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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Contrary to what has often been reported, Walt Disney’s body was never stored cryonically. Walt Disney (1901-1966) is one of the world’s most famous film producers. One of his greatest successes was the opening of Disneyland in 1955, a spectacular theme park in California, USA that bases most of its rides, exhibits, and shows on Disney film characters that include Donald Duck and Mickey Mouse.

Cryogenics is the field of science that deals with extremely low temperatures (below -150°C). Cryonics is the part of this field that involves freezing human bodies, after death, in liquid nitrogen. However, while Walt Disney’s body has not been cryopreserved, the bodies of some other humans and pets have been, based on the belief that advances in science may one day allow them to be brought back from the dead.

In some cases, the head and body have been stored in different containers, and in other cases only the head has been frozen--a less costly option. Most scientists are skeptical, though, about the process. There is no evidence that dead animals--and this includes humans--can be revived after either short-term or long-term storage in liquid nitrogen.

Science Story

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

The Dr Fox Lecture

During the early 1970’s, a group of researchers decided to investigate whether an audience could be “seduced,” by an engaging, expressive speaker, into believing that they had learned something from a lecture that contained very little substance. Dr

Fox, an expert in applying mathematics to human behaviour, was invented, together with fake resume. A professional actor, of very distinguished appearance, was engaged to play the role of Dr Fox in presenting a bogus lecture, in his apparent field of expertise, to three groups of mainly mental health professionals, most of whom possessed a graduate degree. His preparation comprised reading an article written for a lay audience, together with some coaching by one of the researchers. He was instructed to "present his topic and conduct his question and answer period with an excessive use of double talk [sic] [i.e., evasive/ambiguous], neologisms [new words/phrases], non sequiturs [inferences/conclusions that do not follow], and contradictory statements. All this was to be interspersed with parenthetical humor and meaningless references to unrelated topics" (Naftulin, Ware, Jr., & Donnelly, cited in Mamola, 2004).

Feedback from the lecture was overwhelmingly positive, showing that participants had been won over by the lecture, which had been presented with an authoritative style. Dr Fox had apparently, for example, stimulated their thinking, with participants praising his organisation and appreciating the use of sufficient examples to clarify the material. "Good analysis of subject that has been personally studied before," wrote one. Not one of the 55 participants recognised the hoax.

What can we learn from the Dr Fox effect? First, and in conjunction with other studies (Mamola, 2004), an enthusiastic, expressive teaching style may impact positively on both students' achievement and motivation--so certainly go for it! Second, and in light of other studies showing that student ratings can indeed be useful for monitoring teaching quality (Mamola), the Dr Fox experiment reminds us that they should not be used alone for this purpose. As the researchers concluded, "student satisfaction with learning may represent little more than the illusion of having learned" (Naftulin, Ware, Jr., & Donnelly, cited in Mamola).

Reference

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"Every one of us is given the gift of life, and what a strange gift it is. If it is preserved jealously and selfishly, it impoverishes and saddens. But if it is spent for others, it enriches and beautifies." *Ignazio Silone (1900-1978), Writer*

The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching

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Abstract

The implementation of inquiry-based teaching is a major theme in national science education reform documents such as *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990) and the *National Science Education Standards* (NRC, 1996). These reports argue that inquiry needs to be a central strategy of all science curricula**.** Using a learning cycle approach in the classroom helps to facilitate inquiry practices because learning cycles focus on constructivist principles and emphasize the explanation and investigation of phenomena, the use of evidence to back up conclusions, and experimental design. Although there are several variations of learning cycles, the one that is highlighted in this manuscript as a method to support inquiry-based teaching is the 5E Instructional Model (Bybee & Landes, 1990). The use of this model in several science education professional development programs is also addressed.

Introduction

A flurry of science education reform efforts are sweeping the United States and incorporating state and national level initiatives, high-stakes testing, and funding conditions. Two of these major national reform efforts that aim to develop scientifically literate citizens include the *National Science Education Standards* (hereinafter called *The Standards*) (National Research Council [NRC], 1996) and *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990). *The Standards* for science teaching indicate that what students learn is influenced by the pedagogical methods by which they are taught. On the other hand, *Project 2061: Science for All Americans* is based on the conviction that a scientifically literate person is one who is cognizant that science, mathematics, and technology are human enterprises dependent upon one another. Both reform reports reveal that science teaching should actively engage students, incorporate cooperative learning, and de-emphasize the rote memorization of facts. In addition, the inclusion of inquiry-based teaching methodologies is a prominent theme permeating these reform documents. This paper discusses a specific learning cycle that encourages inquiry in science classrooms.

Inquiry-Based Teaching

Inquiry may be referred to as a technique that encourages students to discover or construct information by themselves instead of having teachers directly reveal the information (Uno, 1999). The implementation of inquiry has had a place in science classrooms for less than a century. Before 1900, most educators viewed science as a body of facts that students were to learn through memorization and direct instruction. However, by the 1950's and 60's, an inquiry-based rationale became more and more visible (National Research Council [NRC], 2000). Recently, *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990) and *The Standards* (NRC, 1996) argue that inquiry needs to be a central strategy of all science curricula. *The Standards* emphasize the inclusion of inquiry-based lessons in the science classroom as part of the process by which new knowledge is acquired. Specifically, *The Standards* describe the inquiry process as follows:

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 23)

However, the shift to inquiry-based pedagogical practices in the classroom may necessitate a transition from textbook-dependency as the main resource of science information to a more hands-on approach, where students are central to the learning episodes. Recent research findings have shown that an inquiry-based approach is beneficial to students and that even young children can learn through inquiry processes (Etheredge & Rudnitsky, 2003). A recent publication from the National Research Council (Bransford, Brown, & Cocking, 1999) illustrates a broad consensus about learning processes. Related to the findings discussed in this document, the National Research Council (2000) reveals that "a classroom in which students use scientific inquiry to learn is one that resembles those that research has found as being the most effective for learning for understanding" (p. 124).

Even though inquiry-based reform efforts are widespread around the country, many educators may be uncomfortable or unaware of ways to design science lessons that support inquiry learning. However, the transfer and application of inquiry-based practices in the classroom can be accomplished by using practical tools or templates for instructional design. For instance, one strategy that can be helpful to teachers, as they embark on the development of inquiry-based lessons, involves the use of a learning cycle approach (Abraham, 1997). The history of the learning cycle method dates back to the Science Curriculum Improvement Study (SCIS), an elementary school science curriculum project during the 1950's (Atkin & Karplus, 1962). A learning cycle model divides instruction into various phases based upon an established planning method, and is consistent with contemporary theories about how individuals learn, constructivist ideas of the nature of science, and the developmental theory of Jean Piaget (Piaget, 1970). A compelling case for implementing a learning cycle as a strategy to design inquiry-based science lessons is illustrated by Abraham (1997). This report synthesizes the findings from several research studies such as Abraham and Renner (1986), Ivins (1986), McComas III (1992), Raghubir (1979), and Renner, Abraham, and Birnie (1985) and suggests that, in comparison with traditional pedagogy, the learning cycle can result in better retention of science concepts, higher achievement in science, superior process skills, improved attitudes toward science and science learning, and improved reasoning abilities.

The use of a learning cycle approach in the classroom differs greatly from traditional teaching methodologies. For example, learning cycles focus on constructivist principles and emphasize the explanation and investigation of phenomena, the use of evidence to back up conclusions, and experimental design. In contrast, traditional pedagogical approaches stress the progression of skills and techniques, the delivery of ready-made information, and knowledge of the outcome of an investigation prior to it being conducted (Abraham, 1997). Although there may be several variations of learning cycles, the one that will be highlighted here as a method to support inquiry-based teaching is the 5E Instructional Model (Bybee & Landes, 1990).

The 5E Instructional Model

The 5E Instructional Model (Bybee & Landes, 1990) can be used to design a science lesson, and is based upon cognitive psychology, constructivist-learning theory, and best practices in science teaching. The cycle appears in Figure 1 and consists of cognitive stages of learning that comprise *engage*, *explore*, *explain*, *elaborate*, and *evaluate*. Bybee (1997) declares that "using this approach, students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment. Learners interpret objects and phenomena, and internalize those interpretations in terms of their current conceptual understanding" (p. 176). Science teachers and curriculum developers may integrate or apply the model at several levels. The model can be the organizing pattern of a sequence of daily lessons, individual units, or yearly plans (Bybee, 1997). Each phase of the 5E Instructional Learning Cycle, as it has been modified from Bybee, is now described.

Engagement. In this first phase of the cycle, the teacher aims to assess student prior knowledge and/or identify possible misconceptions. This student-centered phase should be a motivational period that can create a desire to learn more about the upcoming topic. Students may brainstorm an opening question or ask themselves: "What do I already know about this topic?" Discrepant events, demonstrations, questioning, or graphic organizers such as KWL charts may be included to create interest or generate curiosity. A KWL chart asks students to brainstorm and record what they *K*now, *W*ant to know, and (eventually) have *L*earned about the topic. The KWL chart is used to pre-assess student prior knowledge and is oftentimes referred to throughout the duration of the lesson. The instructional task is identified.

However, this phase does not serve as a time to lecture, define terms, provide explanations, or record definitions.

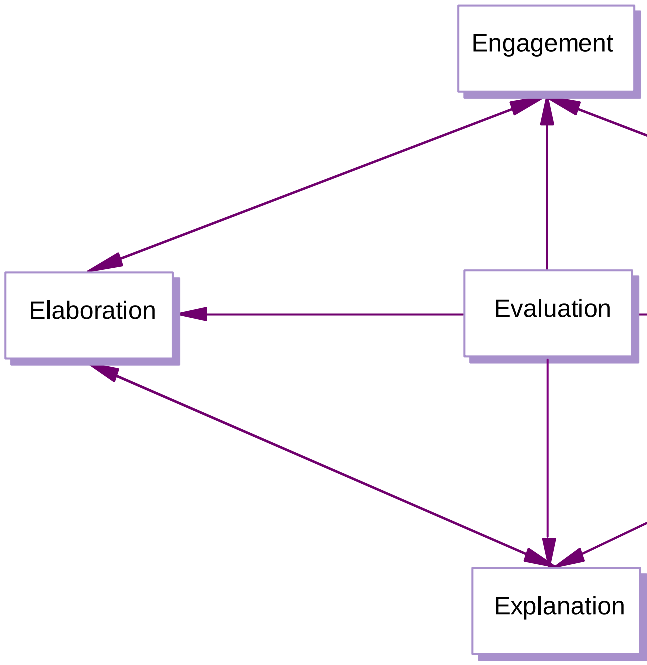

Figure 1. The 5E Instructional Model.

Exploration. Following an engagement phase that promotes a mental focus on the concept, the exploration phase now provides the students with a common, concrete learning experience. This phase is also student-centered and incorporates active exploration. Students are encouraged to apply process skills, such as observing, questioning, investigating, testing predictions, hypothesizing, and communicating, with other peers. This phase of the learning cycle tends to incorporate the main inquiry-based activity or experience, which encourages students to develop skills and concepts. The teacher's role is one of facilitator or consultant. In addition, students are encouraged to work in a cooperative learning environment without direct instruction from the teacher. This phase is also unique because the students are given a "hands-on" experience before any formal explanation of terms, definitions, or concepts are discussed or explained by the teacher.

Explanation. A "minds-on" phase follows the exploration phase, and this is more teacher-directed and guided by the students' prior experience during the exploration phase. The explanation phase enables students to describe their understanding and pose questions about the concepts they have been exploring. It is likely that new questions will be generated. The explanation phase is an essential, minds-on part of the 5E lesson. Before the teacher attempts to provide an explanation, the students must first have the opportunity to express their own explanations and ideas. Thus, the initial part of the explanation phase is a time for the teacher to serve as a facilitator and ask the students to describe and discuss their exploration learning experiences. After the students have had the opportunity to share their own explanations, the teacher introduces scientific and technical information in a direct manner. This phase includes clarification of student misconceptions that may have emerged during the engagement or exploration phases. Formal definitions, notes, and labels are provided. The teacher may also decide to integrate video, computer software programs, or other visual aides to help with student understanding. The students should then be able to clearly explain the important concepts to the teacher and to their peers.

Elaboration. The activities in this phase of the learning cycle should encourage students to apply their new understanding of concepts, while reinforcing new skills. Students are encouraged to check for understanding with their peers, or to design new experiments or models based on the new skills or concepts they have acquired. The goal of this phase is to help develop deeper and broader understandings of the concepts. Students may conduct additional investigations, develop products, share information and ideas, or apply their knowledge and skills to other disciplines. This is a great opportunity to integrate science with other content areas. Elaboration activities may also integrate technology, such as web-based research or WebQuests

Evaluation. Assessment in an inquiry-based setting is very different to that in traditional science lessons. Both formal and informal assessment approaches are appropriate, and should be included. For instance, the use of non-traditional forms of assessment, such as portfolios, performance-based assessment, concept maps, physical models, or journal logs may serve as significant evidence of student learning. During an inquiry-based lesson, assessment should be viewed as an ongoing process, with teachers making observations of their students as they apply new concepts and skills and looking for evidence that the students have changed or modified their thinking. Students may also have the opportunity to conduct self-assessment or peer-assessment. However, the evaluation may also include a summative experience such as a quiz, exam, or writing assignment.

Although the 5E Model has just been explained in serial order, it is often necessary to reverse back into the cycle before again going forward. For instance, numerous explore/explain rotations may need to occur before the students are ready to transition to the elaboration phase. The teacher may move back and forth several times within the Es, or may include an additional engagement prior to starting an elaboration phase. The cycle is very flexible and dynamic. It may take many days to complete the lesson or unit. It is not necessary to complete one learning cycle each day that science is taught. The model is designed to facilitate conceptual change and contribute to more consistent and coherent science instruction (Bybee, 1997).

Several teacher-developed 5E lesson plans are available from TAPESTRIES (n.d.). Also, Duran (2003) contains a lesson that engages students in inquiry following a 5E design, and an abbreviated version of this lesson is provided in Appendix A.

Applications of the 5E Instructional Model

The 5E instructional planning model has been integrated, as a core instructional design strategy, in many science classrooms in the Northwest Ohio region. Specifically, it has been a significant part of the reform-based professional development programs conducted by science educators and scientists from Bowling Green State University and The University of Toledo. This group has worked with K-12 educators to create 5E lessons and unit plans that support science courses of study and *The Ohio Academic Content Standards for Science*.

Included in these grant-funded programs are TAPESTRIES (Toledo Area Partners in Education - Support Teachers as Resources for Improving Elementary Science), a 5-year project funded by the National Science Foundation, and Project ASTER (Active Science Teaching Encourages Reform), a 2-year project funded by the Improving Teaching Quality Program of the Ohio Board of Regents. Both projects are collaborative efforts between two large midwestern universities and urban and suburban school districts. Major goals of both projects are to:

1. provide effective and sustained professional development in science content, pedagogy, and assessment for elementary teachers,
2. implement quality inquiry-based science curriculum and instruction,
3. coordinate curriculum, classroom practice, and student assessment with the district-adopted science courses of study and statewide curriculum models and assessments, and
4. enhance the science content knowledge of elementary teachers in life, physical, and earth/space science.

Although the projects differ slightly in their academic year activities, a core 2-week summer institute experience is similar for all of the teachers. The summer institute is designed to encourage teachers to explore their district-adopted inquiry-based science kits in a hands-on fashion. A scientist and science educator team facilitates each session using 5E Models as the guiding framework. At the end of the summer institute, the teachers develop their own 5E unit plans based upon the needs of their students. Approximately 1,200 classroom teachers from the participating districts received extensive staff development in science content, pedagogy, and student assessment. A recent study released by The Urban Affairs Center from The University of Toledo reveals the positive effects and impact of the TAPESTRIES program on student achievement. A complete copy of the study is available from University of Toledo (n.d.).

A relatively new project, PRISM (Partnership for Reform through Inquiry in Science and Mathematics), is in its first year of implementation at Bowling Green State University with funding provided by the National Science Foundation's Graduate Teaching Fellows in K-12 Education Program. Teams consisting of a cooperating teacher and a natural science or mathematics graduate student are working to introduce hands-on inquiry in science and mathematics classrooms into four school districts. Approximately 25 teams, over a 3-year time frame, will develop comprehensive 5E Model unit plans that span the entire school year.

The ultimate goal of these projects is to improve student learning by conducting sustained teacher professional development. The projects were designed to help prepare scientifically literate students, who can comprehend and use science, while being successful on high-stakes statewide science assessments.

Effectiveness of the 5E Model

A qualitative analysis of TAPESTRIES and Project ASTER final evaluations and participant journals have yielded a prominent theme--that the 5E Model is an effective way to design inquiry-based science lessons that enhance student learning. Sample teacher responses that support this theme are as follows:

> Using the 5E Model will help me to be sure of designing meaningful, purposeful lessons for my students each time I teach science. I appreciate being sure that I am connecting to previous knowledge [engage], giving them meaningful, hands-on activities [explore], and being sure to assess specific skills that I want the students to learn [evaluate]. (TAPESTRIES teacher)

> By following the 5E Model, I will be able to assess the students' knowledge before the exploration activity starts so that their evaluations will be appropriate for their academic ability level. (TAPESTRIES teacher)

> The 5E planning guide enables teachers to personalize lessons according to student needs. Educators often teach chapters or units from the order that is presented in the book. However, various and flexible teaching enables children with attention problems to stay focused. The 5E Model is a tool for teachers to engage the students with topics they may not have much interest in or prior knowledge about. (Project ASTER teacher)

> In order for students to learn and gain an understanding of science concepts, they must be actively engaged in their own learning. They must be lead by their

> teacher to discover things. Teachers must guide their students in directions that will help them observe/discover to correct their own misconceptions. It is this inquiry learning that leads to true learning. A 5E plan helps set-up lessons in a manner that supports this type of teaching. (Project ASTER teacher)

One year after the first cohort of Project ASTER teachers underwent their professional development, a follow-up question about their use and implementation of the 5E Model was sent to 30 participants. A sample of teacher's responses follows:

> After the exploration, the class is more comfortable with how to explain; therefore, increasing their problem solving background and they become better writers too based on their confidence to explain more completely. The students who may have weaknesses in reading and writing really seem to excel with the 5E lesson planning--the plan encompasses all modalities of learning.
>
> I have used the 5E Model and notice that the students are more motivated to learn the topic after I engage them in the beginning. The extend phase allows them to relate science to other subject areas so they see the purpose of what's being taught.
>
> A prolonged engagement period draws in the students who are more reserved--or just disinterested--into sharing their ideas and opinions. These students are more likely to stay with the lesson once they've invested something in it. Exploring scientific applications with hands-on activities helps the students immediately realize that these topics are relevant to their lives and perhaps connected to something they've observed or have wondered about.

After participation in the projects, the teachers are equipped with new skills and an improved confidence level to teach life, physical, and earth science in an inquiry-based environment. Teachers also argue that they are more comfortable teaching science after their participation in the projects. This improved confidence level transfers into the classroom and yields an exciting and dynamic place for student learning.

Conclusion

A national vision of science teaching and learning is being promoted that accentuates the need to restructure science education. Several national reform documents illustrate the need to make science classrooms across the country active and inquiry-based environments. With much research to support inquiry-based teaching and learning, many teachers are opting for this non-traditional teaching approach. The incorporation of learning cycles in the classroom aids teachers in the pursuit of the development of effective inquiry-based science lessons. The 5E Instructional Model serves as a flexible learning cycle that assists curriculum developers and classroom teachers create science lessons that illustrate constructivist, reform-based, best teaching practices.

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Appendix A

Abbreviated 5E Lesson for *Investigating Brine Shrimp*

Objectives: Students will:

1. Design an investigation to test the hatching of brine shrimp eggs.
2. Organize data from an experiment.
3. Draw conclusions about brine shrimp optimal conditions.

Grade Level: 6-12

Materials: (per team)

- Clear plastic cups or jars (i.e., hatching containers)
- Masking tape
- One vial of brine shrimp eggs
- Small measuring spoon for brine shrimp eggs
- Graduated cylinders and beakers
- Microscope and microscope slides
- Kosher salt or rock salt
- Student Sheet: *Observe/Infer* graphic organizer
- Hand Lens
- *Long Term Investigation* rubric

Phase	Event
Engagement	• Teacher disperses Mystery Objects (i.e., brine shrimp eggs) to each student team and does not yet inform the students that the Mystery Objects are called brine shrimp eggs. • Students record and share observations and inferences on graphic organizer. • Students suggest ways to hatch brine shrimp eggs.
Exploration	• Student teams investigate optimal conditions for the hatching of brine shrimp by designing their own controlled experiments. • Make and record observations over a 2-week period.
Explanation	• Use Jigsaw cooperative learning strategy to move students to new teams to share experimental design and results. • Teacher leads class discussion about brine shrimp and components of a controlled experiment (using the student experiments as the focus of the discussion).
Elaboration	• Based upon data and results, each team designs a new brine shrimp experiment to explore a different variable. • Create a classroom newsletter or PowerPoint presentation to share findings with class. • Conduct a *Research Share-A-Thon* day.
Evaluation	• Use the *Long Term Investigation* rubric to evaluate students. • Informal checklist during exploration to evaluate process skills.

For the full 5E lesson plan, please see:

Duran, L. B. (2003). Investigating brine shrimp. *Science Activities*, *40*(2), 30-34.

Demonstrations

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

Modelling Sound With Students

Sound in a solid. Invite 6-8 students to stand in a straight line, one behind the other, and facing the same way. Each student then uses straight, very rigid arms to hold the shoulders of the person in front of them. (The student at the front of the line might simply hold both arms straight out in front.) The rigid arms represent bonds between the particles in a solid. Give the student at the back a gentle push in the direction of the line, causing a pulse to move down the line. Have the front student signal, in some appropriate way, when she feels the pulse, and ask observers to note how quickly the pulse moved through the "solid."

Sound in a liquid. The students are spaced as for the model of a solid, but with their hands by their sides. This gives a model with the same spacing between particles as for the solid, but without rigid bonds between the particles. Tap the shoulder of the rear student, who then raises his hand and taps the student in front, who then does the same, and so on down the line. This simulates the slower propagation of the pulse in a liquid compared with a solid.

Sound in a Gas. Students again form the line described above, but this time with a minimum 2 m between them. When the student at the back is tapped, he steps forward to touch the student in front, and then returns to his original position. Upon being touched, the second person does the same, and so on along the line. The students may be stopped at any convenient instant to highlight the compression and rarefaction.

Extension. This kinesthetic model may also be used to demonstrate that transverse waves do not propagate in liquids or gases. Returning to the model of a solid, a transverse pulse (or wave) can be generated by having the rear student rock sideways (perpendicular to the line), causing the other students to do likewise. However, the absence of rigid bonds between particles in a liquid or solid prevents such propagation in these media.

Source: Whalley, M. (2003). Using students to model sound. *Physics Education, 38*(1), 56-57.

Student Experiments

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

An Alka-Seltzer Rocket

Needed. Empty 35 mm film canister with an internal-sealing lid, Alka-Seltzer (or other effervescing antacid) tablet, water, and eye protection. This experiment is better conducted outdoors.

What to do. One-quarter fill the film canister with water. Ensure close students are wearing eye protection.

You will need to work quickly on the next steps. Also, make sure you are not near a roof (or similar high structure), because you could lose your canister if it lands on top of the roof!

Add one half an Alka-Seltzer tablet to the water, snap on the lid, and stand the canister upside down on the ground (that is, with the lid touching the ground). Stand well back and prepare for lift-off! This may take 15 or 20 seconds, so don't approach the canister early.

Explanation. When the Alka-Seltzer tablet dissolves in the water, the chemicals it contains mix and react to produce carbon dioxide gas, just like baking soda (sodium bicarbonate) and vinegar do when they are mixed. Carbon dioxide is also the gas that gives softdrink its bubbles and fizz. The carbon dioxide particles bounce around inside the canister, pushing outwards on the walls (that is, exerting pressure on the walls). The more carbon dioxide particles that are produced, the greater the push. Eventually, the push is great enough to force the lid off the canister, and the carbon dioxide particles pushing on the other end of the canister drive it upwards. We then have blast-off!

Critical Incident

An Invitation

Readers are invited to send, to the Editor at editor@ScienceEducationReview.com , a summary of a critical incident in which you have been involved. A critical incident is an event or situation that marks a significant turning point or change for a teacher. The majority of critical incidents are not dramatic or obvious, but are rendered critical through the analysis of the teacher (see Volume 3, p. 13 for further detail). You might describe the educational context and the incident (please use pseudonyms), analyse the incident (e.g., provide reasons to explain your observations), and reflect on the impact the incident made on your views about the learning and teaching process. Upon request, authors may remain anonymous.

We have undoubtedly all done things about which we were very pleased, and perhaps done other things about which we did not feel so pleased, and we all need to remain reflexive of our practice. While teachers will view an incident through the lenses of their own professional experiences, and may therefore explain it differently, this does not detract from the potential benefits to be gained from our willingness to share our experiences and thus better inform the practice of other teachers.

Communication

Contributed by: Gary Simpson, Woodleigh School, Victoria, Australia, on behalf of Rejina Naidu simpg@woodleigh.vic.edu.au

Another lunch hour! And I have DETENTION!!! AGAIN! It was the last week of my second teaching round and in the last 4 days I have spent my lunch hour with Year 7 Science students because of homework detention. The fact that I took over mid-way into the term meant that I was left to do all the assessment tasks, which included poster, test, oral presentation, practical report, and a major writing piece. I did not realise till afterwards that assessment tasks also mean lots and lots and lots of marking. I was also running two parallel Year 7 classes, so I had double the marking load. So over the 5 weeks my challenge was not only to properly manage my class and survive, but also to finish the unit I took over, to get the assessment task completed and, most importantly, marked.

By the fourth week, I had marked and returned most students' work but, as was always the case, there were a few students who had not handed in all their work. So they came in to the lunchtime detention for the whole week. Students were required to complete all assessment tasks and hand them in during lunchtime. There were five students from 7E who had not completed the work; 1 girl and 4 boys.

Overall, the class was dominated by a few loud-mouthed boys who didn't really want to be in school, and the girls were really shy and restricted to one corner of the classroom. Dita was one of the quite, shy girls who did all the work in the classroom but absolutely nothing as homework. On Monday, on the first day of detention, I asked everyone for reasons as to why they hadn't submitted any work. As always, the answers added up to them being too lazy, not bothering, or forgetting, which of course led me to give them a good lecture about taking responsibility for their own learning.

As the week progressed, most students handed in their work, but still nothing much was received from Dita. Most students went home and completed the tasks and handed them in the next day, but Dita still didn’t do any work at home. Despite me asking her so many times, I still could not reason with her. Then came Thursday--one more day and that will be the end of teaching rounds. Lunchtime! Which meant detention time for me. Dita came to me to ask for a copy of the assessment task sheet. I asked her where her copy was and she said she lost it. That did it!! Not only does she not hand in her work on time, but she is also irresponsible and careless. There and then I told her off--she should be more responsible.

I checked my folder for an extra copy of the assessment task sheet, but there was none, which meant I had to go and photocopy another one. I couldn’t leave the classroom with students inside, so I told her that I would give her a copy after lunch. Till then she was supposed to borrow the sheet from another student and use it. I dismissed the detention students 10 minutes before last class and went up to my supervisor’s office with Dita. The office was locked and my supervisor was not around, so we just sat outside and waited. While waiting, I started talking to Dita and asked her why she hadn’t been doing any homework.

Then came the whole story. After school, Dita goes to a relative’s house, where she stays till 6.30 p.m. when her mother, who works in the city, comes to pick her up. It’s a fair distance from the city to home. There are kids at the relative’s place and, as they are disruptive and noisy, it is almost impossible for Dita to do any homework there. By the time she reaches home, has dinner, and does some other homework, it’s bedtime. So when was she supposed to finish Science homework?

I asked her if her mother was aware of the situation and she said that she was, but that she also wanted us to call her mum and tell her the situation. So when my supervisor came, I told her what had happened and she called Dita’s mum and explained that Dita hadn’t been able to do any homework because of all the disruption at the relative’s place. The mother was really cooperative and said that she would talk to her family and make sure that Dita gets space to complete her school work.

After all this happened, I was in a state of guilt. Guilt for telling her off! How was I supposed to know? I did ask her a few times in class and during lunchtime, but never got a response; not the correct one, anyway. So what was I supposed to do? Maybe I should not have overlooked the point that she worked well in class and that it was only her homework that was never done. I should have realised that the problem stemmed from home and not from school.

This incident has no doubt changed my approach to dealing with students who do their class work but fail to complete homework tasks. I will no doubt make sure that

I know the exact reason before making any assumption as to why an assigned task was not completed.

Science Poetry

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

I Want to be a Scientist

I want to be a scientist
I want to own a lab
I want to be a specialist
You might think I'm mad
I want to use a laser beam
I want to win awards
I want to measure gravity
and study different laws
I don't want to be a circus clown
I don't want to be a nurse
I don't want to be an undertaker
and drive around in a hearse
I don't want to be a fireman
and battle fires all day
I want to be a scientist
A scientist of today!

Adele O'Driscoll, 11 years
Australia

"It's Change … "

Mum I don't want to go to school today,
'cause I fear our world is in decay.

I feel my teachers are part of the plot,
I'm the only one who sees through the rot.

Scientists are cloning pigs and sheep,
Saying, it's change--a quantum leap.

Biologists are making stem cells grow,
Saying, it's change--the way to go.

Geologists are finding cracks in our earth,
Saying, it's change--predicting it's birth.

Archaeologists are digging up fossils and bones,
Saying, it's change--time for clones.

Yes, scientists are causing me great concern,
Giving us kids too much to learn!!!

Emma Gorrie, 13 years
Australia

Students' Alternative Conceptions

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

1. If a cup of water is placed in the freezer and allowed to freeze, it will:

a. become heavier.
b. become lighter.
c. stay the same weight.   Please explain your reasoning.

Or,

2. When 10 g of water freezes, the mass of the resulting ice will be:

a. less than 10 g.
b. greater than 10 g.
c. 10 g.

Please explain your reasoning. Repeat for 10 g of ice melting.

Comment: Mass is conserved in all three cases, so c is typically the response one is looking for. Students may confuse density or hardness with mass, and confuse a change in the bulk property of a substance with changes in the atoms that compose it.

However, we need to be alert to the possibility of a different answer also being correct, given considerations a student may have made that we did not, or at least did not intend (e.g., evaporation of water as ice melts). Also, some students may give the correct answer for an incorrect reason, and others may even give the correct answer for no good reason, such as "because you [the teacher] told us the mass does not change"--and they may not even believe it!

It is difficult to see how students who don't appreciate the conservation of atoms and mass during physical changes could make sense of such during chemical changes.

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

Teaching Techniques

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

Two-Part Chits

Contributed by: Vidya Hajirnis, India vidya_hajirnis @hotmail.com

This is a quiz game that I have used to obtain feedback from 14 and 15-year-old students during project work, and which could also be used for revision. Write a sentence (perhaps from the textbook) on a piece of paper and tear it into two parts, as illustrated by the following examples:

Boiling is a process in which / lower molecules rise to the surface and evaporate.
Evaporation is a process in which / only the upper layer of molecules turns to vapour.

Alternatively, one might write the first part of the sentence on one piece of paper and the second on another. The first and second parts can even be a question and answer, respectively. With 35 students in a class, say, one might prepare 35 such items, resulting in 70 chits.

Divide the class into 7 groups (5 students per group), and distribute the chits randomly among students so that each student receives two chits. Invite a student to read a chit (it may be a Part 1 or a Part 2), and ask students to stand if they think they have the matching chit. Typically, no more than 1 student will stand. However, subtle differences between the content of the chits may lead to more than 1 student standing. Each standing student then reads her chit. A correct response scores one point for that student's team, with an incorrect response resulting in a one-point deduction. Continue in this way to provide all students with an opportunity to participate.

For my convenience, I initially numbered the chits--No. 1 on each of the first matching chits, No. 2 on each of the second, up to No. 35. However, the children were very clever, worked out what I had done, and helped each other, so I changed to a different coding system. The children enjoyed the process.

PS I also highly recommend Joyce, B., & Weil, M. (1985). *Models of teaching* (2nd ed.). New Delhi: Prentice-Hall as an excellent source of teaching methods, including inductive thinking, inquiry training, the memory model, nondirective teaching, and the classroom meeting.

Devising Mnemonics

Mnemonics are mental tools that help recall information, and have been shown to be valuable in a wide range of settings (Schunk, 2000). They include the following examples:

Acrostics. For the names of Earth’s planets, “***M***y ***v***ery ***e***ducated ***m***other ***j***ust ***s***erved ***u***s ***n***ine ***p***izzas.” Colours of the spectrum, “***R***ichard ***o***f ***Y***ork ***g***ave ***b***attle ***i***n ***v***ain.” Taxonomic classifications, “***K***ing ***P***hilip ***c***ame ***o***ver ***f***or ***g***ood ***s***oup.” Galilean satellites of Jupiter, “***I e***at ***g***ood ***c***ake.”

Gestures. For direction of the magnetic field around a current, the right-hand rule.

Sayings. For daylight saving, “Spring forward, fall back.”

Acronyms. For colours of the spectrum, “Roy G. Biv.” Oxidation and reduction, “Oil Rig,” short for “oxidation is loss, reduction is gain.”

Rhymes. For days in each month, “Thirty days hath September, ...” To tighten or loosen a nut or screw, “Righty tighty, lefty loosey.”

Others (no group name). For stalactites and stalagmites, the “c” in the former is associated with “ceiling,” and the “g” in the latter with “ground.” Waxing and waning of the moon in the Northern hemisphere, "DOC," reminding us that a waxing moon has its round side to the right, like a "D," "O" represents the full moon, and the waning moon has its round side pointing left. In the Southern hemisphere, the mnemonic is "COD."

Invite students to construct and share their own mnemonics, as these may be more meaningful to an individual and therefore work better. New mnemonics are being invented constantly and, with rap currently popular, students may even enjoy constructing mnemonics that comprise rap-style rhyming.

Reference

Schunk, D. H. (2000). *Learning theories* (3rd ed.). Upper saddle River, NJ: Merrill.

Source: Glynn, S., Koballa, T., & Coleman, D. (2003). Mnemonic methods. *The Science Teacher*, *70*(9), 52-55.

Invitation. You are invited to send, to The Editor at editor@ScienceEducationReview.com and with a view to publication in a future issue, those mnemonics that you or your students find useful.

Practising Active Science With Child Refugees: A Clinical Perspective

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Abstract

In this paper, pilot sessions in Rwanda and Nepal are analysed to evaluate the therapeutic benefit of active science for traumatised child refugees. The nature of the activities, choice of tools, organisation of the sessions, group size, and the role of the educators are investigated. Despite the lack of quantitative assessment, practical suggestions and theoretical issues emerge. Activities favouring integrated projects and affective dimensions, such as getting familiar with insects, dinosaurs or planet watching, are able to induce positive attitude changes. Large models, built during the sessions and decorating the setting, and small objects that can be taken away, support a recovery process by containment and symbolisation of the inner psychic sanctuary. The most important therapeutic aspect seems to be the opportunity for reactivating curiosity and creative play, and for experiencing the joy of discovery. The inferred recommendations could be relevant in a wide range of circumstances, including psychosocial intervention after war trauma, rehabilitation of street children or child soldiers, as well as paediatric hospital settings.

To read the full text of this article (20 pages), please **click here**.

Ideas in Brief

Summaries of ideas from key articles in reviewed publications.

The Narrative Lab Report

Inquiry-based learning requires teachers to collect information about student understanding in a variety of ways. Writing is one very useful tool for assessing understanding, and the traditional lab report is a commonly used instrument. Such a report typically requires the following sections: Aim, Materials, Procedure, Results, Analysis of Results, and Conclusion.

Erekson (2004) identifies the first few sections as requiring only the regurgitation of information and suggests that, in accord with the old adage that we learn best when we have to teach someone else, the narrative lab report (Licata, 1999) allows students to better demonstrate their understanding of a lab experience. This style of report may be thought of as a letter, with data tables and calculations included where appropriate, that "tells a story" about the lab activity to a friend who will be tested on the material. The report might be structured on the following four questions:

- What was I looking for?
- How did I look for it?
- What did I find?
- What does this mean?

References

Erekson, T. (2004). Assessing student understanding. *The Science Teacher*, *71*(3), 36-38.
Licata, K. P. (1999). Narrative lab reports. *The Science Teacher*, *66*(3), 20-22.

Teaching Controversial Issues: An Improved Approach

A controversial issue is one that a significant number of people argue reasonably about without reaching a conclusion. Controversy can arise as a result of insufficient evidence being presently available to decide an issue, where the outcomes depend on future events that cannot be predicted with certainty, and where judgement depends on how different people value the known information. In the case of the latter, the differences are usually based on underlying beliefs or understandings, such as religious beliefs in relation to abortion, cultural differences regarding links between "race" and intelligence, and moral issues connected with genetic engineering.

In addition, while many controversial issues do have a scientific component, they may also have social, political, or economic concerns. For example, the development of genetically modified crops can be viewed as scientists helping to feed the world, as companies trying to make money, or as “mad scientists” inventing “monsters.” Oulton, Dillon, and Grace (2004) therefore conclude that asking students to resolve a conflict based on scientific reasoning alone seems insufficient.

Problems with present approaches. An approach that might be presently used with 14-19 year-old students, say, is to display a newspaper article, ask students what they know about the issue, display this information and fill in any major gaps, discuss the pros and cons of a particular solution in small groups, invite a whole class debate, and ask students to vote for or against the solution. Homework might require students to write a short argument for or against the solution, and be assessed on the basis of the accuracy of the scientific content.

However, such a traditional approach does not adequately address the nature of controversial issues. This, in conjunction with misunderstanding of the nature of science, the role of scientists, and the potential and limitations of science, may be contributing to the public’s lack of confidence in science and scientists as effective problem-solvers.

Also, debates requiring students to vote on an issue can require them to draw a conclusion prematurely, or based simply on some appealing characteristic of a presenter. Besides, isn’t it unfair to ask students to make such a decision about an issue that adults cannot agree on?

At the same time, teachers might be striving to focus on rationality, reasoning, and the facts, to present a balanced view, and to remain neutral themselves, but all of these positions have shortcomings. As has been previously discussed, focussing on scientific reasoning alone is insufficient and unrealistic. While the notion of a balanced view might at first seem reasonable, it is a contested one because the balance is likely to differ with the worldview of the teacher. Teachers need to make subjective judgements about what information to provide, and in what format, and different formats may affect students differently. Perfect balance is probably impossible. Finally, teachers find it difficult to sustain neutrality, as this can impact negatively on rapport with a class and their personal credibility. In light of the foregoing rejection of balance, neutrality is hard to justify. And, can we really expect students to be open about their thoughts and feelings if the teacher never does the same?

Role-plays and simulations are often suggested for stimulating debate and developing an appreciation of the perspectives of others. However, there is little evidence to support the effectiveness of role-play in changing affective outcomes, preparation for such activities is time-consuming, and teacher training is needed. Besides, it may be difficult, even impossible, for a student to play a role that requires a different worldview from their own. Role-plays such as a public enquiry may still be useful, but more for developing an understanding of such an event than of the issue involved.

Classroom discussion also has its drawbacks. Successful discussion requires a deal of teacher preparation time, students--possibly even teachers--need training in discussion techniques, and the poor models of debate presented by society (e.g., the outrageous antics on television shows) impede effective classroom debates.

The purpose of schooling. Before considering an improved approach, we do need to acknowledge the varying educational contexts in which controversial issues will be treated, and that different schools may adopt different positions on different issues. The nature and purpose of schooling includes the following, not necessarily mutually exclusive, possibilities:

1. To encourage students to develop personal views and opinions.
2. To instil societal norms.
3. To reflect critically on the nature of controversial issues (i.e., a socially critical approach that explores the power and authority behind issues).

All schools might accept the first position when considering, say, genetically modified crops, but this is unlikely to be encouraged in, for example, Catholic schools in relation to the morality of abortion or, in the case of racism, in societies where an antiracial approach has been mandated. The third position would not be welcomed in some societies, as it would challenge the political status quo.

Suggestions for a way forward. Oulton, Dillon, and Grace (2004) suggest that the following be included in a revised approach to the teaching of controversial issues:

1. Make the nature of controversial issues explicit. For example:
   - Different groups can arrive at different views (i.e., there can be multiple perspectives) based on different information, or different interpretation of the same information as a result of a different worldview or value system.
   - Reason, logic, or experiment may not always resolve an issue.
   - A controversial issue may be resolved when further information becomes available.
2. Promote a more realistic view of the nature of science, including its strengths, limitations, and tentative nature.
3. Develop skills of critical inquiry in students (e.g., asking probing questions, not being put off by stock answers, and distinguishing between strong and weak evidence, sound and unsound reasoning, and facts and emotions).

4. Be open about balance in presenting controversial issues not being perfectly achievable, and develop students' ability to be critically aware of bias. Perhaps it is indoctrination that is to be avoided, emphasising balanced learning rather than trying to strive for balanced teaching.
5. Have the teacher make his position, and the way he arrived at it, explicit at the beginning so students are aware of potential bias in aspects of the learning experience. This will actually help to protect teachers from being accused of bias in their teaching. At all times, though, both teacher and students retain the right to remain silent on matters they do not wish to share.

An alternative model. An improved approach to teaching a controversial issue might be to display a newspaper article (or use some other stimulus activity), question students to gather their ideas about the issue, display these ideas and fill in any obvious gaps, provide the class with various position statements as to solutions (e.g., in the case of Foot and Mouth disease on English farms in 2001, the UK Government, National Farmers' Union, an organic farming organization, an animal welfare group, and the Dutch Government), have the teacher explain why she chose these groups to represent a range of opinions, and working in groups, invite students to use the position statements and other resources (e.g., the Internet) to answer the following for their allocated organisation:

1. Who comprises this group?
2. What are the aims of the organisation?
3. Who does the group represent?
4. How is the group funded?
5. Does the group's publicity materials indicate any key values or position?
6. What evidence is the group using in the debate?
7. From where do they get their evidence?
8. Are the limits of their evidence described?
9. Does the group identify contrary arguments?
10. What are they aiming to get us to believe?
11. How strong does their argument appear to be?
12. What consequences follow from their argument?

Then, each group might present its findings using, for example, a short oral, handout, and/or poster, with the teacher leading a class discussion of the strengths and weaknesses of both the presentation and the arguments from each group. Homework might comprise designing a television news critical question for a representative of each organisation, explaining (for assessment purposes) why they were asking the question. The question would be marked on the basis of the degree to which it reflects a student's ability to analyse weakness in arguments and to pose questions that could effectively elicit answers.

(*Editor:* To take the next step and make a decision on an issue, the background developed using the foregoing process might be used as input to a Decision Making Matrix [see Volume 2, p.86].)

Reference

Oulton, C., Dillon, J., & Grace, M. M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education*, *26*, 411-423.

Finding Meaning and Value in Science

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Abstract

In order to examine how students find meaning or value in science, we present four stories of the lives of college-aged minority students and how they confronted science amid their lived experiences. Their narratives prove insightful in that they situate science among larger circumstances and thus help us to consider the conditions under which a sense of value in science can be both lost and found. Further, these students challenge the idea that there is no larger meaning to be found in science education beyond learning subject matter and scientific concepts. They illustrate that through science one can also learn about self, other, and world. Based on their stories, we contend science education needs to address issues of identity and the developing self, which impact authentic engagement, in order to facilitate such a process. (This paper is a summary of Kozoll & Osborne, 2004)

Introduction

In this paper we tell a series of four stories of engagement, or lack of engagement, with science by students of color in the United States, reported at further length in Kozoll and Osborne (2004). Through these stories we develop an argument that perceptions of science are embedded within particular issues of lifeworld, identity, and self. The first three stories describe the educational experiences of Mexican American migrant agricultural workers who have been, despite the odds, successful in traditional schooling. These students migrated annually, with their extended families, back and forth through the central United States for crop harvest. In many instances this migration pattern had been followed for multiple generations. These students are academically successful in the sense that they graduated from high school and, with some financial assistance, have moved on to a post-secondary education. With statistics placing this population of students significantly behind their peers in both academic achievement and retention, their successful completion of high school and entrance into college makes them unique. These students' stories focus on their thoughts, feelings, and perceptions of science as part of broader recollections of their lives, school, and classes prior to entering college. But more importantly, the stories capture the visions and understandings these students possess of themselves within the learning and teaching of science.

Our fourth story revolves around Keith, a Jamaican American immigrant. Keith's story exemplifies how engagement with science can develop through experiences and understandings that are not white, middle class, and Eurocentric. Science can become infused into the lived experiences of a student in an enriching and truly educative manner. Keith's story provides a specific image of what such a relationship to science subject matter might look like, which extends beyond his professional affiliations and aspirations within science. His relationship with science is personal and his perceptions of science, as part of his broader worldview, illustrate science's further link to his identity, self, and development. Keith’s science experiences involve discovering meaning in a discipline, for it is through the discipline that Keith engages a larger and deeper notion of education.

The Stories

> *Well everything that science has involved with it I didn’t like. Chemistry, biology, all that stuff. I just always tried to avoid it. The things you do in chemistry like learn about the periodic table and all those stupid things. I don’t see why I need it, I’m not gonna be a scientist or something.*
>
> *Hector*

Hector, a Mexican-American born into the migrant life and traveling between his home in the Texas valley and Iowa to find work, discussed his education as the means to actualize a future where opportunities existed beyond migration. He saw education, in general, as instrumental to leaving the life of an agricultural worker behind. Science did not fit into this ideal so when there was no longer a way for Hector to avoid the science classes he needed to graduate, he struck a balance between high scores on homework and failing test grades and this allowed him, in the end, to get through. More than science being something too difficult or something he simply dislikes, in Hector’s estimation, there was no reason to learn foreign concepts that remain irrelevant in their future utility.

Unfortunately, despite the many hours students spend studying science, only a few relate to it in such a manner that it advances their education in the larger sense Hector describes; one in which they make a connection to the subject matter so that it becomes a source of inspiration and occupies a formative position in their life. In particular, children of the working poor in America, although often living in conditions where they might profit greatly from a working understanding of science, show little interest in the field. Although Hector has found little value in science, the argument could be made that if there is anyone who might profit from an understanding of biology, chemistry, chemicals, and these “stupid things” it is a migrant agricultural worker. Although the reason for migration is almost always economical, decisions about when and where to move are in part based on knowledge about the length of the growing season, timing of crops, and changing agricultural conditions. Further, while in the fields or in migrant labor camps these agricultural workers are often exposed to pesticides and other chemicals which can cause ailments such as skin rashes, eye irritation, flu-like symptoms, and even death. Why is it that Hector, a mature, thoughtful, intelligent 18-year-old college freshman dismisses science categorically rather than realizing that science may be a lens used to understand and control certain facets of his experiences migrating?

Within science education, the question of how learners find meaning or a sense of value in science so that they choose to engage in science studies would seem to be answered by current concepts of best practice in the field. For example, conconstructivist and situated learning theories hold that establishing connections between science concepts and student's lives promotes personally meaningful, worthwhile, understandings. Arguments around the importance of scientific literacy and authentic, project based learning suggest the usefulness of scientific knowledge in personal and social decision making. Given current science education practices, why is it so hard, then, to develop students' investment in science so that they resonate to our convictions about the importance of science understanding? Given decisive understandings of their lifeworld, or the entirety of lived experiences such as Hector's, we argue that such educational practices are not enough. To be effective, science education needs to address issues of identity and the developing self.

> *But that teacher she would make it sound so easy. We would do experiments in class and she would work with you and she would make it fun. Oh, and I remember one time we had a science project and my friend and me did a report on landfills. On landfills and we actually went to a landfill there in Brownsville. And we interviewed the paper* [sic] *there and we walked around the landfill. We even got on top of the trash and then we came back and presented it and she loved it so much that we got to present it on this major event that goes on in school called Earth Day where you present several things that try to save the environment. So that was pretty fun. And I actually got to be in Earth Day! Me, who's not a science person!*
>
> *Clara*

Clara is the second of the Mexican American migrant agricultural workers who shared their stories with us. In the above quote Clara describes how she found herself being complemented for the creative manner in which she and her partner completed their project and, even if only for a moment, saw science as a discipline she could grasp and participate in--she could become "a science person." Clara, like Hector, also had certain broader understandings of science based upon her experiences and interests. With her time migrating, Clara expressed a determination to succeed in school and move on to college so she might become "somebody" and avoid further time in the fields. But science was never a very good topic for Clara and she has had trouble grasping many of its concepts. Clara carried that history with her as she faced further situations in school science where these experiences necessarily constituted another understanding of herself not only as a student but also as a person. She is not a "science person". Thus, the contexts Clara brings to any event of understanding that may involve science not only include her cognitive insights but also the affective tendencies and responsiveness that constitute her impression of a personal identity. In this manner Clara's identity in relation to science is set in culturally normative and changing views of self, which include inherent values and insights about what it means for her to be a person. If we examine Clara's identity as a student relative to science we can see Clara has come to some broader understandings that concern not only the topic of science, but also a type of self-understanding involving practical involvement.

> *Oh yes! I love science, anything that has to do with nature. Science is always a lot of group work, a lot of coming together and getting results from other people you know? "What did you see? Well I observed this. What did you observe, you know?" A lot of interaction and I like that. Through science I got to know a few people.*
>
> *Andrea*

Andrea, our third Mexican American migrant worker, moved to Texas from Mexico City. Migrating took Andrea from school to school and left her feeling lonely and isolated from her peers. Andrea longed for people to know her for who she was and not the new face that knew little about the things her peers cared about, such as popular clothes and music. Among these feelings of solitude science emerged as more than just a class. Science provided a space where she made connections to nature and helped facilitate relationships with people in the sharing of ideas, observations, and results. Thus, as a source of social development Andrea described science as one way she could more authentically interact with the people around her. For science to act as an intermediary of this type, it becomes a part of the relationship between the student, other people, and the natural world. This whole contains the social, humanistic, aesthetic, and spiritual elements constituting a subjectively personal relationship between a passionate, dependent, and intuitive self and others and is what enables engagement with science as a medium of deeper personal development that defines authentic engagement.

> *I think that's the driving force you know. It's like you have this picture that probably will never be finished and you don't know what it's of. But maybe if you look at the whole picture, you'll see what it's about. I mean I just feel that that's been driving me. I want to, I want to get the complete picture. I know that I'm not going to get the complete picture but I want to get the complete picture.*

> *So I want to get as many pieces of that puzzle as I can. I really want to know more. I want to know more about that grass, I mean even though I, I don't want to have anything to do with that grass! I enjoy knowing why that grass grew there. And that I think that has been just the driving force. Just knowing that I got another piece of the puzzle, and I see something else that somebody may not see you know.*
>
> *Keith*

Our fourth story describes Keith, a Jamaican American, who found broader meaning in science through everyday experiences and understandings. Keith's story centered on more than the science he did in school. His story begins at home and included science experiences in Jamaica observing nature, doing things with his father there and mother in Chicago. Moreover, Keith brought these experiences with him into the science classroom. Keith used concepts learned in his entomology and ecology classes to reflect upon and understand the ants and vegetation he observed playing with his cousins in Jamaica. In establishing such connections Keith continued to use science to analyze and understand his current circumstances. He explained how science provided him the ability, confidence, and caring to both notice and question the grass growing in someone's yard while walking home, or the trees growing along the road. Through such personal experiences and relationships, past and present, Keith found unique value in science as a means to understand the significant people and places in his life. In such a connection, Keith's understanding of science is simultaneously an understanding of himself relative to others.

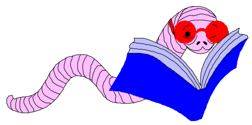
Conclusion

When we considered how students find meaning or value in science, these students' thoughts, feelings, and perceptions of science informed our understandings. Their narratives positioned science amid holistic concerns, which further reflected critical understandings of their social circumstances. As a consequence the value, or lack thereof, they found in science included, but extended beyond, their knowledge of scientific facts, theories, and ideas. Taking into account how these relationships between student and science formed, both positive and negative, directed our attention to the larger perspectives and frameworks from within which meaning and value in science is constructed.

Keith's story suggests that a pedagogy fostering connections to science across contexts can cohere aspects of a student's lifeworld while fostering the self-understandings associated with identity negotiation and authentic engagement. In so doing, science turns into a source of inspiration. It becomes a motivational starting place not only for those students who want to become doctors or science teachers, but also those who desire the confidence, caring, and knowledge to face the world in such a way that enables their development as an individual.

Reference

Kozoll, R. H., & Osborne, M. D. (2004). Finding meaning in science: Lifeworld, identity, and self. *Science Education*, *88*, 157-181.



Research in Brief

Summaries of research findings from key articles in reviewed publications.

Incorporating Problem-Based Learning in Biology Project Work

By: Christine Chin, National Institute of Education, Nanyang Technological University, Singapore and Li-Gek Chia, Paya Lebar Methodist Girls' Secondary School, Singapore hlcchin@nie.edu.sg

A major aim of project work is to develop students' thinking and problem-solving skills by providing them with opportunities to solve authentic problems. One way of doing this is to use problem-based learning (PBL).

In our study (Chin & Chia, 2004), a class of Year 9 biology students in Singapore worked in collaborative groups (4-5 students per group) on problems which they identified themselves, and which were inspired by real life experiences. The students generated questions and identified learning issues which acted as springboards for their inquiry and learning. We were interested to find out (a) how self-generated problems and questions directed students in their learning, (b) how students reacted to this instructional approach, and (c) the problems that students encountered when using this approach. The five stages of the study spanned 18 weeks.

Stage 1. Students formulated an ill-structured problem statement that presented a scenario, and role-played a character in the problem with whom they could identify.

Stage 2. Students designed their own project tasks, based on their identified problem, by organising their discussions around three focus questions and using a Need-to-Know worksheet (Gallagher, Stepien, Sher, & Workman, 1995). This required them to identify what they knew, what they needed to know, and how they could find out what they needed to know. Students regularly recorded their ideas and questions on this worksheet.

Stage 3. Students gathered data to answer their own questions via library and Internet searches, lab investigations, field investigations, surveys, and interviews.

Stage 4. Students consolidated their information and recorded what they had found out and learnt.

Stage 5. Students presented their findings using technology-based multimedia modes of delivery and submitted artefacts and group project files.

Students' project topics included Nutrition and Hair Growth, Eating Disorders, Betel nut, Nutritional Value of Insects, Ginseng, Slimming Centres, and Dentition. It was found that students' learning activities, and what they subsequently learnt, were influenced by the questions they had asked. The students also investigated related disciplinary elements beyond the typical school biology syllabus which interested them. In addition, they engaged in different modes of inquiry, and learnt about varied methods of seeking answers to their questions.

Students' self-evaluation of their learning, and views about their PBL-based project experiences, were generally positive. The students liked coming up with their own topic, role-playing the character in their problems, generating their own questions and answers, and learning things outside the classroom. However, some students faced difficulties in formulating problem statements and posing their own questions. Other problems that students encountered included unhealthy group dynamics, difficulty in scheduling common meeting times outside curriculum hours, the narrow scope of the topic, a lack of time, off-task behaviour, and meeting people during field studies who were unwilling to provide information.

PBL has the potential for active and independent learning. For it to be successful, the teacher needs to play an important role in helping students to formulate a feasible problem, to evaluate the information amassed, and to work cooperatively. By using graphic organisers and guide sheets such as problem logs, Need-to-Know worksheets, learning logs, and project tasks allocation forms, she can help students to structure and organise their thinking, prepare action plans, and document their progress.

(*Editor:* Christine has kindly offered to elaborate, in future issues, on the teaching techniques mentioned in this summary.)

References

Chin, C., & Chia, L. G. (2004). Implementing project work in biology through problem-based learning. *Journal of Biological Education, 38*(2), 69-75.

Gallagher, S. A., Stepien, W. J., Sher, B. T., & Workman, D. (1995). Implementing problem-based learning in science classroom. *School Science and Mathematics, 95*, 136-146.

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

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

What benefits might I gain by maintaining a website, and what suggestions do you have for someone about to try it?

There can be many benefits associated with establishing a teacher website. One of the first decisions will be to think about your target audience. Possibilities include students, parents, and prospective employers.

Student section. The main aim here could be to promote an on-line learning community as an extension of your local learning environment, possibly including students from a "sister" school elsewhere in the world. This can work well if students take ownership of the site by contributing to its design and content and helping to maintain it. Possible sections include an on-line noticeboard with interesting student work, links to students' e-portfolios, homework, and a resource section catering for all learners (slow learners, gifted students, etc.) with material such as quality on-line tutorials, reference sites, webquests and other collaborative projects, virtual excursions, interesting web cams, on-line science demos, simulations, and games. A must would be a communication section with opportunities for students to use e-mail and an asynchronous discussion section for questions and answers, peer and teacher tutoring, mentoring, guest expert scientists, or the like. For examples of student science education resources, visit the K-12 Science Learning Gems section at http://www.ed-dev.uts.edu.au/teachered/science/webresources.html .

Parent section. The purpose of this section would be to communicate between yourself and parents, keeping them up-to-date with exciting classroom developments. An e-mail link to the teacher, general asynchronous discussion forums, and a guestbook would be useful. Apart from a link to the students' section (they'd probably like a sneak preview . . .), other parent-friendly sections could include a curriculum overview section outlining what the students are currently studying, links to their child's web-based portfolio tasks, links to government department web sites, an on-line noticeboard to publish excellent student work, and a resource section catering for life-long science learners!

Prospective employer section. This is a shameless self-promotion section for the purposes of impressing prospective employers! Possibilities here include a description of your teaching philosophy, audio and visual snippets of innovative teaching episodes to supplement your philosophy statement, audio or video-based references from referees, a (password-protected) link to your electronic resume, and, of course, inviting links to other sections of your web site!

Matthew Kearney, University of Technology, Sydney, Australia

Do all animals have hearts?

All animals have some sort of fluid for carrying nutrients, gases, and wastes in their body cavities, and this needs to be able to reach all the cells of the organism. In higher order animals, the fluid is pumped around the body through specialized tubes. Mammals have developed a four-chambered, double-pump system we call the heart. In other higher order animals (reptiles, birds, and fish) the heart may consist of two or three chambers, and in some insects the heart has only one chamber.

In the smaller, lower order animals the fluid simply sloshes about propelled by the muscular movements of the animal. This tends to limit the size to which these organisms can grow.

Gary Simpson, Woodleigh School, Victoria, Australia

The short answer is "not at all." The heart pumps blood to tissues in some animals to provide oxygen and nutrients and to remove carbon dioxide and other products of metabolism. In other animals, this function occurs without the blood and pump. One example is the jellyfish (see http://dockwatch.disl.org/anatomy.htm , http://www.aquamarine.unsw.edu.au/tS/Biology/Anatomy/Anatomy.html). The following four animal phyla are without hearts.

Porifera: The sponges circulate environmental water to achieve the same function as the heart (http://www.encyclopedia.com/html/section/Porifera_Anatomy.asp).

Cnidaria: This phylum includes anemones, jellyfish, and much more (http://www.ucmp.berkeley.edu/cnidaria/cnidariamm.html).

Platyhelminthes: Flatworms lack hearts. Their small size allows them to use other methods for distributing nutrients and removing waste (http://reference.allrefer.com/encyclopedia/P/Platyhel-anatomy.html).

Nematoda: Nematodes lack respiratory and circulatory systems. They do have a digestive system and a sexual reproductive system (http://www.okc.cc.ok.us/biologylabs/Documents/Animals/Nematode%20Anatomy.htm).

To the best of my knowledge, the remaining animal phyla all have hearts: Annelida, Gastropoda, Bivalvia, Cephalopoda, Echinodermata, Crustacea, Arachnida, Insecta, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves, and Mammalia. Because people see hearts in these 14 phyla and don't see any mention of the lack of them in the other four phyla (or don't see the phyla at all), we can readily see why a conclusion regarding hearts in all animals might arise. This issue demonstrates why everyone should learn to think as scientists do. Carl Sagan, in *The Demon-Haunted World: Science as a Candle in the Dark*, said it well:

> In the course of their training, scientists are equipped with a baloney detection kit. The kit is brought out as a matter of course whenever new ideas are offered for consideration. If the new idea survives examination by the tools in our kit, we grant it warm, although tentative, acceptance. If you’re so inclined, if you don’t want to buy baloney even when it’s reassuring to do so, there are precautions that can be taken; there’s a tried-and-true, consumer-tested method.

I give much credit to the person who posed the question, because this person questioned what must be a common (mis)conception. Constant questioning of "common knowledge" is one of the hallmarks of science.

Harry Keller, USA

Further Useful Resources

Teaching About Evolution and the Nature of Science

http://www.nap.edu/readingroom/books/evolution98

Background information, strategies, and activities for learning about evolution.

It’s Elemental: The Periodic Table

http://pubs.acs.org/cen/80th/elements.html

Eighty-nine essays, many written by eminent scientists, that share facts and stories about the elements.

Science and Faith http://www.pbs.org/wgbh/evolution

A contribution to the exploration of the struggle between science and religion. Use the *Religion* link to review the statements of four panelists (a biology professor, a professor of Christian thought at a religious college, a biochemist, and an Anglican minister) seeking to answer the question: “How can you reconcile the conflict between evolution and religion?”

Understanding Evolution http://evolution.berkeley.edu

Information, lesson plans, and links for, and potential obstacles and pitfalls in, teaching evolution. Includes the nature of science.

Humour

When the Principal asked to meet with the teacher, the teacher had a pretty good idea why. Speaking first, she said: "Yes, I know, I have a weakness for repeating gossip." "No," replied the Principal, "you really are quite strong at it. And repeating it probably wouldn't be so bad, but you tend to improve upon it." Adapted from *Bits & Pieces*

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

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