accurate explanations. In the elaboration phase, children participate in a related learning experience to deepen their understanding of the concept previously explored. The fifth phase, evaluation, may include a summative appraisal of learning at the end of the lesson. However, formative assessments take place during the other phases of the 5-E lesson to learn what children know and/or are able to do as a result of their experiences.

Description of the Learning Sequence

During this lesson, children explore papier-mâché to create two- or three-dimensional representations of animals based on characters from picture books, learn about characteristics of animals during the explanation phase, and extend their understanding of animal characteristics through a cooperative research project during the elaboration phase. The lesson addresses National Science Education Content Standards A and C (NRC, 1996). Content Standard A, Science as Inquiry (K-4), states that activities should develop children’s abilities to conduct scientific inquiry. Standard C, Life Science (K-4), states that activities should develop children’s understanding of the characteristics of organisms.

Table 1
The 5-E Model at a Glance (Adapted from Bybee, Powell, & Trowbridge, 2008)

Phase	Event
Engagement	• Teacher initiates the learning experience by creating interest and sparking curiosity. • Teacher elicits responses that uncover students' prior knowledge and/or misconceptions. • Connections to past and future activities are made clear.
Exploration	• Concrete learning experiences that encourage students to work together to build conceptual understanding. • Students are active explorers of concepts, experiences, and/or situations. • Teacher acts as a coach or facilitator during student interaction.
Explanation	• Teacher encourages the students to use their own wording to explain their understanding of concepts discovered during the exploration phase. • Teacher formally provides definitions, explanations, and clarification of misconceptions. • Teacher capitalizes on, and draws from, students' previous learning experiences afforded in the engagement and exploration phases as a basis for explaining concepts.
Elaboration	• Teacher expects the students to use formal labels, definitions, and explanations provided previously to apply or extend the concepts and skills in new situations. • Teacher challenges and/or extends students' understanding and skills through new learning experiences.
Evaluation	• Assessment of students' knowledge and/or skills by a variety of formal and informal evaluation strategies. • Teacher looks for evidence that the students have changed their thinking or behaviors. • Students encouraged to assess their own learning.

Developmentally appropriate practices are consistently used to accommodate individual differences in children's ability and interest (Bredekamp & Copple, 1997; Gestwicki, 2006). For example, during the explore phase children may choose from a variety of papier-mâché animal representations and they may choose to make a representation of their favorite storybook animal, a pet, or an animal they may remember from a zoo or on television. In kindergarten and first-grade classrooms, children can create flat representations or small sculptures; however, community volunteers may be needed to help out. These projects are relatively easy for second- and third-graders to produce and they can be managed by a single teacher. More complex representations, such as papier-mâché masks and hats, may be attempted with the older children, but these may also require volunteers to assist children. During the engagement and elaboration phases, developmental needs are considered as children acquire information about animals through books read by the teacher, individuals, or groups of children.

During the elaboration phase of the lesson, children work cooperatively on a project to find out how their favorite animal really looks and behaves. The project approach to learning has been described by Helm and Katz (2001) as the in-depth research of a topic, usually by small cooperative groups, posed by the children, teacher, or both. The purpose is to provide an authentic learning experience to make learning more meaningful for children. These researchers highlight a number of benefits to using the project approach, including strengthening children's motivation to master a variety of literacy and inquiry skills, establishing connections among different domains of knowledge, and enhancing social development, making it an excellent strategy for curriculum integration. Some of the lesson's enrichment activities incorporate the project approach as well.

Engagement phase. The engagement phase introduces the science-language arts-visual arts connection. It starts with a combination of guided, shared, and independent reading of books that feature animal characters (Figure 1). Whether done individually, in small groups, or as a class, reading provides the common experience necessary for children to begin thinking about animal characteristics and creating their animal representations. The teacher encourages children to talk about the animal characters; what they look like, what they did, who they interacted with, and how they behaved. Children may act out the roles of the characters and retell the stories. Through these experiences, children develop ideas for an animal to create out of papier-mâché.

Brett, J. (1998). *The hat*. New York: Scholastic.
Brett, J. (2005). *Honey…honey…lion! A story from Africa*. New York: G. P. Putnam.
Brown, D. (2005). *The good lion*. New York: Houghton Mifflin.
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Edwards, P. D., & Cole, H. (2001). *Clara caterpillar*. New York: Harper Trophy.
Martin, B., Jr., & Carle, E. (1992). *Brown bear, brown bear what do you see?* New York: Holt.
Livingston, I. (2003). *Finklehopper frog*. Berkeley, CA: Tricycle Press.
Numeroff, L. J., & Bond, F. (1985). *If you give a mouse a cookie*. New York: HarperCollins.
McKee, D. (1989). *Elmer*. New York: Lothrop, Lee & Shepard Books.
Paul, A. W., & Long, E. (2005). *Mañana, iguana*. New York: Scholastic.
Rohman, E. (2003). *My friend rabbit*. New York: Scholastic.
Wilson, K., & Chapman, J. (2006). *Bear's new friend*. New York: Simon & Schuster.
Young, E. (1996). *Lon Po Po: A red riding hood story from China*. New York: Putnam Juvenile.

Figure 1. Recommended picture books with animal characters.

Exploration phase. In this phase, children create papier-mâché representations of their favorite animal character inspired by readings in the engage phase or personal experiences. The purpose of this activity is to enable children to translate their mental constructs into concrete representations, an essential component of the artistic process. The representations serve as springboards to encourage critical thinking about animal characteristics that they began to think about in the engagement phase and will develop further in the explanation and elaboration phases. The representations could take different forms, including miniature sculptures, two-dimensional pictures, masks, or hats. Possible materials and directions for constructing different types of papier-mâché animals are provided in Appendix A. The picture books should be displayed and available to children as they work. Children may work independently or in small groups to create their animal representations modeled after, or inspired by, a character from one of the picture books (see Figure 2). The amount of time needed to complete the exploration depends on the type of papier-mâché projects that are created. The application of the papier-mâché itself requires between 30 minutes (two-dimensional pieces) and 60 minutes (masks and hats). The projects need at least 48 hours to dry before decorating, which may require an additional 30 to 40 minutes.

Explanation phase. The purpose of the explanation phase is to stimulate critical thinking about the characteristics of animals. Begin by asking each group to describe which animal character is represented by their papier-mâché creation, the materials they used to decorate it, and why they chose this particular character. Encourage children to expand upon their thinking, initiated during the engagement phase, about how the stories portrayed their animals' physical and behavioral characteristics and environments, such as body color and size, food choices, speaking and reading, shelter, locomotion, clothes, defense strategies, emotions, personal hygiene, growth and development, and so forth. Using a graphic organizer, make a class list of fictional characteristics from the animals depicted in the fictional books (Figure 3). Further use of this organizer will be elaborated later.

Figure 2. Papier-mâché animal projects from beginning to end.

Name: ______	Animal: ______	
Fiction	Nonfiction	Similar?

Figure 3. Graphic organizer to compare animal characteristics from fictional and nonfictional sources.

Elaboration phase. In this phase, the project approach (Helm & Katz, 2001) is used to help children discover how their animals really look and behave. The project approach poses authentic problems to encourage children to take the lead in their own learning. For example, the teacher might pose questions such as: "Do you think a frog would really take a bubble bath before going to bed?" or "Do you think caterpillars really say such things?" Children should be encouraged to explain why they think so. Next, pose the problem: "Today, you are all junior zoo keepers. Your job is to make sure the information you tell visitors about the animals is correct. How do you think we could find out if real animals behave like the ones in our story?" Emphasize the point that television documentaries and nonfiction books tend to portray animals as they really are and, therefore, are more reliable sources of information.

For nonreaders, the teacher can read nonfiction books out loud and help children compile a list of characteristics similar to the one created from the fictional story. Webcams and documentaries can be used to help children discover how real animals look and behave. The Animal Webcam Locator (2005) provides links to live video feeds of a variety of animals.

The teacher should provide a variety of age-appropriate options for the children to report on their findings. For example, younger children can reuse the graphic organizer they completed earlier, to record fictional animal characteristics from fictional books, to now record animal characteristics from nonfiction sources (Figure 3). The children then decide if the descriptions of the animals in the fictional story are similar to the ones provided in the nonfiction books, an important formative assessment for the literacy component of the lesson. More advanced children can organize their findings using a Venn diagram. Older children can produce a computer presentation of their findings, incorporating images and text to support their conclusions.

Evaluation phase. By making careful observations and asking focused questions, the teacher assesses the children's ability to perform skills associated with scientific inquiry, including observing, inferring, and communicating, as well as their understanding of animal characteristics at various checkpoints through this integrated learning cycle lesson (NSES Content Standards A and C). For instance, during the engagement and explain phases, the children's ability to use the text to identify animal characteristics can be assessed and fostered. At the beginning of the elaborate phase, children reveal initial conceptions about their understanding of personification as the teacher asks children to consider whether animals really look and behave like the characters in the stories. By listening to children's responses and explanations, an initial picture of student understanding is revealed. Another checkpoint of the children's understanding and/or ideas occurs at the end of the elaboration phase when they report on the differences they identified between real and fictional animals using graphic organizers or computer presentations.

Finally, an engaging summative assessment is used. In addition to reading about popular characters, many children also are accustomed to watching popular cartoons and/or movies in which nonrealistic and realistic characters are portrayed. Examples of some popular movies include Disney's *Finding Nemo* and Pixar's *A Bug's Life.* The teacher has children work in small groups and focus on particular characters to keep the task manageable. For instance, in Disney's *Finding Nemo* movie, each group can focus on a particular character (e.g., Group A focuses on Nemo, Group B focuses on Marlin, Group C focuses on Dori, and so on). Children can view these clips and follow along with T-charts noting realistic and nonrealistic characteristics. A follow-up classroom discussion led by the teacher using the T-chart responses is used to clarify real and unreal characteristics and to make comparisons between different animals to develop generalizations (e.g., animals have basic needs, communicate, and respond to their environment).

A rubric for assessing the children's T-charts can be used to document the children's understanding in a summative fashion.

Discussion

As stated in the introduction, the goal of this project was to use papier-mâché as a unifying theme to develop a set of activities based on the 5-E learning cycle model that seamlessly integrates science, language arts, and visual arts with engaging, developmentally appropriate learning experiences firmly grounded in the content standards. Additional activities are provided that can be used to develop an entire unit themed around papier-mâché. Children's fictional literature is a wonderful way to get children ready to learn. In the engagement phase of the lesson, the teacher and children read books that feature animal characters. The teacher encourages children to talk about the characters; what they look like, what they did, who they interacted with, how they behaved. Through these conversations, children develop ideas for an animal they want to create, investigate, and write about.

If time permits, the engagement phase can be enhanced by having the children participate in a readers' theater to role play the characters as the books are reread, or create and participate in their own classroom skits or plays. Children can also explore the storytelling device of portraying animals with human qualities to teach lessons about manners and morality through fables and fairy tales.

Visual arts are integrated into the lesson during the exploration phase when children create their animal representations with papier-mâché. Children express their ideas, experiences, and stories through their creations, as well as apply elements of design such as shape, color, and texture. They are also allowed to make choices about the type of object they create and the materials they use. As children discuss their choices, the teacher should emphasize the connections between the creation of art, the importance of good observation skills, and the influences of experiences and interests on the final product.

Physical and behavioral characteristics of animals are introduced during the explanation phase as children discuss their papier-mâché creations and their characteristics as presented in children's books. Science content knowledge is deepened during the elaboration phase as children assume the role of junior zookeeper and research nonfiction resources to learn about how their animals really behave. Children are provided with a variety of resources to collect information and prepare a presentation about their animals. The language arts are also emphasized during the explanation and elaboration phases as children talk and write about their animals' physical and behavioral characteristics and the differences between their papier-mâché animal creations, the animals' portrayals in storybooks, and how they really look and behave.

Learning centers should be used to enrich and further integrate the content areas as part of the explanation and elaboration phases. The use of centers is a developmentally appropriate practice that enables young children to work at their own pace, interact with other children, gain hands-on experiences, and make choices (Hyson, 2008). At the science center, children may choose to explore the chemical and physical properties that make it possible to construct objects out of papier-mâché (NSES Content Standard B). They can use magnifiers to observe dried fragments of papier-mâché. The teacher works with the entire class to create a list of the children's observations, making sure that the holes in the paper and the network of strands are noted. The teacher facilitates a discussion about how the holes and strands may be clues as to how the papier-mâché sticks together. Specifically, water enables white glue or wheat flour to penetrate the pores of the paper. White glue and flour contain polymers, long strands of repeating molecules that bind together. When the water evaporates the polymers remain, mechanically bonding the strips of paper.

At the language arts center, children can choose to create their own stories about their papier-mâché animal creations. Additional fiction and nonfiction books about animals should be provided to encourage independent reading and conversation. Children can also systematically investigate how fiction and nonfiction trade books portray animals (Gomez-Zwiep & Straits, 2006). Older children can use the project approach to write their own children's books that use animals to teach young children important lessons, such as colors, manners, counting, cooperating, and telling the truth. Children can also choose to investigate and write factual reports about other animals.

The visual arts learning center provides children with materials to create two- and three-dimensional representations of scenes from books, realistic environments in which the animals are likely to be found in nature, or fantasy landscapes inspired by the stories and classroom conversations. Children can choose to use papier-mâché and other media to construct their scenes. The project approach is used here to create a scenario to engage children in the activity. For example, children can choose to work cooperatively to create a museum exhibit depicting a realistic habitat for their animals and lead "tours" for children from other classrooms. Children may also choose to illustrate the stories they wrote at the language arts center.

Mathematics is also integrated into the curriculum with center activities. For example, younger children may choose to make bar graphs to represent the number of individuals/groups selecting a particular animal character. Older children may choose to determine the volume of masks and hats using rice, popcorn kernels, or small beans. Children may also choose to measure the circumferences of their hats and masks. Data for the entire class is organized in a table and represented graphically. Children then calculate the range and mode for the entire class.

At the social studies center, books and photographs are used to illustrate the origins and historical uses of papier-mâché, including art, furniture, and boxes. Additionally, children may choose to explore the historical and cultural relationships of piñatas to Mexican culture through books such as *Hooray, a Piñata!* (Kleven, 1996) and *Magda's Piñata Magic* (Chavarria-Chairez, Ventura, & Vega, 2001). Through teacher-facilitated discussions, children talk about the relationship that their animal creations have with humans. For example, is it a scary monster, a pet, an animal we might see at a zoo, or a wild animal living in our backyards? If it is a monster, what makes it scary? If it is a pet, why do we like to keep it in our houses?

Implementation and Lessons Learned

Lastly, the implementation of the activities by teachers has been well received. Several elementary teachers have provided suggestions and ideas to help facilitate this activity. For example, children at the younger end of the elementary school level (Grades K-2) and/or children with special learning needs will need additional help, time, and support if they are creating full-coverage masks. A first-grade teacher also suggested that it is much easier for children at this age to focus on developing flat representations and/or mini sculptures (discussed in the exploration phase). Another suggestion provided by a second-grade teacher was to expand the exploration phase (animal hat creation) across a week and ask for help from students at the upper elementary and/or junior high/high school levels. In addition, all of the teachers who responded to the authors have suggested that it has always been very helpful to invite parents, grandparents, or other student teacher volunteers into the classroom during this activity. Teachers also pointed out that giving the children a choice in their animal hat design helped keep them focused. Another teacher encouraged the children to bring in craft items, such as beads, feathers, or sequins, from home to contribute to their hats. Other teachers suggested sending a letter home explaining the project, inviting parents to sign up for a time to help, and/or asking for materials to assist with creative parts of the hats.

Conclusion

This article described how papier-mâché animals may be employed as a unifying theme to integrate science, language arts, and visual arts using developmentally appropriate learning experiences, including the project approach, without compromising each discipline's content standards. Suggestions for integrating mathematics and social studies were also provided. Curriculum integration is a powerful strategy to help children make better sense of the material they are learning and transfer their knowledge across content areas and to new situations. Developmentally appropriate learning experiences were used throughout the lesson to encourage children to make choices, interact with each other, and participate in hands-on, minds-on activities. The 5-E learning cycle lesson culminated with an authentic, project-based activity to motivate children to work hard and strive for quality. Suggestions and examples for incorporating the project approach in some of the enrichment activities were also provided. As the pressure increases for teachers to address the content standards in all subject areas with the same amount of instructional time, thematically integrated curricula are an effective strategy to meet the challenge.

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Appendix A: Materials and Directions for Constructing Papier-Mâché Animal Representations

Materials

- Newspaper (torn into long strips)
- Wheat flour
- White glue
- Water
- Measuring cups
- Containers or basins for mixing paste
- Large balloons (10-15 inch diameter)
- Tempera paint (various colors)
- Paint brushes
- Scissors
- Tape
- Construction paper
- Card stock
- Tissue paper (various colors)
- Styrofoam balls (optional)
- Paper towel rolls (optional)
- Scrap fabrics (optional)
- Cardboard pieces (optional)
- Pom-poms (optional)
- Fictional trade books featuring animals

Directions

1. Make the papier-mâché mixture by mixing equal amounts of flour and water or glue and water. Glue will yield a stiffer product when dry. The mixture should be about the consistency of thin pancake batter. About 4 cups of the mixture are needed to complete a hat or mask.

2. To create flat representations, children dip the strips of newspaper into the mixture and

apply it to a sheet of card stock or construction paper. The result is a relief image of their animal's face or entire body. Miniature sculptures can be created by shaping the moistened strips of paper into animal shapes.

3. Groups wishing to create hats or full-coverage masks need a large balloon filled completely with air and tied securely. Children use their fingers to affix paper strips to the balloon until the balloon is completely covered with two to three layers of newspaper. It is not necessary to wait for each layer to dry before applying a new layer.

4. The papier-mâché representations should be allowed to completely dry for approximately 48 hours in an undisturbed place indoors. Groups making hats or masks can now use a pair of scissors to pop the balloon and carefully cut a hole into the base. For a mask, the hole should be large enough for a child's entire head to fit inside. For a hat, the hole should be slightly smaller than the diameter of a head. The papier-mâché can also be cut longitudinally to create two masks that cover just the face. The teacher should assist children with cutting out the holes for the eyes and mouth.

5. Children can then begin to develop their animals in fun and creative ways, which addresses the visual arts standards. Colored tissue paper can be applied to the dried newspaper by dipping them into a papier-mâché mixture or affixing them with white glue or glue sticks. This step allows children to add color and dimensionality to the animal creations. Washable paints can also be applied to the dried paper to add color. Adornments such as horns, eyes, noses, ears, hair, and teeth can also be applied using paper towel rolls, cardboard, styrofoam balls, strips of fabric, and marbles.

Dr Skateboard's Action Science: Teaching Physics in Context

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Abstract

In order to create student interest and promote new connections to the understanding of fundamental physics concepts, there is a need for new approaches and methods that are both contemporary and relevant. Dr Skateboard's Action Science, a curriculum supplement comprising video instruction and classroom activities, is an example that focuses on the physical science concepts found in the areas of forces, motion, Newton's laws of motion, and simple machines. The use of familiar activities, situations, and objects, such as skateboarding and bicycle motocross (BMX), around which students can explore and explain scientific concepts can be defined as action science.

Dr Skateboard's Action Science is designed to teach fundamental physics concepts using an approach that utilizes transformative educational strategies that help students move from memorizing facts and content to constructing knowledge in meaningful and useful ways. Students learn to develop questions, consider multiple points of view, and seek explanations in ways that require critical thinking and problem solving. The goal of this approach is to make physics education transformative through action science, a process in which educators integrate familiar experiences and materials from students' lives in order to amplify scientific concepts. In the case of Dr Skateboard's Action Science, the materials and experiences focus on skateboarding and bicycle motocross (BMX).

Dr Skateboard's Action Science integrates specific scientific concepts in a curriculum that contains both video instruction and classroom activities. Both sets of materials are designed to address both physics content and scientific process skills in both the National Science Standards (U.S.) and Texas Essential Knowledge and Skills (TEKS). The main purpose of this educational approach is to provide an interesting way of instructing students in the areas of motion, forces, Newton's laws of motion, and simple machines set in a real world context.

Background and Description

Dr Skateboard's Action Science was designed and developed by a collaborative team that included university faculty and personnel from local school districts, as well as teachers and students. The development team also included pivotal videographers who captured footage from school demonstrations, edited the four video parts following the script for each part, and placed appropriate graphics throughout each episode. The action sports footage provided a contemporary approach for providing students with physics content from familiar places that included skate parks, schools, classrooms, and community sites.

In order to create relevance in the action scenes that appear throughout the videos, a group of professional athletes in BMX and skateboarding were utilized. The athletes demonstrated physical science concepts, such as the relationships between centripetal force and moment of inertia, by performing high-flying and intricate maneuvers that included back flips and spins. With extensive experience performing for students in schools, this group provided the visual content that became the backbone of the video as it served to engage learners in the fundamental physics concepts. This is also another pathway to invite students to learn, in that they may not be initially attracted to science instruction yet do recognize and respect the difficulty of the maneuvers performed by the professional athletes.

In turn, the four-part video provides a series of instructional opportunities that allow students to explore relevant science content in class. It is the premise of this approach that students will better understand science content as a result of engaging in a curriculum that integrates their real world interests. Additionally, there is an underlying message that the characteristics that make action sports athletes successful, such as practice, persistence, dedication, and goal-setting, also can extend to students' individual academic and education pursuits. As one Principal of a participating school commented:

> The message regarding the importance of education, the fact that skaters can be smart students, and the need to set life goals took on a different meaning after seeing this presentation. The encouragement and presentation will be something that our students will never forget. (S. Haynes, Bonham Elementary School, El Paso, Texas, personal communication, April 14, 2007)

Accompanying the four-part video are 20 classroom activities, 5 for each of the parts that focus on the themes forces, motion, Newton's Laws of Motion, and simple machines, respectively. Sample videos and classroom activities may be found at *Dr Skateboard's Action Science* (n.d.). The activities utilize common household materials such as paper clips, card stock, string, and tape. This provides teachers with an affordable and practical series of experiments that engage students in hands-on explorations of the physics concepts presented in the video instruction. As the activities were being developed, they were field tested in real classrooms and revised on the basis of interactions with the 15 teachers involved in the design, development, and implementation of the activities.

Using the Approach

Dr Skateboard's Action Science is an example of transformative education, a student-centered curriculum supplement built around interesting content linked to specific physics knowledge and skills in science. The videos and classroom materials provide the classroom teacher with an instructional series rich in science and include topics such as moment of inertia and centripetal forces, inertia, center of gravity, and momentum. The purpose is to contextualize the classroom process of acquiring critical knowledge, developing proficiency in problem-solving, engaging in self-directed learning, and participating in collaborative teams.

The activities and materials are designed for students to interact in small teams, and this sharing within cooperative groups is a fundamental constructivist strategy that allows the teacher to facilitate the learning process. As a student-centered approach, it also helps to develop a common base of experiences on which to help students make connections to content. In the classroom, problem-solving strategies depend on the development of conceptual understandings, and hands-on explorations of simple topics combined with collaborative interactions among learners help to build an understanding of processes and concepts (Apple, 1993). It is important for educators to not merely regard the learner's point of view alone as fully complete and significant (Dewey, 1970), but to guide the students in the analysis and synthesis of content information. The learner is always defining meaning within the context of action and reflection (Brooks & Brooks, 1993), and the social situations, including discussion, explanations, and hands-on experiences, provide the context for knowledge construction.

The video segments themselves do provide action, but also relevant content for the classroom and complement the activities that teachers can implement in the classroom. Used in tandem, these can help reinforce the conceptual emphasis in a lesson. For example, the portion of the "Newton's Laws" video that covers the concepts of force, mass, and acceleration has been designed as an effective introduction to the activity "Force Makes a Mass Move." This brief video segment serves as a hook to introduce the activity and additionally as a review for the content covered in class. In that sense, the materials serve both pre-activity and post-activity purposes, and allow the teacher the flexibility to have students explain fundamental physics as well as pursue inquiry extensions. Each activity contains both a teacher section and a student section. The teacher section provides standards alignment information, background knowledge, guiding questions with answers, and extensions for student enrichment. The student section contains the classroom science activity, connections to real-world examples, explanations of concepts, and actual photographs of BMX riders and skateboarders in action.

Each learner understands content and concepts differently based on his or her previous experiences, and the materials help to provide a context for understanding both science concepts and real-world connections. So much fascinating content is at the fingertips of learners everywhere, and with computer access and technology becoming more affordable, more information is accessible. The main emphasis is to engage students in the exploration of science in a real-world context and to link physics to action sports. The students need opportunities to address misconceptions and to develop concepts in real-world situations. "Students come to school with their own ideas, some correct and some not, about almost every topic they are likely to encounter" (Rutherford & Algrehn, 1990, p. 198). Learning is the responsibility of the learner, but the teacher guides the student into developing meaning from content material and classroom experience.

It is important to engage learners in learning situations that effectively integrate their own experiences and familiar materials that students can use to better understand specific concepts (Eisenkraft, 2003). For example, students who enjoy skateboarding can be given opportunities to explore the concepts of velocity, acceleration, center of gravity, and moment of inertia. They may also use the skateboard and a local skate park to investigate topics such as inclined planes, levers, fulcrums, and screws. The purpose of this approach is to allow the students to explore meaningful science topics set in the context of something they enjoy doing.

Exploring Center of Gravity in the Classroom

Another classroom example from the program is the use of the video segment in the "Forces" video that focuses on the concept of center of gravity, which additionally bridges the concepts of gravity and lift. Prior to showing the video segment, the teacher can use open-ended questions with students in order to activate their previous knowledge concerning this content. Sample questions could include: "What do you do when you ride a skateboard or a bicycle?" "How do you balance on a skateboard or bike?" "What forces are acting on you as you are trying to ride a bike or skateboard?" Additionally, previously marginalized students who have experience in these activities, but who may struggle in science, can become experts in this discussion and contribute greatly to the classroom investigations.

Then, the teacher could conclude the series of questions by asking "what is the center of gravity and why is it important?" and then facilitating the conversation in order to introduce the segment in the "Forces" video that covers both gravity, lift, and the center of gravity. This approximately 4-minute segment of the video then serves as the engagement to the activity "Flatland BMX and the Center of Gravity," in which students create irregular cardboard shapes and determine the object's center of gravity through a series of step-by-step procedures. Students exploring a concept should be given opportunities to work with hands-on materials so that they can have experiences that are real and fundamental. Hands-on learning plays a valuable role in the constructivist paradigm, as it is the process of learning by doing (Dewey, 1970) that is utilized in explorations and experiments.

Next, students modify their shapes by either adding paper clips (which increases the mass) or by cutting off part of some of the cardboard (which decreases the mass). In turn, they come to see that there is a fundamental relationship between the center of gravity and the mass distribution in an object, and that the center of gravity can move in relation to an increase or decrease in mass at a particular location. After the classroom lesson, the teacher can revisit the activity by asking the students to explain their findings and the relationships they discovered. As students explore concepts, they develop a broader understanding of those concepts. When they relate what they are learning, seeing, or doing to others, they can begin to see similarities in their understandings, as well as self-identify misconceptions they may have about content material (Bybee et al., 2006). Finally, there is a list of open-ended questions for students to answer, as well as a series of extensions that they can engage in if there is additional time and motivation to explore these concepts. This entire activity can be done in the time frame of a normal class period with minimal set up and clean up, and can provide both the teachers and students with an interesting alternative to exploring these fundamental physics ideas.

Inquiry Activities Using the Ideas of Levers and Fulcrums

A constructivist curriculum must be designed so that it reflects real life situations (Bentley, 1995), and the use of relevant contexts helps to contextualize the concepts, as well as helps provide connections across subject areas (Hofstein & Yager, 1982). Research scientists cross over the barriers between academic disciplines all the time, seldom operating solely on isolated areas of content but rather integrating the use of language, knowledge, and process application. Science programs that emphasize investigation give students the ability to retain facts through critical thinking by working through problems logically and making connections to the real world.

The materials in Dr Skateboard's Action Science were also designed to emphasize inquiry in classroom explorations. As a foundation for discovery, the teacher can use the video segment in the "Simple Machines" episode that relates to fulcrums and levers and then have the students perform the classroom activity "Skateboards Have Levers and Fulcrums." After the activity, the teacher may revisit these ideas and then create an extension inquiry exercise for the students to do in teams. The teacher can provide the students with the same materials used in the activity, such as rulers, tape, plastic spoons, rubber bands, and modeling clay, and challenge the students to design a simple machine made of at least three of the provided materials that uses a lever and a fulcrum and can propel a small marshmallow the farthest distance.

In making this transition in class, the teacher guides the students towards developing their own ideas and, within a given time period, has the students create and test their unique designs. By engaging students in a design competition, there is a spirit of enthusiasm and excitement among the groups. There are also excellent opportunities to develop cooperative group skills and to have students use critical thinking to solve the problem presented. "Students should know what it feels like to be completely absorbed in a problem. They seldom experience this feeling in school" (Bruner, 1962, p. 50). Finally, the teams of students not only have to launch the marshmallow, but they also have to record the distances, calculate the average distances travelled, and indentify the lever and fulcrum within their machine. In this manner, the students have to present their ideas, justify their understandings, and support their findings with experimental data.

Conclusion

The use of action science as a mechanism for integrating transformative education is an approach that appears to be enhancing the interest and motivation of middle school students in science. It is the purpose of Dr Skateboard's Action Science to positively impact achievement for Middle School students in the area of physical science knowledge and skills. By immersing students in a science learning approach based on action sports and focused on the goals and objectives in physical science, the process skills and overall content knowledge of the students have the potential to greatly increase. Studies have shown that students who are involved in active learning in meaningful contexts acquire knowledge and become proficient in problem-solving (Robertson, 2008). In the longer term, research in this area will seek to determine how the implementation of curriculum approaches built around student interests such as skateboarding and bicycle motocross (BMX) can impact student achievement in science content and conceptual understanding.

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