

# Computer Technology in the Science Classroom

Specific to the parameters of the National Science Education Standards and the National Educational Technology Standards, this article examines the role of constructivism as a philosophy to incorporate technology into the science classroom.

Within the last two decades, there has been considerable discussion regarding the appropriate use of computers in the classroom. Though most of this conversation seems to support and encourage the use of computers and multimedia in the classroom, there seems to be some debate as to whether computer use can promote student achievement and enhance problem-solving skills. In effect, few efforts to determine the pedagogical appropriateness of the computer exist. As schools continue to expand their technology budget each year, and at the same time the instructional budget decreases, this uncertainty of pedagogical appropriateness becomes paramount.

Serious questions exist regarding software programs accompanying the computer and their application in the science classroom. Research agendas have for some time tried to evaluate learning as a result of computer use (Kulick, Bangert, & Williams, 1983; Clark, 1983; Roybler, Castine, & King, 1988; Clark, 1994; Jonassen, Carr, & Hsui-Ping, 1998). Yet, even with presidential proclamations and several million dollars spent that provide for computers in the school, studies certainly question the ability of computer software to

actually enhance anything other than rote memory. Many researchers seem to be concerned with the wrong question. Perhaps the question should not be whether or not learning is improved, but “how can we facilitate the learning of students using computers as tools?” Essentially, the use of the computer in the classroom should juxtapose the standards in both science and educational technology.

## *National Science Education Standards*

The National Research Council (1996) suggests that the primary role of technology in science classrooms is to enhance methods of inquiry and discovery. These standards are rapidly becoming the guidelines for science curricular development and design.

In the vision of science education portrayed by the *Standards*, effec-

tive teachers of science create an environment in which they and students work together as active learners. While students are engaged in learning about the natural world and the scientific principles needed to understand it, teachers are working with their colleagues to expand their knowledge about science teaching. To teach science as portrayed by the *Standards*, teachers must have theoretical and practical knowledge and abilities about science, learning, and science teaching.

Certainly, the use of the computer can “create an environment in which teachers and students work together as active learners,” but simply having a computer in the classroom or networked in a computer lab does not guarantee appropriate use. The Systems Standards D declares emphatically that policies must be in place to mandate an inquiry approach. Included in these policies is an implicit order to guarantee an adequate supply of “necessary print and media materials, laboratories and laboratory supplies, scientific apparatus, technology, and time in the school day with reasonable class size required by this approach” (p. 232). More specifically, the technology provided to the schools, from pencils to computers, must be used

**Computer software programs utilized in the teaching of science that promote constructivist learning techniques are a rarity.**

## The technology provided to the schools, from pencils to computers, must be used to enhance inquiry.

in such a way as to enhance inquiry. Consequently, the software programs utilized in the teaching of science must also be such that they promote constructivist learning techniques. These programs are a rarity in the public school libraries.

The National Research Council (1996) also describes successful science classrooms, where “teachers and students collaborate in the pursuit of ideas, and students quite often initiate new activities related to an inquiry. Students formulate questions and devise ways to answer them. They collect data and decide how to represent it. They organize data to generate knowledge, and they test the reliability of the knowledge they have generated”(p. 33). Specifically, how does the use of a computer or computers in the classroom fit into such an open-ended strategy for student learning? The *Standards* do mention the use of computer technology in the context of the pedagogical structure of the classroom. Though details are not given, essentially the NSES, as does the *National Educational Technology Standards* (NETS), encourage teachers to utilize technology as a tool to enhance the curriculum. More importantly, the NSES suggest that “effective science teaching depends on the availability and organization of materials, equipment, media, and technology” (p. 220). The NSES

continue with the fact that science inquiry is broader than first-hand investigation; hence, “print, video, and technology sources of information and simulation are also required” (p. 220). The computer can provide these sources and can do it in an expedient manner.

Statistical studies and national discourse support the generalized use of computers in the classroom, yet little effort has been made to define best practices regarding specific use of technology in the classroom, or research that more specifically defines practice that accentuates student learning and student inquiry. Technology could be used to excite, engage, and instruct students beyond the limitations of the textbook and into a global society. If we are to create changes in the classroom that juxtapose the NSES and the NETS, perhaps more research into the significant effects of computer use and inquiry learning should occur.

### Pedagogically Appropriate Instruction

The NSES Standards are very clear about appropriate teaching strategies to enhance student learning. However, the integration of computer technology with an inquiry approach to teaching is not as well established. As with any lesson plan designed to maximize learning, pedagogical soundness must be employed. The use of multimedia and computers is certainly no different. To better understand how the appropriate use of the computer can enhance learning, let us first discuss the meaning of inquiry and constructivist techniques.

Constructivism offers a sharp contrast to the view of traditional teaching. The theoretical framework for constructivism has its foundation

in the work of Jean Piaget (1964). Piaget believed that the reason a five year old cannot not be taught higher-level mathematics, for example, is that to receive and make sense of this information the child must have the cognitive structures to enable assimilation of the information. Piaget continues with “it is only when they themselves are in firm possession of this logical structure, when they have constructed it for themselves, that they succeed in understanding correctly the linguistic expression”(p. 178). The key is self-construction and individual understanding of the knowledge presented. It follows then, that individuals in the science classrooms, when presented with new information, will construct it in individual ways.

The constructivist theory of learning allows for children to develop these structures on their own. This idea is illustrated by Piaget’s position that children create ideas about their world, and these ideas are not passively received through their environment. Hence, the use of computers and multimedia as tools that would help children to create their own meanings, and not just tell them or tutor them, would be more constructivist-bounded, and certainly provide knowledge that is meaningful and not meaning-less. The teachers involved in constructivist techniques would use indirect methods of teaching that would foster social, moral, and intellectual development from the inside out. Children, in the world of the constructivist, are not simply empty vessels, but come to the classroom with a rich diversity of experiential knowledge. It is from this knowledge that the constructivist begins to individualize the child.

Constructivists perceive a difference between information and knowledge. Information can be given

or easily transmitted through telling. Information is all that is necessary to achieve correct performance. Thus, when the purpose of instruction is to transmit information and get correct performance, explanations meet the needs. However, knowledge is something that cannot be transmitted or given. Constructivists suggest that knowledge in the form of explanations will not allow assimilation of information. Piaget's writings, as discussed in Blais (1988), show that the construction of knowledge by the child is of utmost importance. He stated, "The goal of intellectual education is not to know how to repeat or retain ready-made truths. It is in learning to master the truth by oneself, at the risk of losing much time and of going through all the roundabout ways that are inherent in real activity" (624).

In contrast to the constructivist classroom, lessons in the traditional classroom give examples, model, and assign work to be completed for the next day. Under this context, the use of the computer might not prove to enhance a student's problem-solving skills. Perhaps the problem is not with the technology, but with the strategies that use the technology. If teachers use computers to provide the drill and practice to memorize, students are not allowed to assimilate the knowledge and relationships. Instead, exploratory activities, using constructivist

**The keys to Constructivism are self-construction and individual understanding of the knowledge presented.**

theory and computers, might prove to benefit the student's understanding of the concepts. It is not necessarily the teacher's interventions that influence the child's constructions, but the child's experience with these interventions (Brown, 1996). Opportunities for prior knowledge, design of their own problems, and the construction of meaning must be employed. To facilitate this learning, computers need to be used as knowledge construction tools, or "mindtools" (Jonassen, Carr, & Hsui-Ping, 1998). Mindtools are "computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content they are studying" (p. 24).

### ***National Educational Technology Standards***

The *National Educational Technology Standards* (NETS) (1999) support the use of computers as tools to enhance learning, in opposition to using computers to deliver instruction. The goals of these standards are to help students use technology to become information seekers, problem solvers, and decision makers; effective communicators, collaborators, publishers, and producers; and informed, responsible citizens. The NETS are divided into six categories: basic operations and concepts; social, ethical, and human issues; technology productivity tools; technology communication tools; technology research tools; and technology problem-solving and decision-making tools. These categories stress two areas of importance. The first addressed is the ability of students to be proficient and responsible users of technology. The NETS suggest that students need to "practice responsible use of technology systems, information, and software" (p. 4).

### **The emphasis should be on how to use computers as tools.**

Along with being able to use technology proficiently, the NETS (1999) expect students to use technology as tools to construct their learning more effectively and efficiently. According to the *Standards*, students should:

1. Use technology to enhance learning, increase productivity, and promote creativity;
2. Use technology to locate, evaluate, and collect information from a variety of sources;
3. Use technology tools to process data and report results; and
4. Use technology resources for solving problems and making informed decisions (pp. 5-6).

The emphasis of these *Standards* in technology is to effectively enhance learning as it fits the constructivist approach to students' learning. In a constructivist environment, students will use technology as a tool to enhance their learning and the efficiency with which they construct their learning.

### **Research on Computers and Student Learning**

Research in the area of enhancing student learning has been conducted frequently in recent years. Historically, most of these studies compared the use of computers in a given topic, with not using computers for the same topic. For example, Kulick, Bangert, and Williams (1983) conducted a meta-analysis of the results of many of these studies. The results of the meta-analysis showed that computers enhance learning. However, Clark (1983) called these results into question. Clark notes that when examining

**The emphasis should not be on whether computers enhance learning, but on how to use computers as tools with the appropriate methodology for the subject, to teach more effectively and efficiently.**

the effects of different media (computers vs. non-computer), only the aspects of the media can be different. All other aspects of the treatments, including subject matter content and method of instruction, must be identical. Clark points out that in the studies where differences were found, different instructional methods were confounding variables that could have influenced the results. On those studies where the methodology and content were kept constant, no significant differences appeared.

During the latter part of the eighties, however, the results of research on computer-based education (CBE) as a means to improve learning of students continued to be conducted. Roblyer, Castine, and King (1988) conducted a meta-analysis of the effects of CBE from 1980 to 1987. Results of this meta-analysis also showed that CBE is effective in improving student learning.

More recently, Clark (1994) continued to maintain that the use of any specific media, including the computer, will not improve learning. He believed that any media can be used to achieve the same amount of learning, and that it is the methodology, not the technology, that influences the learning.

Given the concerns regarding the results of studies conducted on CBE, we need to quit being concerned about whether or not using the computer as a deliverer of instruction is effective. We need to concentrate on how to use the computer as a tool, together with the appropriate methodology for the subject, to teach more effectively and efficiently. The computer becomes one tool of a set of tools used to facilitate

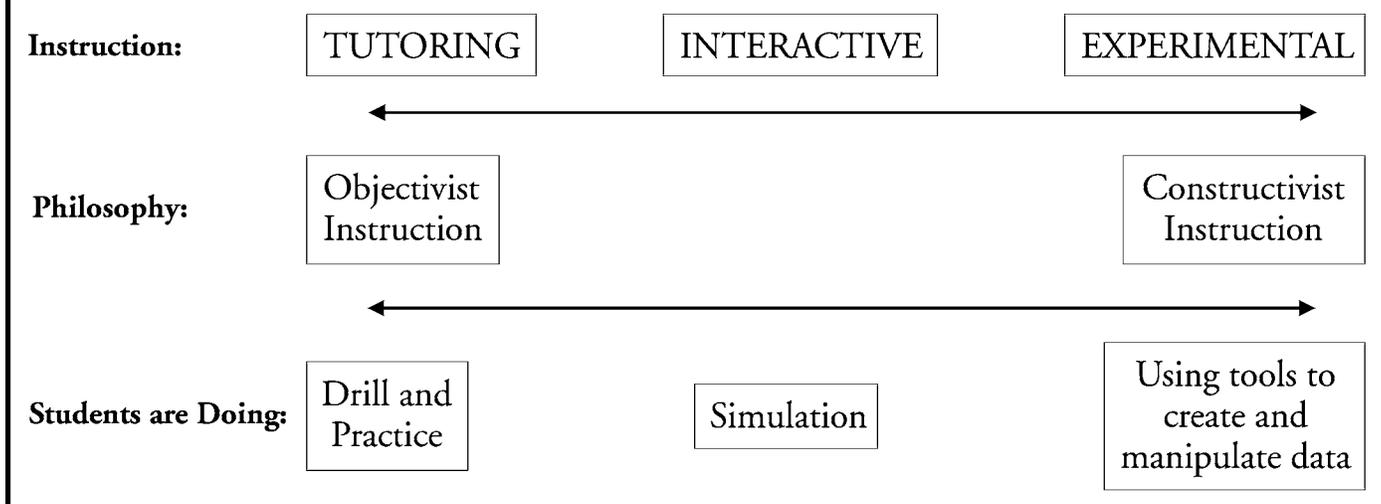
student learning. The emphasis should not be on whether computers enhance learning, but on how to use computers as tools with the appropriate methodology for the subject, to teach more effectively and efficiently.

The other area of emphasis should be on insuring that students become competent consumers of the technology. A constructivist approach, where students use the appropriate technology as tools in constructing their own learning, will allow the students to become the users of technology we wish them to be. In essence, we would want the instruction, philosophy, and methodology to move to the right on the continuum (see Figure One).

**Appropriate Science Classroom Computer Use**

The role of computer technology in allowing students to construct their knowledge must now be considered. In the past, computers have been used as deliverers and quizmasters of instruction. To be consistent with *Standards* methodology, this approach needs to be changed by having the students use the computers as tools, and to match the learning tasks with the tasks that

Figure 1 - A technology continuum



computers can assist with or perform (Morrison, Lowhter, & DeMuelle, 1999). Consider the ways the following programs and computer functions can be used to help students construct their own meaning.

#### Database Use

Database programs are designed to store, organize, and manipulate large amounts of information, or data. The functions of databases are similar to the processes used to facilitate critical thinking skills (Morrison, et al., 1999). In order to create a database, students need to think carefully about how to organize the information they have collected. Once the information is organized into the database, the student can use the sorting and searching functions of a database to solve problems relating to information. In creating and using databases, students are analyzing and categorizing information, as well as manipulating information to solve problems.

#### Multimedia Use

Multimedia presentations programs are tools that allow students to create unique methods communicating their ideas via the computer (Morrison, et al., 1999). In order to produce multimedia-based reports, students must synthesize their ideas to decide what information they want to tell others. While any form of report will allow students to synthesize their findings, multimedia allows them to incorporate sound, graphics, and video into their reports. Students can then present their findings to fellow students in an interesting manner.

#### Internet Use

Assuming that we follow the standards in science and technology, perhaps we should identify the role

### Children come to the classroom with a rich diversity of experiential knowledge; from this, the constructivist begins to individualize the child.

of the Internet in helping the teacher integrate the computer as a tool into existing pedagogical structure. Consequently, use of the Internet in the classrooms can encourage teachers to move from instructionism (knowledge transfer) to constructivism more closely aligned with knowledge building. Use of the Internet can encourage teachers to be more creative in their science classrooms, moving from a traditional lecture model to one that depends heavily on student collaboration and peer teaching (Upgedrove, 1995).

Ebenezer and Lau (1999) suggest fourteen uses of the Internet that would correlate with the *National Science Education Standards*.

1. Testing Personal Ideas
2. Conducting Internet Labs
3. Taking a Virtual Trip
4. Conducting Research
5. Participating in a Joint Classroom Project
6. Communicating Ideas
7. Asking Experts
8. Collaborating with Scientists
9. Sharing Classroom-Based Work
10. Creating an Electronic Portfolio
11. Using Time Efficiently
12. Learning in a Relaxed Environment
13. Motivating Students
14. Simulating Dangerous and Costly Experiments

For example, students can test their “personal ideas” by searching the Internet for a multitude of activities designed to test their ideas. Constructivist techniques allow students to engage in learning that follows from the questions they ask. In this way, students might ask about the speed of sound at different temperatures. Searching the Internet, they might find this site:

(<http://www.glenbrook.k12.il.us/gbssei/phys/Class/sound/ull12c.html>), that would provide the framework for their experimentation to learn the answer. From this site, additional questions might also be answered.

Similarly, the site: (<http://www.witg.lbl.gov/vfrog/>) provides a good example of the possibility of “conducting laboratory activities” over the Internet. At this site, students are taken through the dissection of a frog at a very sophisticated level. Using this procedure cuts classroom costs and enables students to participate and question at their own pace. By accessing this site:

(<http://www.sandiegozoo.org/zoo/homepage.php3>), students are able to visit the San Diego Zoo. Students can interact with scientists, view pictures and video, and access information. Similar to the zoo virtual trip, students can access the Jason Project sites (<http://www.jasonproject.org>) and visit a rainforest, manipulate scientific equipment and/or participate in exploring the oceans. Other Internet sites are available in each of these 14 teaching strategies.

#### Conclusion

Care must be taken to provide for appropriate pedagogical strategies based upon inquiry and discovery techniques. With appropriate attention, the teacher can provide for a more constructivist classroom through the

use of the computer and multimedia. If providing for a more standards-based classroom can be accomplished with the computer as a critical tool, teachers and supervisors can monitor its use and budget for its availability to the students in each school.

### References

- Blais, D. (1998). Constructivism: A theoretical revolution for algebra. *Mathematics Teacher*, 81(8), 624-631.
- Brown, D. (1996). Kids, computers, and constructivism. *Journal of Instructional Psychology*, 23(3), 189-195.
- Clark, R. E. (1983). Reconsidering research on learning from media. *Review of Educational Research*, 53(4), 445-459.
- Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development*, 42(2), 21-29.
- Ebenezer, J., & Lau, E. (1999). *Science on the Internet: A resource for K-12 teachers.*, Columbus, OH: Merrill.
- Gabel, D. (1995). Science. In G. Cawelti (Ed.). *Handbook of research on improving student achievement* (pp. 123-143). Arlington, VA: Educational Research Service.
- International Society for Technology in Education. (1999). *National Educational Technology Standards for Students Brochure*. Eugene, OR: Author.
- Jonassen, D. H., Carr, C., & Hsui-Ping, Y. (1998). Computers as mindtools for engaging learners in critical thinking. *TechTrends*, 43(2), 24-32.
- Kulick, J., Bangert, R., & Williams, G. (1983). Effects of computer-based teaching on secondary school students. *Journal of Educational Psychology*, 75(4), 19-26.
- Martin, D. J. (1999). *Elementary science methods: A constructivist approach*. (2<sup>nd</sup> ed.). Belmont, CA: Wadsworth/Thomson Learning.
- Morrison, G. R., Lowther, D. L., & DeMuelle, L. (1999). *Integrating computer technology into the classroom*. Upper Saddle River, NJ: Merrill.
- National Research Council. (1996). *National science education standards*. Washington, DC: Author.
- Piaget, J. (1964). Cognitive development in children: Development and learning. *Journal of Research in Science Teaching*, 2(9), 176-186.
- Roblyer, M. D., Castine, W. H., & King, F. J. (1998). Assessing the impact of computer-based instruction. *Computers in the Schools*, 5, 1-149.
- Updegrave, K. H. (1995). Teaching on the Internet. (<http://pobox.upenn.edu/~kimu/teaching.html>).

---

Kenneth W. Miller is Associate Professor of Science Education, Department of Curriculum and Instruction, Montana State University-Billings, Billings, Montana 59101.

---

Kathleen M. Sindt is Assistant Professor of Educational Technology, Department of Curriculum and Instruction, Montana State University-Billings, Billings, Montana 59101

# Educational Reform Through High Stakes Testing—Don't Go There

High-stakes testing is seen as being inconsistent with the Standards' goals regarding what students are taught about the nature and purposes of science.

Given the current state of knowledge about the negative impacts of standardized testing, it may seem reasonable to conclude that science education supervisors need not be overly concerned about how such tests are employed within educational policies and initiatives promulgated by state and federal agencies. After all, a rich literature base documents the risks and potential pitfalls of standardized testing, and a number of well-researched national standards, such as the *National Science Education Standards* (National Research Council, 1996) provide unambiguous guidance based upon that literature. Before we grow complacent, however, we should take a careful look at what is going on in at least some of the 20 states that have begun implementing "high-stakes" accountability testing programs. In this paper, we outline the impacts of one such state program, North Carolina's *New ABCs of Public Education*, on K-8 science instruction and reform efforts. The evidence presented indicates that the North Carolina *ABCs* Program, which was held up by President Clinton in his 1999 State of the Union Address as a model for the nation, has derailed efforts to implement *Standards*-based reforms in many of North Carolina's classrooms. We believe that science education supervisors across the nation should view North Carolina's *ABC Program* like a warning alarm from

a coal miner's canary.

In a 1997 article, *Time Magazine* referred to "high-stakes testing" as, "the latest silver bullet designed to cure all that ails public education" (Kunen, 1997). Unfortunately, as pointed out by Robert Shaffer of FairTests, an advocacy organization concerned with equity issues in standardized testing, this trend demonstrates a disturbing disregard for the scientific literature on testing. Shaffer states, "every professional guideline says, 'don't use these test scores as a sole criterion to make decisions.' But this is guidance that is widely abused and ignored" (CNN.com, 1999).

The admonition to use test results cautiously is highly consistent with the *National Science Education Standards*. While the *Standards* does recognize accountability testing as

an acceptable practice (National Research Council, 1996, p. 89-90), the *Standards* also stresses that such testing should be conducted in accordance with rigorous quality assurance safeguards—which are consistent with *Standards*-based reform practices and goals. For example, the testing should utilize (1) authentic assessment tasks, (2) unbiased assessment tools, and (3) sound sampling and analysis strategies. Additionally, the programs or initiatives that give rise to the assessment should be sound and supportive of broader educational reform efforts and goals, including those within the *Standards*-based reform movement.

Importantly, the *Standards* specifically addresses the need to be wary of policies set by elected or politically appointed leaders. Within the discussion of System Standard C, which calls for coordination among reform initiatives, the *Standards* explain that,

New administrations often make radical changes in policy and initiatives and this practice is detrimental to education change, which takes longer than the typical 2- or 4- year term of elected office. Changes that will bring contemporary science education practices to the level of quality specified in the *Standards* will require a sustained effort (National Research Council, 1996, 231-232).

**High-stakes testing programs are a product of the growing movement to improve public education by ensuring that schools more fully reflect and conform to the needs of business and industry.**

**The Standards strongly emphasizes that the process of increasing the authority and control afforded to teachers will be very slow because the changes in teachers' roles will occur only as substantive reforms are made throughout the educational system.**

These concerns are echoed in the literature on testing-based reform initiatives. For example, Corbett and Wilson (1991) discuss how "reform by comparison" initiatives, such as the *New ABCs*, lack "the inherent patience needed to nurture better educational results over the long run" (p. 3).

System Standard F of the *National Science Education Standards* directs science education supervisors to address concerns such as those noted above. System Standard F calls upon the science education community to be vigilant in reviewing new educational initiatives and policy instruments that may have negative "unintended effects on the classroom practice of science instruction" (National Research Council, 1996; p. 233). As explained within the discussion of System Standard F, "Even when as many implications as possible have been carefully considered, well-intentioned policies can have unintended effects. . . . unless care is taken, policies intended to improve science education might actually have detrimental effects on learning" (National Research Council,

1996). This standard is perhaps nowhere more important than in the case of "silver bullets," where program implementation tends to progress more rapidly than does program evaluation and validation.

**Overview of the New ABCs as an Example of High-Stakes Testing**

High-stakes testing programs are a product of the growing movement to improve public education by ensuring that schools more fully reflect and conform to the needs of business and industry and the criteria used to judge success and effectiveness in business and industry. Towards this end, the *New ABCs* and other high-stakes testing programs emphasize the importance of holding teachers and schools accountable for student learning as measured by students' performances on standardized tests. In order to ensure that these personnel are adequately motivated, substantial rewards and hefty sanctions are linked to testing outcomes. The central role of accountability testing in the *New ABCs* is demonstrated by the fact that the letter "A" in the "ABC" acronym stands for "accountability." The other two core objectives of the program are to increase the emphasis placed upon the "Basic" subjects and to provide an increased level of "Control" of program implementation and pedagogy at the local (school) level (North Carolina Department of Public Instruction, 1996).

The "control" component of the program appears to have been intended to help mitigate known or predicted problems associated with standardized and/or accountability testing. In theory, the increased local control would ensure that personnel working close to the students--teachers and

school-level administrators--would keep the students' best interests in mind when making decisions about how to implement the program. Unfortunately, this component of the program does not appear to have been successful (Jones, 1999).

As suggested above, the poor performance of the *New ABCs* with respect to its "control" objectives could have been anticipated had attention been paid to warnings in the *Standards* and in the professional literature regarding the need for "long-haul" (rather than 2- or 4- year) perspectives. The *Standards* strongly emphasizes that the process of increasing the authority and control afforded to teachers will be very slow because the changes in teachers' roles will occur only as substantive reforms are made throughout the educational system. Thus, it is unreasonable to hold teachers accountable for executing such authority effectively prior to having successfully completed the prerequisite substantive systematic reforms necessary to support teachers in their new roles.

Additionally, some researchers are concerned that the types of high-stakes utilized within the accountability component of the *New ABCs* program undermine efforts to increase control at the school level. For example, Wildy and Wallace (1997) discuss how it is particularly important in science education that accountability programs follow professional models that (1) maintain long-term perspectives (2) promote a culture of trust and support, and (3) emphasize professional development. Unfortunately, such approaches appear incompatible with the high-stakes accountability agenda of the *New ABCs*. As stated by Jones (1999), "when the State Board of Education has the power to shut the doors of the school based on end-of-grade

test scores, there is no local control of education.”

The stakes associated with the accountability component of the *New ABCs* are substantial. In North Carolina schools, teachers receive bonuses when test scores are high (schools receive as much as \$1,500 per teacher). Severe sanctions are applied when schools fail to meet their “expected growth” standards, especially for schools that “earn” the “low-performance” label. These sanctions include the following:

- publication of performance measurements (the distinctions range from “school of distinction” to “low performing school”),
- mandated assistance from state-provided teams (comparable to a hostile takeover in the business world),
- competency tests for teachers (teachers are given three chances to pass the test before being discharged), and
- removal of principals and teachers who are “not willing to improve their practice.”

The stakes continue to rise as the

**Proponents and critics of high-stakes testing both advocate that the high-stakes have a powerful impact on motivating teachers and school administrators to do what is necessary to bring about higher scores.**

program is implemented. For example, recent legislation in North Carolina has simplified the procedures for dismissing teachers by “streamlining” the appeals process. Additionally, test results are playing an increasingly more significant role in decisions concerning student placement, advancement, and retention.

Proponents and critics of high-stakes testing both advocate that the high-stakes have a powerful impact on motivating teachers and school administrators to do what is necessary to bring about higher scores. However, there is less agreement about what can be inferred from those test scores. Proponents advocate that the results demonstrate success. Consider, for example, the meaning North Carolina’s Governor Hunt attributed to data showing a rise in test scores for the 1997-98 school year:

The results show us that North Carolina’s schools are working. . . . Through the ABCs of Public Education, our schools are working like never before to put children and their education first (North Carolina Public Schools Infoweb, 1998).

In contrast, critics question the assumption that high scores equate with improved schools. Additionally, the literature on standardized testing raises concerns about the desirability of programs that may motivate teachers and administrators to do “whatever is necessary” to bring about higher scores (Jones, 1999; FairTest, 1999a; CNN.com, 1999; Shapiro, 1998; Neill, 1998; Darling-Hammond, 1991; Haladyna et al. 1991; Madaus, 1991; Neill and Medina, 1989; Brandt, 1989; Smith, 1991a; Smith, 1991b). In fact, for at least a decade researchers have argued that using standardized test scores as the primary basis for any policy decision-making is “reckless,” given what

is known about the limited validity, accuracy, and reliability of the tests (Neill and Medina, 1989). In a survey of state programs used to establish accountability in the public school systems (not all of which were high-stakes programs), FairTest concluded that 2/3 of the programs impeded rather than promoted educational reform (FairTest, 1999a). In this study, North Carolina’s ABC program received the lowest possible rating (1 on a scale of 1 to 5), which distinguishes it as a program “requiring a complete overhaul” (FairTest, 1999b).

### **The New ABCs and Standards-based Reform Goals**

In assessing the *New ABCs* in terms of the *Standards*, this paper considers the two areas of emphasis in the *Standards*--equity and excellence.

#### **Equity Issues**

System Standard E of the *National Science Education Standards* states that, “science education practices must be equitable” (National Research Council, 1996; p 232). In explaining this standard, the *Standards* emphasize the need to ensure that programs overcome, rather than compound, “well-documented barriers” to learning science for selected groups of students, including those from economically disadvantaged populations. One of the objections to accountability testing is that the testing may promote such inequities. As stated by Darling-Hammond (1991):

Applying sanctions to schools with low test scores penalizes already disadvantaged students. Having given them inadequate schools to begin with, society now punishes them further for failing to perform as well as

students attending schools with more resources (p. 222).

A number of other serious equity issues have been raised in the literature on standardized testing. For example, there is evidence that the tests are biased to middle class, white, male worldviews (CNN.com, 1999; Darling-Hammond, 1991; Neill, 1998). As the high-stakes testing movement builds momentum, the legal implications associated with these issues is drawing increasing recognition and attention. For example, the U.S. Education Department's Office for Civil Rights has recently begun the process of developing a policy that would restrict testing practices. A draft policy statement, which is being circulated within the educational community for comment, would ban "the use of any education test which has a significant disparate impact on members of any particular race, national origin, or sex. . . unless it is educationally necessary and there is no practicable alternative form of assessment" (CNN.com, 1999).

The *New ABCs* program purports to address these issues by using a "complex formula," which focuses on improvements, to determine each school's required performance goals. Proponents of the program claim that, "the decision to focus on progress removes the nettlesome problem of unfairly expecting poor rural schools or inner-city schools to do as well as their counterparts in wealthy suburban areas" (Simmons, 1997).

Given the complexity of equity issues of concern, the efficacy of this relatively simplistic solution is less than self-evident. For example, there is no reason to assume that the practice of focusing on improvement would remove racial or cultural biases in tests. Additionally, concerns have

Table 1: Shifts in emphasis called for in the National Science Education Standards (based on National Research Council, 1996, pp.52, 72, 113, 239)

Less emphasis On...	More emphasis On...
Standardized tests and assessments unrelated to Standards-based programs and practices	Assessments aligned with the Standards
Assessments aligned with "traditional" content of science education. (Science directed toward memorizing scientific facts and "getting an answer")	Assessments aligned with the Standards expanded view of science. (Science as argument and explanation directed toward using evidence and strategies for developing or revising an explanation)
Students doing relatively few experiments and using experiments primarily as a means of concluding an inquiry	Students doing more experiments in order to develop understanding, ability, values of inquiry, and knowledge of science content. Applying results of experiments to scientific arguments and explanations
Focusing on student acquisition of information and assessing "what is easily measured" discrete factual information	Focusing on student understanding of the use of scientific knowledge, ideas, and inquiry processes. Assessing "what is most highly valued"-- rich, well-structured knowledge, including scientific understanding and reasoning abilities
Assessing at the end of learning to determine what students don't know	Ongoing assessment to inform decision-making throughout the period of instruction
Development of external assessments by measurement experts alone	Teachers developing authentic assessments of student science learning
Instructional activities that ignore or marginalize affective domain learning. Using competition among students as a motivational tool	Instructional activities emphasizing affective domain learning and social skills
Teacher as technician, follower (including follower of established curriculum), and target of change	Teacher as intellectual, reflective practitioner (who is constantly adapting curriculum), leader, and source/facilitator of change

been raised that schools may have difficulty in recovering from a “low performance” rating because the label might scare away highly qualified personnel—including principals and teachers who might otherwise be recruited to help turn around schools in disadvantaged districts (Kurtz, 1998). We believe that education supervisors should be wary of “silver bullets” in the details of high-stakes testing programs, such as the practice of measuring improvement discussed here, which purport to resolve complex issues through strategies that appear to be relatively simplistic and largely invalidated.

### **Excellence Issues**

The *National Science Education Standards* outlines numerous changes in emphasis that will occur as the *Standards’* vision is realized, some of which are summarized in Table 1. The evidence reviewed here indicates that high-stakes testing programs appear to drive changes in the opposite direction of those envisioned in the *Standards*.

As shown in Table 1, the *Standards* envisions a shift of focus away from one in which instruction and assessment focus on a broad body of discrete knowledge. Instead, the *Standards* advocate a narrower focus on key concepts directed towards deeper, richer understanding. The central role of inquiry drives a shift of focus from lower-level thinking to problem solving and other higher-order thinking skills. Importantly, the changes envisioned in the *Standards* call for substantial increases in the amount of time allocated for science instruction. Without exception, the *New ABCs* appears to be driving science instruction in North Carolina’s elementary and middle school classrooms in the



## **Within the arena of the tested subjects, teaching practices appear to have been degraded to strategies focused on “teaching to the test.”**

opposite direction as advocated by the *Standards*, that is, away from inquiry.

High-stakes assessments programs in general, and the *New ABCs* in specific, clearly are antithetical to the *Standards’* goal of decreasing the emphasis placed on “standardized assessments unrelated to *Standards*-based programs and practices.” One consequence of this shift is that teachers are spending more time teaching the tested subjects, at the expense of other subjects. In grades K-8, where the testing focuses on the “basic” subjects of mathematics, reading and writing, science often is marginalized. Additionally, teachers are spending more time teaching test-taking skills and having students take “practice tests.”

The changes in how instructional time is allocated can be substantial. For example, in a survey of North Carolina elementary school teachers, Jones (1999) reports that 80% of the teachers indicate that they spend over 21% of their total teaching time practicing End-of-Grade (EOG) tests. Additionally, over 28% of the teachers indicate that they spend from 61% to 100% of their teaching time practicing for the tests. The mean amount of time devoted to science instruction among these teachers is 99 minutes per week. The teachers also report that science

instruction was often radically marginalized as test time grew closer.

There is reason to doubt science instruction would be aided by the addition of a science test to the testing schedule. Within the arena of the tested subjects, teaching practices appear to have been degraded to strategies focused on “teaching to the test,” which are antithetical to *Standards*-based practices. For example, in mathematics instruction, at least one county system provides teachers with a database of math questions representative of end-of-grade math test questions. Teachers are also provided with a breakdown of the questions that organizes them by objective and identifies the percentage of questions per each objective that were present in previous EOG tests. We have observed teachers being instructed (pressured) by county-level and school-level administrators to adjust the emphasis of their instruction to match the pattern of emphasis identified on past years’ tests.

Although evaluative literature on the *New ABCs* is just beginning to become available, questionable practices such as those described above appear to be prevalent (Jones, 1999; Jones, 1997; FairTest, 1999b). Additionally, concerns have been raised in the literature about the tendency for high-stakes testing programs to encourage school administrators and teachers to engage in practices that are questionable in terms of both pedagogy and ethics. For example, the literature on standardized testing raises substantial concerns about the how widespread practices of “teaching to the test” lead to unethical teaching practices that invalidate test results (Haladyna et al, 1991). The insidious nature of these problems and the evidence to date on the *New ABCs* suggests that numerous undesirable practices might well follow in

the wake of a science accountability test, should one be implemented in the future. We believe that science education supervisors should be proactive in addressing high-stakes testing and that they should not wait for mandated science testing to reach their schools before taking action.

High-stakes testing in general, and the *New ABCs* in particular, also appear to work against the *Standards*' goals involving affective domain learning. Test anxiety replaces an open atmosphere of exploration where diverse ideas are respected and risk-taking is valued (Hill and Wingfield, 1984). Competition flourishes at the expense of community (Shapiro, 1998). A love of science--and of learning in general--is anything but nurtured. For example, Jones (1999) found that teachers were six times more likely to report that the *New ABCs* program resulted in a negative impact on students' "love of learning" than a positive impact.

Finally, the *New ABCs* appears inconsistent with the *Standards*' goals regarding what children are taught about the nature and purposes of science itself. The *Standards* calls for a shift of emphasis that de-emphasizes science as a body of factual knowledge and emphasizes science as a way of structuring and using inquiry to answer real questions and investigate real problems. This shift of emphasis is a move away from science as the accumulation of factual knowledge separate from exploration and experimentation (with experimentation often limited to the closing activity for a unit of study). The shift of emphasis is a move towards a model of science as "argument and explanation," involving ongoing, repeated, and public investigation and experimentation in which students "combine process and scientific reasoning and critical think-

ing to develop their understanding of science" (National Research Council, 1996; p. 105).

It seems unlikely that high-stakes testing programs, such as the *New ABCs*, will further these goals for at least two reasons. First, as suggested above, high-stakes testing tends to promote an emphasis on teaching what is easily measured with objective (e.g., multiple choice) tests. Objective tests are a poor tool for testing the ways in which a student has developed the values and attitudes conducive to being able to truly apply scientific inquiry to real world problems. Secondly, once again the realization of the *Standards*' vision takes time, which is all too often a scarce resource with end-of-grade tests only a matter of a few months or weeks ahead.

### Conclusion

As a case study, North Carolina's *New ABCs of Public Education* provides compelling evidence that high-stakes testing is not a "silver bullet" that will cure all the ills that beset our schools. In fact high-stakes testing is problematic. Nonetheless, it is reasonable for the public to expect that schools and teachers be held accountable to high professional standards. Further, as recognized in the *Standards*, assessments of student learning can be used as a valid tool for establishing such accountability. However, such testing will only be effective if it is implemented properly. Towards this end, The *National Science Education Standards* is a useful guide in that it provides a model and a vision of recognized best practices.

Importantly, the *Standards* also provides a guide to potential false starts and pitfalls in educational reform. For example, one major weakness of the *New ABCs* appears to be that it has

been implemented under a cloud of urgency. Also, many of the concerns raised here may well stem, at least in part, from failures of the *New ABCs* to accomplish its objective of providing increased control of educational policies to local schools and teachers. As a consequence of these shortcomings, teachers may have had less, rather than more, control in ensuring that the sweeping changes wrought by the *New ABCs* are in students' best interests. As noted above, the *Standards* provided warnings relevant to both of these apparent shortcomings.

There are no simple solutions to the complex problems associated with accountability testing. However, research and standards of best practice can inform decisions about how to move towards viable solutions and sound practices. Science education supervisors can play an important part in helping to guide research and policy development. It is the professional educator's responsibility to help ensure the established knowledge base on assessment practices is not disregarded.

### References

- Brandt, R. (1989, April). On the Misuse of testing: A conversation with George Madaus. *Educational Leadership*. 26-29.
- CNN.com (1999, June 14). Standardized tests under fire. [On-line]. Available: <http://cnn.com/US/9906/15/standardized.tests>.
- Corbett, H. D., & Wilson, B. (1991). *Testing, reform, and rebellion*. NJ: Ablex.
- Darling-Hammond, L. (1991, November). The Implications of testing policy for quality and equality. *Phi Delta Kappan*. p. 220-225.
- FairTest (1999a) Testing our children: [On-line]. Available: <http://www.fairtest.org/states/survey.htm> ("Introduction" link).

- FairTest (1999b) Testing our children: [On-line]. Available: <http://www.fairtest.org/states/nc.htm>.
- Haladyna, T., Nolen, S., & Haas, N. (1991). Raised standardized achievement test scores and the origins of test score pollution. *Educational Researcher*, 20(5), 2-7.
- Hill, K., & Wingfield, A. (1984). Test anxiety: A major educational problem and what can be done about it. *The Elementary School Journal*, 85(1), 105-126.
- Jones, G. M., Jones, B. D., Hardin, B., Chapman, L., Yarbrough, T. and Davis, M. (1999), The impact of high-stakes testing on teachers and students, *Phi Delta Kappan*, 199-203.
- Jones, T. (1997, August 17). ABCs warrant an F. *Raleigh News and Observer*, section 29-A.
- Kunen, J. S. (1997, June 16). The test of their lives. *Time*, 149(24), 62-63.
- Kurtz, M. (1998, Nov. 6). State poised to approve teacher tests. *Raleigh News and Observer*, section A-1.
- Madaus, G. F. (1991, November). The effects of important tests on students: Implications for a national examination system. *Phi Delta Kappan*. 226-231.
- National Research Council. (1996). *National Science Education Standards*. (1st ed.). Washington, DC: National Academy of Sciences.
- Neil, M. (1998, March). National tests are unnecessary and harmful. *Educational Leadership*. 45-46.
- Neill, M. D., and Medina, N. J. (1989, May) Standardized testing: Harmful to educational health. *Phi Delta Kappan*. 688-697.
- North Carolina Department of Public Instruction. (1996) *A guide to the ABCs for teachers*, Raleigh, NC.
- North Carolina Public Schools Infoweb (1998). ABCs results show strong growth in student achievement K-8; high schools post first year's results. [On-line]. Available: [http://www.dpi.state.nc.us/news/abcs\\_results\\_98.html](http://www.dpi.state.nc.us/news/abcs_results_98.html).
- Shapiro, S (1998). Public school reform: The mismeasure of education, *Tikkun*, 13 (1), 51-55.
- Simmons, T. (1997, August 8). 43% of schools in N.C. fall short. *Raleigh News and Observer*, section A-1.
- Smith, M. (1991a). Meanings of test preparation. *American Educational Research Journal*, 28, 521-542.
- Smith, M. (1991b). Put to the test: The effects of external testing on teachers. *Educational Researcher*, 20(5), 8-11.
- Wildy H. & Wallace, J. (1997). Improving science education through accountability relationships in schools. *Science Educator*, 6(1), 11-15.

---

Richard A. Huber, Associate Professor of Science Education, Curricular Studies Department, University of North Carolina at Wilmington, Wilmington, North Carolina 28403.

---

Christopher J. Moore, Middle School Science Teacher, Saint Mary's School, Wilmington, North Carolina 28403.

# Pre-college Outreach and Cooperative Programs in Oceanography at the US Naval Academy

The Oceanography Department of the United States Naval Academy (USNA) has embarked upon a vigorous effort to support the advancement of education in Oceanography.

## Introduction

The United States Naval Academy (USNA) is an undergraduate educational institution of the United States federal government, charged with the preparation of officers to be commissioned in the United States Navy and Marine Corps. The Academy is located in Annapolis, the capital of the state of Maryland, on the west bank of the Chesapeake Bay, the largest estuary in the country.

At the conclusion of a four-year program the students (midshipmen) receive a Bachelor Degree in one of nineteen major areas, including Oceanography. The Oceanography Department is the second-smallest at the Academy, with a total of six civilian professors, seven naval officer instructors and three technicians. Appropriately enough, Oceanography is consistently the most popular major in the Division of Mathematics and Science, graduating every year 70 to 90 midshipmen.

The Oceanography Department operates a fully equipped thirty meter long vessel, as well as several wet and dry laboratories; oceanographic research can be accomplished utilizing a full complement of state-of-the-art

instrumentation. Given the ultimate destination of its students, the fleet, the Oceanography Department places a large emphasis in the study of physical oceanography in general. Coastal and estuarine studies are also part of the elective curriculum, including “hands-on” experience with short cruises in the Chesapeake Bay. A three-week summer research cruise in the Chesapeake and Delaware estuaries has been offered to interested students since 1989.

The Oceanography Department actively supports the advancement of education in Oceanography by sharing its resources and expertise with the academic and scientific communities. Three main venues have channeled this effort: the Mentorship Program, the Maury Project and Cooperative

**The overall objective is to provide a creative environment for the students while exposing them to the working world.**

Research Projects. What follows is a discussion of each of these endeavors. It is hoped that readers may find in these paradigms the inspiration to develop similar programs at other institutions.

## The Mentorship/Internship Program

This program is a partnership between the Anne Arundel County (Maryland) public schools and several institutions, including the USNA. It serves as a catalyst in the formation of mutually beneficial relationships between mentors and high school students. Applied learning opportunities are offered to participants who, in turn, provide valuable human resources. The overall objective is to provide a creative environment to the students while exposing them to the working world.

The mentor is a professor or instructor interested in supervising the participation of the student in support tasks and research projects. The program matches the mentor’s needs with a gifted and talented high school junior or senior student. Students receive one half high school credit for 66 hours of volunteer service per semester or sum-

mer session. Participating students follow their normal school schedule, providing their volunteer service after school hours on a prearranged time frame for about five hours per week; mentors are expected to provide direction and guidance in assignments that challenge the students' abilities.

The program is administered by the Gifted/Talented/Advanced Programs (GTAP) office of the Anne Arundel County Public Schools, 2644 Riva Road, Annapolis, MD 21401; every year it contacts several local institutions and solicits faculty and staff volunteer mentors.

Student candidacies are accepted each year in March and consist of the following (GTAP, 1999):

1. Submission of a completed application by the due date
2. Attendance of a scheduled orientation session presented by the GTAP staff
3. Signed parental authorization
4. Guidance counselor verified grade point average (GPA)
5. Teacher recommendation

From a list of available mentorships and summer internships, the student picks a first and a second choice in the application. GTAP staff reviews the applications and schedules student interviews with the mentors. Students accepted into the program must make a firm commitment to carry it through; applications of students not selected remain open during the school year in case an opening may appear.

In order to qualify for the Mentorship/Internship program a student must:

1. Be a high school junior or senior
2. Have a GPA average of B or higher
3. Have a recommendation from a professional who knows the student in the academic sense

4. Show commitment, capacity to learn independently, and ability to follow directives from adults

5. Provide own transportation

The student is expected to meet the following requirements:

1. Keep a monthly project log
2. Pass a satisfactory evaluation by the mentor at the end of the project
3. Submit to on-site visits by GTAP staff
4. Notify the mentor of any changes in schedule
5. Complete the project in a timely, responsible, and mature fashion

One example of the participation of the Oceanography Department in the program involved a high school senior testing a new piece of equipment, designed to measure and record surface waves. The student installed the sensor in the Severn River estuary (a small tributary of the Chesapeake Bay), tested its performance, and wrote simple instructions for its use. In this instance the mentor's time was freed, and the student learned about waves and their measurement. In another case a student generated a computer data base, dealing with estuarine literature and technical papers. This has been a ready source of reference materials for the mentor in the execution of research and course preparation, while the student became acquainted with oceanography through close contact with the literature and the statement of oceanographic problems.

### **The Maury Project**

The motto of this enterprise is "Exploring the Physical Foundations of Oceanography." This teacher enhancement program is funded by a National Science Foundation grant which began in 1994. This is

a partnership between the American Meteorological Society, the USNA and other US Navy agencies, with assistance from the National Oceanic and Atmospheric Administration (NOAA). The purpose of the Maury Project is the improvement of teacher effectiveness in generating interest and understanding in oceanography (particularly physical oceanography) among precollege students (kindergarten through 12th grade). Whereas the Mentorship/Internship Program acted on a one-to-one basis, the active principle of the Maury is a grassroots approach with a multiplicative effect. This strategy works by training a core of teachers, who in turn extend their knowledge to a larger number of colleagues able to reach an even wider student population.

Major components of the Maury Project are:

1. Identification and training of a cadre of master oceanographic education resource teachers.
2. Creation of a national oceanographic communications network to promote the flow of science and pedagogical information relating to pre-college physical oceanography education.
3. Development of scientifically correct and pedagogically appropriate instructional materials for teacher use.

Teachers from all over the United States apply to this program in response to announcements; there has been also an effort to recruit teachers from abroad (Australia, Canada, South Africa and the United Kingdom have been represented). The teachers have their travel, lodging expenses and tuition paid, and receive a small stipend and all didactic materials. The selection criteria for acceptance into the program include (AMS, 1999):

1. Being a pre-college science teacher
2. Having had sufficient college level training
3. Be able and committed to promote the teaching of the physical foundations of oceanography in their home areas. This includes organizing and presenting a minimum of two training sessions for home area pre-college teachers.
4. Consideration of national geographic distribution, as well as school environment (inner city, urban, suburban, rural).
5. Consideration of groups under-represented in the sciences.

A central component of the Maury Project is a series of two-week workshops, which have been held at the USNA since the summer of 1994. These workshops mobilize the human resources, as well as the facilities of the Oceanography Department, and focus on the physical foundations of modern oceanography. The faculty is involved in preparing and delivering seminars, assisting with demonstration projects, and taking the teacher-students on short data collecting cruises

**...the active principle of the Maury Project is a grassroots with a multiplicative effect... training a core of teachers, who in turn extend their knowledge to a larger number of colleagues able to reach an even wider student population.**

in the Chesapeake Bay aboard the department's research vessel. Included are field trips and visits to relevant institutions in the Washington-Baltimore area. During the workshop instruction guides developed especially for the project are supplied to the students, while demonstrations are done of simple activities and exercises that the teachers can take back to their classrooms. The titles of the teacher's guides prepared so far are: Coastal Upwelling, Deep-Water Ocean Waves, El Niño: The Atmosphere-Ocean Connection, Density-Driven Ocean Circulation, Measuring Sea Level from Space, Shallow-Water Ocean Waves, Ocean Sound, Ocean Tides, Ocean Tides on the Web, and Wind-Driven Ocean Circulation.

Each summer a group of about 25 teachers has participated in this program, for a total of 122 since the onset in 1994. All participants in the program are required to execute at least two peer-training sessions in their home states. This multiplicative feature of the Maury program, i.e. "teachers teaching teachers," is quite apparent: in the academic year 1994-95 there were a total of 82 peer training sessions were organized by the first graduates of the program, reaching a total of 1600 teachers throughout the country (Smith et al., 1996). Since 1994 the total number of peer training sessions approaches 600, and the total number of teachers trained is approximately 10,000 (McManus, 1999). The efficiency rate of this approach is truly remarkable. These peer-training sessions have an approval rate of 99%, while 96% of those who have attended indicate that they will use the Maury teacher's guides in their own classes (Smith et al., 1998). It must be noted that seven Maury Project participants have won the coveted Presidential

Award for outstanding science teacher from the National Science Teachers Association in their states.

For further information on the Maury Project and the names and addresses of the trained master teachers in a state or region, contact The Maury Project, American Meteorological Society, 1701 K Street, NW, Suite 300, Washington, DC 20006.

### **Cooperative Research Projects**

The third direction of shared activity by the Oceanography Department of the USNA encompasses the area of scientific cooperation. At this upper technical level the department's faculty collaborate with outside agencies, lending their expertise and equipment to a common goal. Typically, a memorandum of understanding is signed between the institutions, detailing the degree of participation and the responsibility of each partner.

One recent example of this approach was a collaborative project between the USNA's Oceanography Department and the United States Environmental Protection Agency (USEPA). The goal was to carry out the first-ever study of the dynamics of the Severn River estuary, the waterway on whose bank the Academy stands. In this case the USEPA provided a radio telemetry buoy, one conductivity, temperature and depth (CTD) recorder and technical support; the Oceanography Department provided the mooring, two currentmeters, maintenance of the system and oceanographic expertise. This mooring was deployed in the Severn for three months at a time, in the autumns of 1994 and 1995. The mooring relayed in real time some of the data to the USEPA ground station where it was publicly displayed in a monitor. The data acquired have been

analyzed as part of a major honors student project (Irwin, 1997), and several oral presentations at professional conferences have resulted. This is the first study of the oceanographic regime of this small tributary of the Chesapeake Bay and a contribution to an understanding of the mechanisms of estuarine destratification that follow the highly stratified summer conditions.

Aside from the strictly scientific interest of such collaborations, there were sizeable benefits for the USNA. First, the involvement of the oceanography and ocean engineering students in the experiment: planning, logistics, diving, data collecting. Secondly, the availability of the data not only for faculty research use but also for student research projects, laboratory exercises and classroom use. The opportunity for student participation in scientific endeavors of this caliber, with all the advantages of hands-on activity, is by itself enough of an incentive to continue this type of institutional collaboration.

**The opportunity for student participation in scientific endeavors of this caliber, with all the advantages of hands-on activity, is by itself enough of an incentive to continue this type of institutional collaboration.**

## Summary

Three different venues were presented to illustrate how the resources of an oceanography oriented academic institution can be managed to offer valuable opportunities to other professional communities. As demonstrated, human resources are essential in terms of providing the technical expertise; providing instructors and technical personnel can be accomplished during the regular academic year with minimal disturbance, if the involvement is limited to small periods of time (case of the Mentorship/Internship Program and Cooperative Research). For more intense contact time (such as required by the Maury Project), it is suggested that academic down time be considered, such as the summer period (typically non-salaried); this will normally imply obtaining financial support from grant dispensing organizations.

Logistical facilities, equipment, and instrumentation can be shared with the cooperating entities in different ways. As shown in the case of the joint study with the USEPA, a collaborative arrangement where each partner provides part of the needed resources is perhaps the most successful, since each "gives" to the common project, thus avoiding a "donor" and "receiver" type of relationship.

Finally, it is desirable to let the academic community know of success stories such as those described here. Institutions which have the means should be encouraged to realize the practical value of sharing their resources: better prepared students, more enlightened teachers and more effective scientists. Intangible side benefits come in the shape of reputation as good neighbor, patron, supporter and other positive evaluations. It is hoped that the initiatives suggested in this article

may serve as a catalyst for outreach at other institutions.

## Acknowledgements

I would like to acknowledge with thanks the participation of all the colleagues, midshipmen and Navy personnel involved in the many aspects of the projects discussed in this article; their enthusiasm and professionalism were essential to the success of these enterprises.

Special thanks are due to the administration of the US Naval Academy, chairs of the USNA's Oceanography Department, Kent Mountford of the Chesapeake Bay Program Office of the USEPA, David Smith and Ira Geer co-chairs of the Maury Project and the Gifted/Talented/Advanced Programs Office of Anne Arundel County Public Schools. Without their involvement and support, these initiatives would not have been possible.

I gratefully acknowledge the comments of Prof. David Smith, Oceanography Department, United States Naval Academy, and his review of a draft of the manuscript.

## References

- American Meteorological Society. (1999). *The MAURY PROJECT: Exploring the physical foundations of oceanography*. American Meteorological Society, 1200 New York Avenue, NW, Suite 410, Washington, DC 20005.
- Gifted/Talented/Advanced Programs. (1999). High School Mentorship/Internship Program. Anne Arundel County Public Schools, 2644 Riva Road, Annapolis, MD 21401.
- Irwin, C. S. (1997). Dynamics of destratification in the Severn River estuary. Trident Scholar Project Report #248, US Naval Academy, Annapolis, MD.
- McManus, D. E. (1999). Personal Communication.

Smith, D. R., Guth, P. L., Vieira, M. E. C., Whitford, D. J., Jones, D. W., Miller, E. J., Eisman, G. A., Strong, A. E., Kren, R. S., Dillner, D. S., Geer, I. W., McManus, D. E., & Murphree, J. T. (1996). The Maury Project: providing teachers with the physical foundations of oceanography. *Proceedings of the 4<sup>th</sup> International Conference on School and Popular Meteorological and Oceanographic Education*. Royal Meteorological Society, Bracknell, Berkshire, United Kingdom.

Smith, D. R., Saltzman, J., Vieira, M. E. C., Whitford, D. J., Wright, Jr., W. A., Robichaud, R. M., Geer, I. W., McManus, D. E., & Murphree, J. T. (1998). The Maury Project: A look to the future. *Preprints of the 7<sup>th</sup> American Meteorological Society Symposium on Education*. Amer. Meteor. Soc., Boston, MA.

---

Mário E. C. Vieira, Associate Professor, Oceanography Department, United States Naval Academy, Annapolis, MD 21402.

# Creating a Professional Development Opportunity Within the Supervisor–Student Teacher Relationship

Reflection through metaphor can be a means by which preservice teachers and practicing teachers can share the development and constant modification of their personal philosophies of learning and teaching science.

I was a cooperating teacher returning to the classroom after finishing a year long educational sabbatical at the university. Tiff was a prospective elementary teacher of science preparing to begin her student teaching. While we were both entering a sixth grade science classroom with different expectations, we had one in common; to grow professionally from our shared experiences. To guide our journey, we chose some strategies and tools for collaborative reflection. First, we agreed to share the development and constant modification of our personal philosophies of learning and teaching science. To accomplish this, we committed ourselves to be critical listeners and to question and discuss deeply any observed disagreements between philosophy and practice. In particular, we chose metaphor as a tool for our purposeful, collaborative reflection.

Previous studies have suggested that until extant beliefs about learning and teaching science are made explicit, it is unlikely that they will mature (Treagust, Duit, Fraser, 1996). For both prospective and practicing teachers, reflection can help make beliefs

and ideas about science teaching and learning explicit. Dewey (1933) called reflection the hallmark of intelligent action and suggested we learn more from reflection on our experiences than we do from the actual experience.

One vehicle to prompt and assist reflection is metaphor. Lakoff and Johnson (1980) concluded that the value of metaphor is in understanding a new experience in terms of a more

**...We committed ourselves to be critical listeners and to question and discuss deeply any observed disagreements between philosophy and practice. In particular, we chose metaphor as a tool for our purposeful collaborative reflection...**

familiar one. Several studies have indicated that reflection through metaphor can be a means by which pre-service teachers come to terms with experience (Bullough & Stokes, 1994; Tobin, Tippins, & Hook, 1994). However, the extent to which prospective teachers put their beliefs into action within field experiences seems largely dependent on their perceived safeness of the learning-to-teach environments as influenced by their cooperating teachers (Sillman, 1998).

Greater communication between a student teacher and a cooperating teacher could also result in perceived safeness of the learning-to-teach environment for the student teacher, opening the possibilities of increased risk taking and growth. Working closely with a cooperating teacher who is visibly continuing to learn about learning and teaching science could also assist the prospective teacher in becoming a lifelong learner of learning and teaching science and all content areas.

Since reflection through metaphor could also help practicing teachers make sense of experiences (Tobin et al., 1994), the collaborative reflection

**Tiff— Week Four:  
...I have been  
considering another  
metaphor: *Teacher  
as bridge...the idea of  
this metaphor is that  
teachers are a bridge  
they invite children to  
cross.***

between a student teacher and a cooperating teacher could lead to deeper understandings of personal beliefs and actions about learning and teaching for both prospective and cooperating teachers. Collaboration is one way to take teacher development beyond personal reflection to a point where teachers are learning, sharing, and developing their expertise together (Lieberman & Miller, 1984).

Collaborative reflection is a theme found throughout the standards for professional development for teachers of science (National Research Council, 1996). Opportunities for self-reflection, collegial reflection such as peer coaching, and collaboration among all involved in a program is encouraged. Learning experiences for teachers of science should: “use inquiry, reflection, interpretation of research, modeling, and guided practice to build understanding and skill in science teaching,” (National Research Council, 1996). Working with student teachers in this manner can become one way to achieve the standards about professional development for all learners involved.

Upon successful completion of student teaching, Tiff would be

graduating from a large university in the northeastern section of the United States with a Bachelor of Science degree in elementary education. Prior to her student teaching, she had experienced a semester long science methods course for elementary educators held concurrently with a pre-student teaching experience which included visiting a third grade self-contained classroom in a rural school near the university, two days a week for ten weeks. For her student teaching, she entered a sixth grade science classroom in a middle school (grades 6–8). The sixth grade students went to different classrooms for each of their subject areas. As teachers, this resulted in our teaching science to four different classes of students a day. On the average, thirty students were in each class.

As my student teacher and I journeyed through the first half of the school year together, personal processing of events occurred for both of us constantly as we discussed and questioned incidents each day during and between classes, and during plan time that could be spared for this reflection. It was especially during sacred reflection times held weekly where we probed into our beliefs about learning and teaching science and children. It was during this time of reflection on our journal writings, when using metaphor as a tool to help us understand our changing personal philosophies, that we realized our personal professional growth and development about learning and teaching science. We also gained a deeper respect for the point in time that each of us was within our own individual journeys of professional development.

The record of our experiences is divided into three sections. First, Tiff’s journey over the semester is explained through her changing phi-

losophy about teaching and learning as described with metaphor. My developing philosophy is described next as I examined, through metaphor, my role as a teacher of learning but also my own personal learning. The last section is devoted to the growth we experienced together through collaborative reflection discovering we were both *teachers as learners*.

**Teacher as Bridge: Tiff,  
Prospective Teacher**

I feel most strongly about *teacher as bridge*. Now that I have taught full time, I can really appreciate the value of preparing students and then allowing them to construct their own knowledge. When they are given this opportunity, they learn. I can’t stress enough how talking about my ideas and metaphors has helped me establish my personal philosophy. I can easily state it now.

**Week One**

Philosophy: A safe environment that includes encouragement and praise is needed for students to learn and feel successful.

After her first week of student teaching, I asked Tiff to consider her philosophy of learning and teaching using metaphor. Even though Tiff was doing more observing at this point than teaching, she created metaphors for each of the four science classes that she would eventually be teaching. It was interesting that she saw each of the four classes as separate entities when considering her role as teacher.

For one class, she was *teacher as facilitator*: “When a teacher is a facilitator, I think students learn more. My experience is that students feel relaxed and confident under these circumstances.” For another class, she was *teacher as learner*: “When teachers are willing to learn and show that they are learning,

I think students view teachers as less threatening and authoritative and more like themselves.” Tiff was a prospective teacher with language arts as her area of concentration. She felt very weak in science content and said she was learning science concepts daily. Instead of being discouraged with her lack of science content preparation, her perception was that her position as a science learner helped her role as a science teacher. For the most academically diverse and energetic of the four classes, Tiff crafted *teacher as monitor*: “Students in sixth grade need and want to have rules. There is a need for close monitoring. Some of the students have conflicting ideas; some are egotistical and self-centered.” Another science class included a high number of special needs students. For them, she was *teacher as motivator*: “The students need encouragement and praise to feel successful.” Tiff felt that without that support right from the beginning, these students had little chance of ever taking risks to learn.

#### Week Four

Philosophy: A teacher can only help students construct their own learning methods that meet their individual needs.

**Tiff—Week Twelve:  
I respect each student  
as an individual, and  
as a result, they respect  
me. Due to this respect,  
our classroom is very  
friendly and relaxed.**

After one month of student teaching, Tiff had begun to switch focus from her teaching to that of her students’ learning. Stofflett and Stefanon (1996) contend it is through the metacognitive activity of reflection that the focus moves from self or teacher behaviors to students and learning; however, that process can take some time to occur. For some prospective teachers, this doesn’t occur until they have become full time practicing teachers. Others have concluded that transitions from learner to teacher were greatly facilitated when student teachers worked closely with their colleagues (Gunstone, Slattery, Baird, & Northfield, 1993).

For Tiff, the switch in her philosophy became apparent as she collapsed her series of metaphors for her role into one, *teacher as bridge*. She explained:

Although my metaphors from before still hold, I have been considering another metaphor: *teacher as bridge*. This metaphor was brought to my attention via a short story, and I was very moved by this. The idea of this metaphor is that teachers are a bridge they invite children to cross. Once teachers have facilitated students in crossing this bridge by introducing topics and ways of learning, they collapse as a bridge and encourage students to build their own bridges.

For Tiff, her role as a teacher was to help individual students in their individual knowledge constructions. Tiff continued to explain how the teachers’ actions were important in helping students become independent learners:

Therefore, teachers aid students in learning new topics and teaching them ways to learn, and then teachers ‘back off’ and allow the students to explore learning on their own. Often times, students learn more at this point because

their method of learning has personal meaning or value. Not everyone learns the same way, so students learn by constructing their own ways of learning. *Teacher as bridge* seems to be a positive teaching method because it enables teachers to facilitate the learning of different types of learners. I feel I use this metaphor often with all of my students. I introduce topics to the students and assign projects or assignments, but our cooperative learning groups allow children to ‘build their own bridges.’ Through talking and experimenting in their groups, the students are able to construct learning methods that meet their individual needs.

Tiff was discovering for herself the value of a constructivist approach to learning and teaching. This included not only helping individual students learn concepts and learning strategies for themselves, but also helping children learn together and from each other within a social setting. This shift is supported by the standards for science teaching which include an emphasis on creating a classroom community where there is a cooperating, shared leadership, and respect (National Research Council, 1996).

#### Week Eight

Philosophy: Hands-on activities are important in all content areas and there is no difference between teaching science and other subjects.

As Tiff’s teaching load increased, she began to focus on teaching science specifically.

Tiff began to articulate the importance of hands-on experiences in the meaningful learning of science concepts within children. Following a simulation game involving macro invertebrates, she returned to a metaphor she had crafted earlier, *teacher as facilitator*; however, this time, her metaphor held a richer meaning:

After being actively involved in the game, the students were able to use our class data to determine the water quality of our imaginary stream. During the lesson, I felt I acted as *teacher as facilitator*. I organized the game, set the rules, and monitored; however, I allowed them to use the data from the game to determine the water quality of their stream. I encouraged them to think, but did not give them the answer. As I facilitated, they explored and learned.

Tiff was genuinely surprised at the value and necessity of the game experience in helping students more fully understand the concepts of ecological habitat.

At this point in the semester, I asked Tiff to consider the difference between learning and teaching science and other subjects. After some thought, she responded, "I am a strong believer in hands-on learning and inquiry; therefore, I feel this learning and teaching method should be used in all subject areas. Students learn by doing in science and all subjects." Like most prospective elementary teachers, Tiff approached teaching as

**Kate—Week Four:  
Learning occurs in  
students when they are  
inspired or motivated  
through relevant  
activities which  
engage them on the  
task, and when they  
have the confidence to  
participate in their own  
learning processes...**

a generalist and saw little difference in the learning and teaching of various content areas. With little shared discussion about how inquiry in science was different from inquiry in other subject areas, Tiff interpreted inquiry as raising questions. This is typical of elementary teachers who are prepared as generalists and often embrace a more generalized inquiry orientation (Boardman, Zembal-Saul, Frazier, Appel, & Weiss, 1999; Zembal-Saul, Dana, Severs, & Boardman, 1999).

#### **Week Twelve**

Philosophy: Relating to students in a safe and comfortable environment helps students learn constructively.

As Tiff completed her full time teaching load, she returned again to a metaphor she had developed earlier, *teacher as bridge*: "Now that I have taught full time, I can really appreciate the value of preparing students and then allowing them to construct their own knowledge. The students are creative and impressive. When they are given this opportunity, they learn." With this philosophy and metaphor, she also felt she learned at the same time as the teacher.

When asked to identify her strengths, she responded: "I respect each student as an individual, and as a result, they respect me. Due to this respect, our classroom is very friendly and relaxed." Tiff also felt that the ability to think on her feet was another strength of hers: "Mainly because our classroom is so friendly and relaxed, I am not afraid to stray from my plans to ensure student understanding. I am constantly thinking of examples and making changes as I teach." The safe and comfortable environment not only helped her students learn, it helped Tiff feel able to experiment and learn to teach.

For her future classroom, she had established certain goals for herself: "I hope to create a safe and friendly classroom for hands-on learning... and always stay informed of my students' likes and dislikes. Relating to the students on several levels produces remarkable results." Tiff had come to realize the importance of a student-centered classroom to the learning of individual students.

#### **Week Fourteen**

Philosophy: Students need a safe learning environment with encouragement and praise to feel confident to take risks. To learn, they also need relevant, hands-on activities to provide them an opportunity to construct their own knowledge and their own meaning.

As Tiff began to decrease her teaching load, she increased her time for reflection and revisited and modified her metaphors for teacher. She began to consider the wider learning community of which the students were a part. As a result, Tiff crafted some additional metaphors, showing her flexibility in conceptualizing her role as a science teacher.

*Teacher as architect or safety inspector or temporary bridge* expressed her modified role of teacher. Tiff felt teachers were to guide, protect, and provide guidance and support as needed in varying degrees by individual students. Since Tiff saw the students as constructing their own knowledge, she crafted the metaphor, *students as construction workers*. Tiff also began to view the parents as an integral part of the knowledge construction process. They were the *parents as the bridge building board or building committee*, with a voice that indicated their authority in the learning processes of their children. Tiff also recognized learning itself

through a metaphor. *Learning as the bridge* was knowledge constructed by students for their own use.

As Tiff completed her student teaching field experience, she had, through reflection with metaphor, become more student-centered and holistic in her perspective. As she explicitly stated her beliefs, she became able to articulate with confidence her philosophy of learning and teaching science. In addition, Tiff realized her philosophy would be ever changing as she continued to grow professionally through the reflection of her experiences. This insight might have come from the professional development journey she was sharing with me, her cooperating teacher, as I modeled my own professional growth process. With no extensive conversation about the difference between teaching science and teaching other content areas, Tiff maintained a generalist viewpoint toward teaching science and the other content areas.

### **Teacher as Researcher: Kate, Cooperating Teacher**

Being *teacher as researcher* is what separates teachers who care to do better from those content to do less. Being motivated to try to do one's best at a profession is what results in effective teachers who care about students as humans in need of love and as children in need of the opportunity to learn.

### **Week Four**

Philosophy: Learning occurs in students when they are inspired or motivated through relevant activities which engage them on the task, and when they have the confidence to participate in their own learning processes.

As I returned to the classroom experience after being on a yearlong

sabbatical, I found myself concentrating on meaningful learning, both as a teacher of learning and as a learner myself. **I was driven by the reminder not to fall prey to 'naïve constructivism' which is the tendency to equate doing activity with learning** (Prawat, 1992, p. 357). In addition, I kept Novak's perspective of conceptual change in mind (Mintzes & Wandersee, 1998a) which considers humans as meaning makers who create their own unique knowledge constructions by consciously forming connections between new concepts and those part of their existing frameworks of prior knowledge.

### **Teacher of Learning**

One of the first things that came to my immediate attention upon re-entry into the classroom was the pervasive low self esteem within a large number of our sixth grade students. In response, I constructed the metaphor, *teacher as builder of confidence*:

I am surprised by how low the self esteem of our students really is. Students need to be encouraged over and over again that they can and are thinking – which encourages more thinking. It seems to come down to a lot of positive encouragement which builds confidence so they are more apt to take risks, talk, and learn.

I felt that addressing their confidence seemed to be a prerequisite to their learning. At the same time, I realized the importance of the teacher in motivating students to learn. I was also *teacher as inspiration for learning*: “Unless ideas or concepts are relevant to students, they just go through the motions. It is not meaningful learning. When ideas are relevant, students are immediately engaged and interested. It can be a challenge to capture their interest, however.” While I realized

**I was driven by the reminder not to fall prey to 'naïve constructivism' which is the tendency to equate doing activity with learning.**

how essential it was to inspire and motivate students, I also realized how difficult it was to accomplish that.

As I started the school year, I also realized the importance for hands-on experiences not just as motivators. Students also needed these experiences on which to build their knowledge about certain concepts. Experiences alone were not enough, but they did help students think more deeply or critically about scientific ideas, so I was also *teacher as encourager of thinking*. I commented on the importance of hands-on learning after listening to students: “I've heard students say, ‘I know what you mean. I did a project in third grade. . .’ I have never heard a student say, ‘Oh, I remember that word from a study guide I had to do in fifth grade.’” Students reveal amazing truths and when we as teachers listen, we realize some of those truths and can respond accordingly.

### **Personal Learning**

As I began the year with both a classroom of sixth grade students and a student teacher, I approached teaching and mentoring through the metaphor of *teacher as scientist or problem solver*. Concerning the students, I commented: “As a scientist or problem solver, I have approached one challenging class of 23 students which includes six

**I crafted the metaphor, *teacher as researcher*, as I contemplated the transition between my former role as teacher with prospective elementary teachers at the university level, and my current role as teacher of sixth grade students at the middle school.**

special needs students, with the idea that I can make learning happen here. It is just a matter of figuring out how.” After a yearlong sabbatical where I had concentrated on how children learn, I now had to deal with how to get children ready to learn. This classroom of some potentially volatile students had to be well managed to keep students focused on learning. The metaphor of *scientist* or *problem solver* seemed appropriate to me.

When working with my student teacher, I remembered the lessons I had learned from my dissertation project with prospective teachers (Sillman, 1998). I crafted the metaphor, *teacher as researcher*, as I contemplated the transition between my former role as teacher with prospective elementary teachers at the university level, and my current role as teacher of sixth grade students at the middle school. I commented: “When you are working with students, children or prospective teachers, and when teaching is for learning, teaching is an ongoing research project.” I had combined all of my metaphors into

a larger, more encompassing one, *teacher as researcher*, as I considered the role of teacher from a broader perspective.

For my sixth grade students, I focused on the meaningful learning of science concepts and for my student teacher, the meaningful learning of teaching science. In both cases, I used a constructivist approach to learning and teaching. This was challenging for me:

It has been difficult for me to be so watchful and careful of helping students to construct on their own with less ‘telling’ from me. Also, having Tiff is keeping me focused on providing for her what I found sixth grade students need—a safe, risk free learning environment where they can feel safe to experience and problem solve with me as their sounding board. I am also the *confidence builder* for Tiff as I praise her then marvel at what creativity and enthusiasm results in her actions.

I was now using metaphors I had originally developed for my sixth graders with Tiff as I tried to provide a safe learning-to-teach environment for her.

#### **Week Fourteen**

**Philosophy:** To learn, children (or prospective teachers) need to feel loved, respected, confident, and safe. To learn science, children (or prospective teachers) must experience a concept, either before or during class, and make meaning of that experience through questioning.

I started the school year concentrating on helping students learn science. As I got to know their real life situations better and began to see them as individual humans, I commented: “Now I am thinking about helping children feel loved and confident so they can learn science and other disciplines.” I was reminded that learning

does not occur in isolation; rather, it occurs within a unique human being. As I worked with my student teacher, I realized the same applied to her as a learner.

Included in viewing students more holistically was a blending and interdependence of my metaphors. I wrote in my journal:

More than ever, I believe in *teacher as confidence builder* because students need to feel confident to even begin to think our loud and learn. As a science teacher, one of the most important roles is helping students build an understanding of key concepts in science. When students think and put concepts together, they become more confident. One way to help build confidence in students is to help them realize they can think.

This synergism between confidence and thinking seemed to apply to learners in general, sixth grade students, and prospective teachers.

To determine how to reach a balance between building confidence and encouraging thinking, the metaphor of *teacher as researcher* is essential. I explained:

Playing this role makes teaching exciting. Finding ways to help individual children feel loved so they can begin to feel confident and to open up the possibilities within them to think, feel, have opinions, and learn is a challenge like no other (second only to parenting which I think is full time teaching). It is this role of *researcher* that separates mediocre teachers from those attempting to reach their potential within a profession.

I used this metaphor to subsume my other ones with the students as central to all metaphors constructed for teacher.

## **Collaborative Reflection: Tiff and Kate as Learners**

As we journeyed through the semester together, we discovered that we were both *teachers as learners*. As a prospective elementary teacher, Tiff was aware of her growing beliefs of learning and teaching science, using metaphor as a tool for purposeful reflection with me as her cooperating teacher. Because we both shared our growing and developing philosophies and reflective processes, we examined learning and teaching from different perspectives. This evolved into a learning experience for us both as we broadened our outlook and grew in our professional development as teacher researchers and lifelong learners. After all, if prospective teachers are introduced to the power of teacher research through modeling by cooperating teachers and experience it themselves, chances are greater that the student teacher would more likely be involved in it within their own future practice (Kincheloe, 1991).

Part of my goal for my student teacher was to help Tiff feel safe so she could be creative, experiment, and develop the confidence to become an independent, lifelong learner of learning and teaching. Reflection through metaphor seemed to provide a way of

**Kate—Week Fourteen:  
More than ever, I  
believe in *Teacher as  
confidence builder*  
because students need  
to feel confident to even  
begin to think out loud  
and learn.**

helping Tiff focus on teaching from a more student-centered perspective. In addition, Tiff felt the experience of this reflective process had helped her develop a clarity to her thoughts about learning and teaching. As a result, she was better prepared for her job interviews and obtained employment shortly after the completion of her student teaching field experience. Likewise, the collaborative reflection process served as a way for me, a practicing teacher, to realize reasons behind actions taken for granted and possibly modify those beliefs.

However, if we as teacher educators / science supervisors are going to help develop within prospective elementary teachers an understanding of how children learn science so that all learners have an opportunity to succeed, more is required beyond a safe, learning environment. The cooperating teacher or supervisor must explicitly engage the prospective teacher in conversation about what makes teaching science different from teaching other content areas. It seems that given the little understanding of and experience with scientific inquiry, elementary teachers are at a particular disadvantage when it comes to supporting children's scientific inquiry (Boardman, Zembal-Saul, Frazier, Appel, & Weiss, 1999; Zembal-Saul, Dana, Severs, & Boardman, 1999).

All in all, it is essential that prospective teachers first feel safe within their learning-to-teach environments so they can begin to experience and experiment with putting their beliefs into action. Constantly reflecting both individually and in conversation with others through a tool such as metaphor can help prospective teachers feel safe and comfortable to begin to align their beliefs and actions, monitor their changing beliefs, and construct their

own meanings about this phenomenon of learning to teach science. If they leave the field experience with the confidence to learn and the experience of exploring and articulating their beliefs with others, they will be on their way to becoming lifelong learners of learning and teaching science and all content areas.

## *References*

- Boardman, L.A., Zembal-Saul, C., Frazier, M., Appel, H. and Weiss, R. (1999). *Enhancing the science in science methods: A collaborative effort between science education and entomology*. Paper presented at the Annual Meeting of the Association for the Education of Teachers of Science, Austin, TX.
- Bullough, R.V. & Stokes, D.K. (1994). Analyzing personal teaching metaphors as a means of encouraging professional development. *American Educational Research Journal*, 31, 197-224.
- Dewey, J. (1933). *How we think: A restatement of reflective thinking to the educative process*. Boston, MA: Heath.
- Gunstone, R.F., Slattery, M., Baird, J.R., & Northfield, J.R. (1993). A case study exploration of development in preservice science teachers. *Science Education*, 77, 47-73.
- Hole, S. & McEntee, G.H. (1999). Reflection is at the heart of practice. *Educational Leadership*, 56, 34-37.
- Kincheloe, J.L. (1991). *Teachers as researchers: Qualitative inquiry as a path of empowerment*. Philadelphia, PA: Falmer.
- Lakoff, G. & Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago.
- Lieberman, A. & Miller, J. (1986). *Teachers, their world, their work: Implications for school improvement*. Alexandria, VA: ASCD.
- Mintzes, J.J. & Wandersee, J.H. (1998). Reform and innovation in science teaching: A human constructivist view. In J.J. Mintzes, J.H. Wandersee, & J.D. Novak (Eds.), *Teaching science for*

- understanding: A human constructivist view*. New York: Academic.
- National Research Council. (1996). *National science education standards*. Washington, DC.: National Academy Press.
- Prawat, R.S. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education*, 100, 354-395.
- Sillman, K.A. (1998). *Metaphor: A tool for monitoring prospective elementary teachers' developing metacognitive awareness of learning and teaching science*. Unpublished doctoral dissertation, The Pennsylvania State University, University Park, PA.
- Stofflett, R.T. & Stefanon, L. (1996). Elementary teacher candidates' conceptions of successful conceptual change teaching. *Journal of Elementary Science Education*, 8, 1-20.
- Tobin, K., Tippins, D.J., & Hook, K.S. (1994). Referents for changing a science curriculum: A case study of one teacher's change in beliefs. *Science and Education*, 3, 245-264.
- Treagust, D.F., Duit, R., & Fraser, B.J. (1996). Overview: Research on students' preinstructional conceptions-The driving force for improving teaching and learning in science and mathematics. In D.F. Treagust, R. Duit & B.J. Fraser (Eds.), *Improving teaching and learning in science and mathematics*. New York: Teachers College.
- Zemal-Saul, C., Dana, T.M., Severs, M.J. and Boardman, L.A. (1999). *Web-based portfolios: A vehicle for examining pre-service teachers' emerging developing ideas about science teaching*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA.

---

Kathleen Sillman is a sixth grade science teacher on leave from the Bellefonte Area Middle School, Bellefonte, PA. She is currently a Professional Development Liaison and Science Education Instructor at the Pennsylvania State University, University Park, PA 16802.

---

Tiffani Smith is a sixth grade teacher in the West Shore School District, New Cumberland, PA 17070.

# A Professional Development Model for Exploring the National Science Education Standards

A process is outlined for a professional development workshop whose intent is to help preservice and inservice science teachers gain an initial understanding of how the National Science Education Standards can be integrated into their teaching programs and practices.

The National Commission on Teaching and America's Future's report, *What Matters Most: Teaching for America's Future*, recommends that those involved with education "get serious about standards for both students and teachers" and make teachers and teaching the linchpins of school improvement (1996, p. vii). But, the standards-driven reform movement has generated a general wave of uneasiness within the K-16 educational community as its members struggle with the attendant implications on teaching practice and curriculum content.

Because the final fate of most educational reform initiatives rests squarely among teachers who serve as the ultimate agents of classroom change (Bybee, 1997; Decker 1999), we propose that standards become the cornerstone of their professional practice. In order to accomplish this goal, teachers must first develop a keen understanding of the history and philosophy underlying systemic reform, then gain a working familiarity with standards documents, and finally, engage in experiences that lead to personal meaning or internalization of the standards.

This paper describes a professional development workshop whose intent is to help both preservice and inservice audiences gain an initial understanding of how the *National Research Council* (1996) and *American Association for the Advancement of Science* (1993) can be integrated into their teaching programs and practices. Throughout this paper, the terms standards and benchmarks will be used interchangeably. Through a knowing in action approach (Schon, 1983) participants develop a practical understanding of the purposes, history, and instructional ramifications of standards. The meth-

**Teachers must first develop a keen understanding of the history and philosophy underlying systemic reform, then gain a working familiarity with standards documents...**

ods that we apply model elements of instruction that are consistent with effective professional development practices (Loucks-Horsley, Hewson, Love, & Stiles, 1998). We believe that the workshop's combination and sequence of activities is readily adaptable for considering standards in other disciplines.

## Workshop Description

Our essential premise is that direct experience within the context of a widely practiced instructional model creates an optimum environment for exploring how to use standards for making effective decisions about content, instruction, and assessment. Hammrich (1998) applied a similar approach in dealing with standards by giving preservice teachers the opportunity to learn, reflect, apply new knowledge, and demonstrate proficiency. To establish a backdrop for the workshop, we begin by listing our assumptions about educational standards: that standards-driven reform of education is here to stay; that every teacher should comprehend the fundamental relationship between standards and the conduct of their professional lives; that the most effective way to learn

## Standards assure that key learning goals are met by appropriate grade levels in a student's career.

about standards is by using them; and that implementing standards-based education is a long-term process. The workshop format follows a five stage learning cycle, based on the Biological Sciences Curriculum Study (1993) model. (Figure 1).

### Engagement

The workshop package given to every participant contains a puzzle piece that consists of a section from a laminated cover of a major standards document. One of four different color dots is affixed to the back of each piece. To launch the workshop, teachers must locate the three other people having the pieces needed to assemble the complete puzzle. This randomized grouping activity defines work teams, and the color-coded dot system assigns individual task responsibilities.

As small groups exhibit their assembled covers, the workshop leader gives an overview of standards-driven reform, using a conceptual framework borrowed from Bybee (1997). According to Bybee, the chronology of reform includes statements of purpose, policy development, program alignment, and changes in teaching and learning practices. Each of these elements of reform is illustrated by key documents. We use covers taken from: *A nation at risk* (National Commission on Excellence in Education, 1983), *Science for all Americans* (AAAS, 1989), *Benchmarks for scientific literacy* (AAAS,

1993), *National science education standards* (NRC, 1996), *Blueprints for reform* (AAAS, 1997), *Pathways to the science standards* (NSTA, 1996, 1997, 1998), and *Resources for scientific literacy* (AAAS, 1997). This engagement activity quickly and effectively creates a working atmosphere, organizes groups, delegates team roles, and produces an authentic context for reviewing the background and implications of systemic reform.

### Exploration

In the exploratory phase, a scavenger hunt provides the learning tool for reviewing the general features of the *National Science Education Standards* (NSES) document and website (Figure 2). Fifteen questions divided among separate teams encourage small group interaction. This simple exercise enables participants to examine prior knowledge, explore personal beliefs, and gain a preliminary understanding of the NSES organizational framework and philosophy. The concept exploration stage also serves as the advance organizer for the more focused activities that follow.

### Explanation

Conceptual development occurs during phase three as teachers analyze existing curriculum materials and videotaped examples of instruction to identify points of alignment with the content and teaching standards. We adopted Kesidou's (1999, p. 3) notion that to be considered aligned, an activity or instructional approach should "address the substance rather than the general topic" of the standard. The goal of having teachers gain a working familiarity with standards is anchored in an activity in which they assume the role of curriculum consultants. Their

task is to measure the congruence of representative science curricula with the content standards. Programs developed with National Science Foundation support are ideal to examine. For this basic analysis, teachers use a curriculum review instrument developed by the National Association of Biology Teachers (1996) because the tool is clear, concise, and informative. If a more thorough study were the desired end, then Project 2061's curriculum analysis tool would be ideal to employ (Roseman, Kesidou, & Stern, 1996).

Following this curriculum investigation, workshop participants review videotaped case studies of teaching. A scoring rubric grounded in the Standards for Teaching Science is applied to examine pedagogical practices (Table 1). Only those standards for which evidence can be directly observed are referenced. We use *SourceView* videotapes from the American Chemical Society's Chem-Source Project (1992) for this purpose. To encourage in-depth analysis, teachers identify specific performance indicators that illustrate their conclusions about teaching standards that are being satisfied. Teachers report that videotapes provide a nonthreatening atmosphere for evaluative discussions about instructional methodologies. Other observation protocols could be adapted for this purpose (Cummins & Good, 1998; Horizon Research, 1998; Ingle & Cory, 1999).

These combined activities focus attention and stimulate reflection on specific aspects of curriculum and instruction. Participants begin to develop a knowledge base about how content standards relate to science programs and how teaching standards connect with classroom practice.

Figure 1 - Five Stage Learning Cycle

*Engagement: history of standards-based reform*

- Goal: to establish an interactive context for reviewing the history of science standards.
- Activity: use “puzzles” to kick off workshop, form groups, and assign roles.
- Grouping strategy: make color copies of major standards documents’ cover pages. Laminate copies and cut into 3-5 pieces to create a jigsaw puzzle. Randomly distribute pieces. Have participants mingle and form groups by completing the puzzle. Color dots on back side of pieces to designate roles.
- Performance objectives: participants will be able to identify the major standards documents and describe the history of the standards-driven reform movement.

*Exploration: overview of NSES*

- Goals: to activate prior knowledge of standards and to become familiar with the NSES text and website.
- Activity: participants complete the NSES scavenger hunt.
- Performance objectives: participants will be able to use the NSES text and navigate the NSES website to know the content and organizational features of the standards.

*Explanation: standards alignment*

- Goals: to gain knowledge of Content and Teaching Standards by analyzing examples of practice and apply standards to evaluate curriculum and instruction.
- Content Standards Activity: participants use NABT or AAAS Content Analysis Instruments to evaluate science materials for alignment with content standards.
- Teaching Standards Activity: participants apply a scoring rubric focuses on teaching standards to examine a classroom videotape.
- Performance Objective: participants will be able to use their knowledge of contents and teaching standards to evaluate curriculum materials and instruction.

*Extension: science as inquiry*

- Goal: to gain a working understanding of inquiry standards by analyzing and adapting traditional lab activities.
- Activity: participants take traditionally formatted labs and modify them into activities that apply inquiry based approaches.
- Performance objective: participants will be able to apply their knowledge of inquiry standards to create more open-ended learning experiences.

*Evaluation: reflections upon practice*

- Goals: to reflect upon the workshop, to self-assess knowledge of standards, and to affirm commitment to outcomes gained from the workshop experience.
- Activity: participants compose the “I hereby resolve” letter.
- Performance objective: participants will be able to describe the potential impact of standards on their professional lives.

Figure 2 - National Science Education Standards and Internet Scavenger Hunt

*Purpose: to help educators....*

- become familiar with the content and organization of the NSES book and website;
- develop a personal understanding of the NSES;
- appreciate the impact of the NSES on teaching practices.

*References*

- *National Science Education Standards* (1996). National Research Council. Washington, DC: National Academy Press
- NSES website: [www.nap.edu/readingroom/books/nses](http://www.nap.edu/readingroom/books/nses)

*Instructions for Completing the NSES Scavenger Hunt*

Each group will be given five questions to answer or tasks to complete. After you finish each item please make note of your specific sources of information.

*Group I*

1. What exactly are the National Science Education Standards? (Source: \_\_\_\_\_)
2. What are the eight different Content Areas for which Standards are developed? (Source: \_\_\_\_\_)
3. What does “scientific literacy” mean and how is this issue related to equity for students? (Source: \_\_\_\_\_)
4. What does the NSES say about “authentic assessment”? (Source: \_\_\_\_\_)
5. What are the Physical Science Content Standards for grades K-4? (Source: \_\_\_\_\_)

*Bonus*: What is the relationship between a Standard and a Performance Indicator? (Source: \_\_\_\_\_)

*Group II*

1. Who participated in developing the NSES? (Source: \_\_\_\_\_)
2. What are the grade clusters into which the Content Standards are grouped? (Source: \_\_\_\_\_)
3. What is the meaning of the expression “inquiry based instruction”? (Source: \_\_\_\_\_)
4. What does the NSES say about the important issue of lab safety? (Source: \_\_\_\_\_)
5. What are the Earth and Space Science Content Standards for grades K-4? (Source: \_\_\_\_\_)

*Bonus*: What is the relationship between the AAAS *Benchmarks for Science Literacy* and the *National Science Education Standards* document? (Source: \_\_\_\_\_)

*Group III*

1. What are the six different categories of Science Standards? (Source: \_\_\_\_\_)
2. Are the NSES the same as a science curriculum? Explain. (Source: \_\_\_\_\_)
3. Give two examples of how the NSES will change science teaching. (Source: \_\_\_\_\_)
4. What does the NSES say about computer use in the classroom? (Source: \_\_\_\_\_)
5. What are the Life Science Content Standards for grades K-4? (Source: \_\_\_\_\_)

*Bonus*: What is the percent correlation between the *Benchmarks for Science Literacy* and the *NSES*? (Source: \_\_\_\_\_)

Table 1 - NSES Teaching Standards: Classroom/Videotape Observation Tool

• STANDARDS IN ACTION	• EXEMPLARY	• GOOD	• COMPETENT	• NOT EVIDENT	• NOT APPLICABLE
• A.2 Selects content that addresses diverse student interests and abilities					
• A.3 Uses approaches that develop student understanding					
• A.3 Applies strategies that build a community of science learners					
• B.2 Focuses and supports inquiry					
• B.3 Orchestrates science talk among students					
• B.3 Challenges students to be responsible for their learning					
• B.4 Responds to student diversity					
• B.4 Encourages all students to participate					
• B. 5/E.5 Encourages and models skills, values, and attitudes of scientific inquiry					
• B.5 Encourages and models curiosity, openness, and skepticism					
• C.1 Uses multiple methods to gather data about student understanding/ability					
• C.2 Analyzes assessment data to guide teaching understanding/ability					
• C.3 Guides student in self-assessment					
• D.2 Creates classroom setting that is flexible and supports inquiry					
• D.3 Ensures a safe working environment					
• D.4 Makes tools, materials, media, and technology accessible to students					
• E.1 Respects diverse ideas, skills, and experiences					
• E.2 Requires students to be responsible for the learning of all class members					
• E.3 Encourages collaboration among students					
• E.4 Structures class discussion to reflect rules of scientific discourse					

Table 2 - Schwab/Herron Levels of Laboratory Openness

Level	Problem	Ways and Means	Answers
0	Given	Given	Given
1	Given	Given	Open
2	Given	Open	Open
3	Open	Open	Open

### Expansion

One underlying reason for specifying standards is to assure that key learning goals are met by appropriate grade levels in a student's career. Another is to assure that science teaching is conducted in a manner that is inquiry-oriented and consistent with what is known about how children learn. Many traditional instructional materials have proven to be valuable resources but are not fully consistent with the standards for inquiry (Jansen, 1996). There are several viable alter-

natives to discarding these activities (Caves, Herminghaus, Hurlburt, 1998; McComas, 1997; NRC, 1999; Suttman, Hilosky, Priestley, & Priestley, 1999). With an analytic scoring rubric (Table 2), participants rate the inquiry character of existing learning activities according to an inquiry criteria continuum. Then they employ a technique for making laboratory activities more open-ended.

The concept expansion activity gives teachers an opportunity to apply their growing familiarity with inquiry-based instruction under conditions that they can recognize. The exercise respects present practices but emphasizes the importance of inquiry as the central focus to teaching and learning about science. Participants often discover that current instructional materials may require only slight reconfiguration to become more carefully aligned with the guidelines for inquiry. In other instances, they conclude that a traditional learning activity is fundamentally incompatible with the inquiry process.

### Evaluation

This workshop neither directly addresses the substantial quandaries surrounding the assessment of student performance under a standards-based system nor asks participants to directly evaluate the session. Rather, teachers complete an "I hereby resolve..." activity developed by Silberman (1996). In this self-assessment task, teachers write a letter to themselves in which they describe specific learning outcomes drawn from their participation.

Leaders collect these letters and return them to the writers after sufficient time has elapsed for participants to have reflected upon the salient points of the workshop experience. Some teachers report that a later reading of these letters reaffirmed their commitment to lessons learned and helped them to incorporate these practices into their everyday teaching.

### Conclusion

Many among the current generation of practicing teachers developed their craft under a very different set

**Demystification of standards is a necessary first step toward representing the collective wisdom of teachers, scientists, and science educators to create better conditions for science teaching.**

## Current instructional materials may require only slight modification to become more carefully aligned with guidelines for inquiry.

of guiding instructional and curricular principles than are presently espoused by reform movements. The reluctance of some teachers to implement standards-driven reform seems to be associated less with intransigence than with other factors such as the tenacity of established beliefs and attitudes, the difficulty of making direct connections between standards and the day-to-day job of teaching, and misunderstanding the full implications of a standards-based educational system. The concerns raised by Lynch (1997) bear consideration in this regard. She states that,

a major reason for the difficulties of science education reform is that many educators simply do not understand its principles and implications, rather than not buying into the goals of reform. Further, the apprehension is not so much because of a lack of intelligence or motivation as that this reform is complex or has been able to produce few, if any concrete examples of what reformed classrooms, school, K-12 curriculum or science activities look like. (1997, p. 3)

Our workshop rationale builds on Posner's (1996) assertion that experience plus reflection equals growth. However, several essential features that promote teacher change are conspicuously absent (Guskey, 1988). Bellanca contends that changing one's instructional style is as "difficult as

learning to change one's learning style" (1998, p. 659) and that such a shift requires more than the mere conveyance of technical information. Thus, a one day session is unlikely to challenge existing teacher beliefs and attitudes, provide sufficient opportunities for reflection, or allow for an in-depth review of the topic. Consequently, the workshop would have limited consequence if used as a stand-alone experience aimed at getting teachers to adopt standards-based principles across their professional practice.

This introductory workshop explores some fundamental concerns that preservice and inservice teachers have about standards. Demystification of standards is a necessary first step toward having these benchmarks serve as beacons, dynamic guides representing the collective wisdom of teachers, scientists, and science educators that can help to create better conditions for science teaching and learning.

### References

- American Association for the Advancement of Science. (1997). *Resources for scientific literacy*. New York, NY: Oxford University Press.
- American Association for the Advancement of Science. (1997). *Blueprints for reform*. New York, NY: Oxford University Press.
- American Association for the Advancement of Science. (1993). *Project 2061: Benchmarks for scientific literacy*. New York, NY: Oxford University Press.
- American Association for the Advancement of Science. (1989). *Science for all Americans*. New York, NY: Oxford University Press.
- American Chemical Society. (1992). *SourceView*. Washington, DC.
- Bellanca, J. (1998). Teaching for intelligence. *Phi Delta Kappan*, 79, 658-660.
- Biological Sciences Curriculum Study. (1993). *Developing biological literacy*. Dubuque, IA: Kendall-Hunt.
- Bybee, R. W. (1997). *Achieving scientific literacy*. Portsmouth, NH: Heinemann.
- Caves, T., Herminghaus, T., Hurlburt, J. (1998). *Change chemistry labs: Subtle shifts toward inquiry*. Anchorage, AK: Earth System Implementation Project.
- Cummins, C. L. & Good, R. (1998). *A science teacher observation tool based on current reform documents*. Paper presented at the Annual Meeting of the Association for the Education of Teachers in Science. Minneapolis, Minnesota.
- Decker, K. A. (1999). Meeting the state standards through integration. *Science and Children*, 36, 28-32.
- Guskey, T. R. (1988). Staff development and the process of teacher change. *Educational Researcher*, 5-12.
- Hammrich, P. L. (1998). What the science standards say: Implications for teacher education. *Journal of Science Teacher Education*, 9, 165-186.
- Horizon Research, Inc. (1999). *1998-99 Local systemic change classroom observation protocol*. Available: <http://www.horizon-research.com>. [1998, April 25].
- Ingle, M. & Cory, S. (1999). Classroom implementation of the NSES: A snapshot instrument to provide feedback and reflection for teachers. *Science Educator*, 8, 49-54.
- Jansen, M. P. (1996). Chemistry labs without a cookbook. *Crucible*, 27, 15-17.
- Kesidou, S. (1999). *Producing analytical reports on curriculum materials in science: Findings from Project 2061's 1998 curriculum review study*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA.
- Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

- Lynch, S. (1997). Novice teachers' encounter with national science education reform: Entanglements or intelligent interconnections? *Journal of Research in Science Education*, 34, 3-17.
- McComas, W. E. (1997). The nature of laboratory experience: A guide for describing, analyzing, classifying, and enhancing hands-on activities. *CSTA Journal*, Spring, 6-9.
- National Association of Biology Teachers. (1996). *Aligning with the National Science Education Standards: NABT curriculum review instrument*. Reston, VA.
- National Commission on Excellence in Education. (1983). *A nation at risk: The imperative of education reform*. Washington, DC.
- National Commission on Teaching and America's Future. (1996). *What matters most: Teaching for America's future*. New York, NY.
- National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.
- National Science Teachers Association. (1996, 1997, 1998). *Pathways to the science standards*. Washington, DC.
- Posner, G. J. (1996). *Field experience: A guide to reflective teaching*. White Plains, NY: Longman.
- Roseman, J. E., Kesidou, S., Stern, L. (1996). *Identifying curriculum materials for science literacy: A Project 2061 evaluation tool*. Paper presented at the National Research Council Colloquium, "Using the National Science Education Standards to Guide the Evaluation, Selection, and Adaptation of Instructional Materials."
- Schon, D.A. (1983). *The reflective practitioner*. New York, NY: Basic Books.
- Silberman, M. (1996). *Active learning*. Needham Heights, MA: Allyn & Bacon.
- Sutman, F. X., Hilosky, S., Priestley, W. J., Priestley, H. (1999). *Implications for the use of the inquiry matrix in professional enhancement experiences*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. Boston, MA.

---

Richard Audet, Assistant Professor of Science Education, Education Department, Roger Williams University, Bristol, RI 02809

---

Linda Jordan, Secondary Science Consultant, Tennessee Department of Education, Nashville, TN 37243

# OSHA Laboratory Standard: Driving Force for Laboratory Safety!

OSHA's Laboratory Safety Standards are seen as the major driving force in establishing and maintaining a safe working environment for teachers and students.

*The 1990 OSHA Laboratory Standard established the minimal expectations upon which science laboratory safety programs in educational institutions must be developed.*

The National Science Standards, and national and state science curriculum reforms of the nineties have created an atmosphere, which has promoted more of the doing of science through hands-on activities. In addition, workspace problems for school science laboratories have been precipitated by increases in student enrollments and failure of increases in funding support. This article addresses the importance of OSHA's Laboratory Safety Standard as the major driving force for helping to establish a safe working environment for teachers and students during these times of change. Focus is placed on the essential building blocks of laboratory safety programs for middle and high school science departments, based on the Occupational Safety and Health Administration's (OSHA) *Occupational Exposure to Hazardous Chemicals in Laboratories or Laboratory Standard*. Additionally addressed is the critical need to go beyond the Standard's minimal expectations in efforts to build an effective safety program.

## I. Don't Exceed the Speed Limit!

How often have science teachers and leaders heard the following statements?

"We don't have enough money in the budget for a flammable liquid cabinet. Just put those chemicals in the storeroom on the shelf with everything else."

"I wouldn't be concerned about the ventilation in your laboratory. They usually do smell."

"I don't care if you think that science laboratory was built for 24 students. If I want to put 35 students in there, I will and you will teach them."

With increasing enrollments and shrinking budgets, these types of statements have been made by principals, superintendents, board of education members, and other decision-makers

**"We don't have enough money in the budget for a flammable liquid cabinet. Just put those chemicals in the storeroom on the shelf with everything else."**

with increased frequency. In these types of situations, it is critical for science teachers and leadership to become knowledgeable about safety codes and laws, and be advocates to work with decision makers and help support them in keeping science laboratories safe for employees and students.

This scenario creates a major stumbling block for science educators. On the one hand, they are being asked to provide for more hands-on activity based science, as supported by the National Science Standards. Additional impetus has come from national science curriculum projects such as AAA's Project 2061 and NSTA's Scope, Sequence and Coordination Project. On the other hand, science educators are being told that class size, as well as funding for texts, materials, and other support materials are in jeopardy as a result of increasing enrollments and declining fiscal support.

A fact of learning is that doing science in a laboratory costs more money and takes more time than reading about science in a classroom. If we are to improve science education by moving in the directions advocated by national reform movements, science educators must take a greater role in helping decision-makers to better understand and support these initiatives.

One major area which needs to be targeted is laboratory safety. It is one thing to advocate the doing of science. It is an entirely different thing to provide a safe laboratory in which these activities take place. To this end, it is critical for science teachers and their leaders to become knowledgeable about safety codes and laws, and to be advocates to work with decision-makers and help support them in keeping science laboratories safe for employees and students.

Providing a safe working environment for teachers and students is a serious responsibility for school districts as employers. In efforts to provide direction, OSHA issued *the Occupational Exposure to Hazardous Chemicals in Laboratories* or *the Science Laboratory Standard* (Fox, 1999, p. 834-842) for employees working in laboratories (including academic laboratories such as those found in middle and high schools). OSHA defines the term "laboratory" as "a facility where the laboratory use of hazardous chemicals occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis" (Fox, 1999, p. 835). The term "hazardous chemical" means a chemical that can cause acute or chronic health effects in exposed employees. This claim must be supported by statistically significant evidence in at least one scientifically based study (Fox, 1999, p. 835). These types of chemicals include carcinogens, toxic agents, corrosives, irritants and a host of others.

School employees protected under Federal OSHA or State Plan OSHA (see table 1) are covered by the 1986 Hazard Communication Standard or HazCom/Right to Know law, 29 CFR 1910.1200 (Fox, 1999, p. 823). However, because of the dangers and

uniqueness inherent in laboratory work, employers under federal OSHA or state plan OSHA are required to cover laboratory workers (including science teachers) with the Laboratory Standard, 29 CFR 1910.1450 Subpart Z. Interestingly enough, with the increase in use of chemical technologies, other employees such as technology education or art teachers, can also be covered under the Laboratory Standard. This option is at the discretion of the employer. Minimally, science teachers must be covered under this standard.

Private school employees are covered by either the federal or a state OSHA plan. Public school employees are covered under either a state OSHA plan or an alternative state government safety agency program. Public school employees need to secure information concerning which health and safety standards protect them on the job site.

## II. Rules of the Road!

The Laboratory Standard is performance based. This statement means that OSHA provides the basic outline requirements, and then each employer writes a plan tailored to their needs. For example, plans may vary from district to district, relative to standard operating procedures. However, all plans must contain standard operating procedures. The standard requires that the employer (e.g., Board of Education), appoint a Chemical Hygiene Officer (CHO) to develop and implement a Chemical Hygiene Plan (CHP) (Fox, 1999, p. 834). Some professional associations have provided guidance in establishing the qualifications of the CHO (Alaimo & Fivizzani, 1996). The standard's basic tenets (Fox, 1999, p. 834-836) include the following:

1. Scope and Application--This

standard covers any employee who is engaged in the laboratory use of hazardous chemicals on a laboratory scale (as opposed to industrial level). Most science teachers, as employees in middle and high schools, are classified under this application.

2. Definitions--This section defines terms such as action level, employee, laboratory, hazardous chemical, chemical hygiene officer, and more. These terms are critical points of reference in writing the CHP and standard operating procedures.
3. Permissible Exposure Limits (PELs)--Employees are not to be exposed above the PEL specified in 29 CFR 1910, subpart Z.
4. Employee Exposure Determination--This component requires employees' measurement of exposure to certain chemicals if the action level or PEL is exceeded, providing a monitoring standard has been established. If monitoring is required, the employee must be notified of the results.
5. Chemical Hygiene Plan (CHP)--A written plan must be developed to protect employees from hazards associated with chemicals in the laboratory. Although generic plans

**Teachers and their leaders must be advocates to work with decision makers and help keep science laboratories safe for employees and students.**

are available, each plan must be unique to address the specific needs of individual workplaces. It is the responsibility of the employer to develop the CHP and enforce it. The CHO position is an appointment under the OSHA standard as opposed to a required new hiring.

6. Employee Information and Training--Employees must be made aware of chemical hazards in the laboratory. The training must be provided at time of initial employment and when new chemicals/hazards are introduced into the workplace. Information must include CHP contents and the Laboratory Standard, PEL's and Threshold limit values, exposure signs, and location of related reference material. Training must minimally include methods to detect presence of hazardous chemicals, physical and chemical health hazards in the laboratory/work area, procedures including emergency procedures, work practices and protective equipment.
7. Medical Consultation and Medical Examination--Employer must provide opportunity for employee medical support and follow-up examinations.
8. Hazard Identification--Adopt a labeling system such as National Fire Protection Association labeling codes, maintain and make Material Safety Data Sheets available.
9. Use of Respirators--Procedures and equipment must be provided by employer when respirators are required, as per 29 CFR 1910.134 (Fox, 1999, p. 219).
10. Recordkeeping--Employers must keep records of exposure monitoring, medical consultation and examinations of employees.

11. Dates--CHP must have been developed and implemented by 31 January 1991.
12. Appendices--Non-mandatory recommendations are provided for consideration in the CHP. Although the noted references are not endorsed by OSHA, they address professional expectations and provide specific safety protocols in the laboratory situation. A CHP will be more effective if based on these safety protocols.

### III. Map Out Your Destination!

The CHP components are prescribed by the Laboratory Standard. Each plan must contain the following minimum parts (Fox, 1999, p. 835-836):

1. Standard operating procedures (SOPs)--What are the standards for laboratory operation that all employees are required to follow? For example, what is the protocol for testing showers in the laboratories? SOPs should be rooted in standards, codes, or other professional expectations. One reference source often overlooked is the OSHA Standards Interpretation and Compliance Letters. Relative to testing showers, an OSHA position letter titled "Clarification regarding the frequency with which showers must be tested" is available (Donnelly, 1995).
2. Criteria to determine and implement control measures to reduce employee exposure--What type of engineering controls, use of PPE, and hygiene practices will be required?
3. Requirement that fume hoods and other protective equipment are functioning properly and within specific measures--Is there a

## Remember that OSHA covers employees, but not students.

preventive maintenance program in place, which fosters optimal performance of protective equipment?

4. Provisions for employee information and training--How often and what type of safety training is available where laboratory operation requires prior approval from the employer--What information will be provided for employees?
5. Circumstances where laboratory operation requires prior approval from the employer--What is the protocol used to undertake a special laboratory activity or new procedure?
6. Provisions for medical consultation and examinations--What procedure has been established to provide for medical assistance if an employee has a chemical exposure or incident?
7. Designation of personnel responsible for implementation of CHP, including Chemical Hygiene Officer (CHO) and if appropriate, Chemical Hygiene Committee--Who is the employer-designated Chemical Hygiene Officer? This person must be qualified by training or experience to provide technical guidance in the development and implementation of CHP. This person usually is a chemistry teacher, department head, or laboratory technician.
8. Provision for additional employee protection when working with particularly hazardous substances--What procedures are in place

Table 1

State Plan Programs Covering Both Private and Public Sector (21 states and two territories)

Alaska	Kentucky	New York	Utah
Arizona	Maryland	North Carolina	Vermont
California	Michigan	Oregon	Virgin Islands
Connecticut	Minnesota	Puerto Rico	Virginia
Hawaii	Nevada	South Carolina	Washington
Indiana	New Mexico	Tennessee	Wyoming
Iowa			

State Plan Programs Covering Public Sector Only (Private sector coverage provided by Federal OSHA)

Connecticut	New York
-------------	----------

States Covered by Federal OSHA (29 states and the District of Columbia)

(Private sector only The OSH Act does not provide the authority to cover public sector employees.)

Alabama	Idaho	Montana	Pennsylvania
Arkansas	Illinois	Nebraska	Rhode Island
Colorado	Kansas	New Hampshire	South Dakota
Connecticut	Louisiana	New Jersey	Texas
Delaware	Maine	New York	West Virginia
District of Columbia	Massachusetts	North Dakota	Wisconsin
Florida	Mississippi	Ohio	
Georgia	Missouri	Oklahoma	

Source: Connecticut State OSHA

for employees if they are to work with reproductive toxins, carcinogens?

Any school involved in an OSHA inspection knows that the OSHA Compliance Officer initiates the process by reviewing the employer's Chemical Hygiene Plan. They then focus on plan implementation and policing during an inspection. Can the OSHA Compliance Officer, or any other observer, walk into a high school chemistry laboratory when the use of hazardous chemicals is taking place without being challenged by the instructor to put on goggles? This type of situation must be addressed in the CHP.

**IV. Improved Features for New Models!**

OSHA standards represent only

the minimum expectations for safety. Remember that OSHA covers employees, and not students. However, in order to maintain a safe working environment for employees such as science teachers, the CHP should also cover students. The rationale is that in order to maintain a safe working environment for teachers as employees, students must also be accountable for following standard operating laboratory procedures.

Those working with the employer in the development of the CHP need to consider additional policies/regulations to go beyond the minimal safety expectation. Included for consideration should be items such as:

- Use: The CHP should address policies on use of laboratories by non-certified instructors and non-

science students; e.g., assignment of study halls or English classes in science laboratories. The employer will assume liability should an untrained employee or student be injured in a science laboratory.

- Occupancy Load: Occupancy loads in science laboratories are restricted by the The National Fire Protection Association's NFPA 101 Life Safety Code (Life Safety Code 101, 1997, p. 97), in addition to the Building Official and Code Administrator's BOCA Building Code (The BOCA National Building Code, 1996, p. 112). This restriction limits the number of occupants allowed in a science laboratory. Be careful to distinguish between the terms science laboratory and science

## Science teachers making safety their first priority will make it safer for themselves and will instill a commitment on the part of their students.

classroom. These designations have different ramifications, relative to code applications.

- Security: Science laboratories are considered secured areas, given the inherent dangers from gas, electricity, hazardous chemicals, etc. Policies need to be written to foster security, relative to entering laboratories and storerooms. For example, only chemistry teachers might be provided with a key to the chemical storeroom. Science laboratories are to be locked when they are not in use.
- Special Needs: Policies for working with students or employees who are physically challenged or have other special needs should be addressed in the CHP. There are various options available to meet both the safety and educational needs of all students and employees in the laboratory (Cheney & Roy, 1999).

### Learner's Permit!

The Laboratory Standard is only the foundation for an effective laboratory safety program. Safety must be further developed as an ongoing attitude and a commitment that never takes a rest. Science teachers and leaders must be advocates for safe science in the laboratory or field. They must work to help educate school administrators and boards of education, legislators and other government officials, to promote and facilitate a safe working environment for employees and students. Science teachers who make safety the first priority for their students will not only make it safer for themselves, but will also instill a commitment on the part of their students as future employees.

### References

Alaimo, R. J. & Fivizzani, K. P. (1996). Qualifications and training of chemical hygiene officers. *Chemical Health & Safety* [Online], 3(6), 10-13. Available: <http://pubs.acs.org/hotartcl/chas/96/novdec/choall.html?> [1999, September 9].

The BOCA National Building Code, 1996 Edition

Cheney, M. S. & Roy, K. R. (1999). Inclusive safety solutions. *The Science Teacher*, 66 (6), 48-51.

Crown-Cyr, A. (Ed.). (1999 Winter). State plan programs covering both private and public sector. *Connecticut State OSHA Job Safety & Health Quarterly*, 11 (2)

Donnelly, R. E. (1995, May). *Clarification regarding the frequency with which showers must be tested* [OSHA Standards Interpretation and Compliance Letters]. Available: <http://www.osha-slc.gov/OshDoc/Interp data/19950621.html>.

Fox, D. (Ed.). (1999). *Occupational safety and health standards for general industry*. Chicago: CCH Inc.

NFPA 101, *Life safety code*, 1997 edition

Occupational Safety and Health Administration. (1990). *Laboratories* [Online]. Available: <http://www.osha-slc.gov/SLTC/laboratories/index.html> [1999, June 17]

Kenneth R. Roy, Science Supervisor and Safety Manager, Glastonbury Public Schools, Glastonbury, CT 06033

# Tweaking Science Education

An experienced science educator discusses his views on science education.

One is often asked to share a vision of the future that is based on past experiences. I have often wondered about the validity of such predictions, and my skepticism has been intensified by the increasingly rapid increase in the quantity of innovation that has taken place and the suggestion that the rate of introduction of new technologies is more likely to speed up than slow down. When thinking about my own career, I frequently recall a former Dean who reminded his faculty that it was not good enough to simply be on the right track unless you were moving fast enough to avoid being run over by a faster-moving train. I've struggled to keep up in science education; I have never felt very far ahead. In fact, the train has always seemed to be about two ties behind me and closing the gap.

I have always believed that looking back over one's shoulder to examine one's roots can be a useful exercise. Therefore, I begin this piece with a look back to the first edition of *A Handbook for Science Supervisors*, (Harbeck, 1967) which was produced by the National Science Supervisors Association and published by the National Science Teachers Association as it is today. In 1967, J. Darrel Barnard writing in this book said:

In tomorrow's schools, supervisors will be expected to take more active roles in dealing with at least three of the pressing problems facing education today:

1. Development of more effective practices of inducting college graduates into teaching,
2. Evaluation of curriculum innovations and evaluation of technological innovations as they are applied to teaching and learning, and
3. Guidance in selection of both curriculum and technological innovations. (6).

Many good solutions to Barnard's problems have been found, but no one solution has been universally applicable. Hence, the challenges are as valid today as they were when they were first presented.

**Schools must commit to providing real-time support for clinical supervision and mentoring because universities and colleges do not and will not have the expertise and resources to prepare teachers for the unique environments of individual schools.**

## Inducting College Graduates

Since I began teaching secondary science methods in 1966, more than 3000 pre-service teachers have completed my class, graduated, obtained certification, and begun their careers as science teachers. Some of these former students are now outstanding teachers with over 30 years of experience. Some, I am sure, have had one year of experience 30 times, and many have dropped out of teaching. I am proud of those with 30 years of experience and remind them that I, with over 40, am still learning better ways to teach. I remain concerned about those who did not grow with the profession and wish they had dropped out. However, my greatest concern is the student who drops out of the profession early in his/her career.

Some enter new professions; others find easier, higher paying jobs. Some claim the job simply burned them out. The administration, apathetic unmotivated students, uncooperative parents, work conditions, or lack of recognition as professionals are blamed for their decision to leave the teaching field.

Unlike some of my students, I fondly remember my first year as a high school teacher. The school was new, the facilities excellent, the administration very supportive, and the parents wonderful; the kids loved to learn, and I was assigned to teach five classes in my major. My classroom was loaded with teaching aids, class sizes

**Preparation of a portfolio demonstrating one's teaching performance should be an exciting endeavor; however, for the over-burdened beginning teacher it is another huge task to be completed.**

were 20-24, and I was given a budget of \$3,000 (1960) dollars to purchase whatever else I needed. Furthermore, my department chair was fantastic, and she immediately introduced me to a master biology teacher who volunteered to mentor me. That first year, teachers did not have any extra-curricular assignments.

Most beginning teachers are not so fortunate. Many have multiple preparations, teach from a cart that they push from room to room, or have the least desirable teaching load in the department. Frequently, in southern Indiana, the one beginning teacher is the entire science department. If they have a mentor, he/she may teach subjects other than science, and if the mentor is a department chair, release time may not be given to serve as a mentor. If the beginning teachers survive, they are considered successful. If they don't survive, it is presumed that they were not properly prepared at the university.

The education of a science teacher cannot be completed on the college campus. The National Council for Accreditation of Teacher Education (NCATE), which established *The*

*New Professional Teacher Project*, argues that teacher preparation must be a three-phase continuum, consisting of a minimum of four years of preservice preparation, blending into an extended clinical preparation and assessment program (Intern Program), followed by continuing professional development.

Similar concern of The Council of Chief State School Officers about the plight of the beginning teacher led to the establishment of the Interstate New Teacher Assessment and Support Consortium (INTASC), which created the Performance Assessment Development Project (PADP) with the charge to develop a way of assessing beginning teacher's performance through the use of portfolios. Portfolios illustrating the ability to perform as a teacher would be prepared by beginning teachers during a two-year internship immediately following the preservice preparation program. Completed portfolios would then be submitted to the state for judging by teachers trained in portfolio assessment.

**Preparation of a portfolio demonstrating one's teaching performance should be an exciting endeavor; however, for the over-burdened beginning teacher it is another huge task to be completed.** Some serious questions must also be raised. As presently planned, the portfolio assessment would determine if the teacher would be:

1. Given a regular teaching license,
2. Provided, or required to engage in, extensive remedial training and education and submit a second portfolio, or
3. Advised to pursue another profession.

Questions include:

Will the student be able to obtain quality mentoring?

Will the mentor have the same major? Another science major? A discipline other than science?

Will the mentor have portfolio preparation or evaluation experience?

Will students be disadvantaged if the beginning teacher is not teaching his/her major subject?

Will schools provide support for the portfolio development process?

Will the student preparing the portfolio be teaching in her/his major or minor area? If not, how will that affect the ability to prepare a portfolio?

Will the portfolio rubric and other assessment materials be used reliably and objectively?

Is it too much to expect a beginning teacher to produce an extensive portfolio in the second year as a teacher?

Requiring teachers to submit a portfolio for evaluation at the end of their second year of teaching will place a significant burden on them, and one or more of the problems suggested by the questions will be sure to exist at every school site. However, preparing the portfolio will force the student and his/her mentor to focus considerable attention on two very important things: instruction and student learning. This intensive focus should facilitate maturation as a teacher.

Preparation of the portfolio can be ignored until the internship and left for the mentor and student to complete; however, students who experience portfolio preparation prior to this time will be advantaged. Students probably should prepare a first-draft portfolio while in the science methods class. Materials produced by the INTASC Performance Assessment Project under the direction of Angelo Collins of

Vanderbilt University could be used to guide these efforts (1998).

In an attempt to prepare my students for the future, I present the portfolio idea as an authentic task for preservice teachers to complete prior to student teaching. This task is authentic because they can use the lesson sequence developed during student teaching, and, in three years, can submit it to meet the portfolio requirement for obtaining continued teacher certification. Hence, on day one of my methods class, the students are presented with the following assignment.

Select, **with the advice and consent of your cooperating teacher**, a cohesive instructional sequence (approximately 8-12 hours of instruction) organized around an authentic science idea, inquiry, or application. The length of your instructional sequence should be determined by the time that it would take you and your students to develop the idea, inquiry, or application. Your lesson sequence should include a description of the observations and assessment instruments you will use to determine the effectiveness of your instruction. Your instruction should be consistent with the *National Science Education Standards*, the *Indiana Science Proficiency Guideline*, <http://www.doe.state.in.us/science>, and/or the local curriculum guides.

The *prospect* of preparing a portfolio of lessons and assessments for a cohesive sequence of instruction is not very different from the older *prepare a unit* assignment. However, this assignment is different because the stakes are a lot higher, and when students learn they must have a good portfolio or change professions, the task becomes authentic and somewhat frightening. In attempting to convince my students that preparing a quality portfolio is possible I remind them

they will be able to try out their lessons while student teaching, revise them for use in the first year of teaching, and revise them again before they must submit them for evaluation by the trained state portfolio evaluators.

In addition to preparing a portfolio, the students will be given instruction on portfolio evaluation including note taking, summarizing findings, and using a rubric to evaluate a portfolio. As the culminating activity, each student evaluates another student's portfolio. The students will also be encouraged to share portfolio evaluation materials with their cooperating teachers, who are potential mentors.

Admittedly, the portfolio will be important, perhaps too important in some instances, because the portfolio is only an artifact representing the processes used in its development. It is hoped that reviewers will see the process in the portfolios developed.

The first draft of the sequence of instruction can be developed on campus for use in student teaching. Preparing a portfolio that fully represents the science content and the processes used in delivering it involve four steps: Development, Implementation, Assessment, and Revision. The success teachers have in the process will often be determined by the quality of their mentor because the mentor will guide the students through the steps of implementation, assessment, and revision.

The term "mentor" is often used synonymously with "advisor," but there is a fundamental difference between advising and mentoring: Mentoring is a personal as well as a professional relationship, developing over long periods of time, during which the student's needs and the nature of the relationship tend to change. Mentors try to be aware of the changes taking

place in the student and vary the degree and type of attention, help, advice, information, and encouragement provided. (National Academy Press, 1997, 1) Mentors try to become critical friends of the mentee; they stretch the mentee to articulate precisely their rationale and to see information from a different perspective. (Fine. et al., 1997, 59) To be an effective mentor of beginning science teachers, one needs to understand the science content and the best teaching practices for the content; one must also know how to become a critical friend. Becoming a mentor and identifying suitable persons to serve as mentors should become an increasingly important function of science supervisor because only they have access to the knowledge needed to make these decisions.

In addition to arranging for quality mentoring, new and more intensive relationships between science supervisors and university science education faculty are needed. As stated earlier, teacher education cannot be completed on the college campus, nor can it be completed in a school setting that typically offers a marginal teaching facility, limited teaching resources,



**To be an effective mentor of beginning science teachers, one needs to understand the science content and the best teaching practices for the content; one must also know how to become a critical friend.**

**I believe that the induction processes [of college graduates as beginning teachers] should be managed by local expertise, assisted by university faculty, and monitored by state licensing authorities.**

and access to good-hearted assistance, volunteered by already overloaded faculty and curriculum supervisors. Schools must commit to providing *real time* support for clinical supervision and mentoring because universities and colleges do not and will not have the expertise and resources needed to prepare teachers for the unique environments of individual schools. Schools may have the expertise, but they often lack resources; e.g. money for *real time* support for science supervisors and science mentors.

As a university-based science educator, Barnard saw inducting college graduates into specific teaching environments as a major problem in 1967. Many courses designed for preservice teachers answered specific questions long before the inexperienced preservice teacher asked them. This happened because university faculty were frustrated by the fact that they would not have the opportunity to answer these questions when practicing teachers began asking them. Likewise, university faculty were not familiar with every teaching situation and could not prepare students for each and every teaching environment. However, Barnard must have realized that science supervisors were in the

best position to gain the specialized knowledge needed to make science instruction effective in their schools. Therefore, he stated that, "Rather than being concerned primarily with the in-service improvement of teachers in his school, he [the science supervisor] will also be highly involved with developing and managing experiences that will effectively induct college students into teaching" (Barnard, 1967, 6).

I believe that teacher education must continue far beyond the *walls of ivy*. I also believe teacher education should be in the hands of experts. Both experts and potential experts needed for guiding the induction to teaching process are frequently the overextended science supervisors and science mentors, located far beyond the shadows of *academia*. This does not mean that college teachers can't be useful adjuncts; in fact teacher education could be vastly improved if university professors did serve as adjuncts to science supervisors and science mentors. I believe that the induction processes should be managed by local expertise, assisted by university faculty, and monitored by state licensing authorities. Furthermore, the induction period should run on real, paid time, not on the backs of overburdened science supervisors and mentor teachers.

**Evaluation of Curriculum and Technological Innovations**

"Rather than being concerned solely with the implementation of a single curriculum in his school, he will also be highly involved in directing experimental studies to evaluate promising innovations" (Barnard, 1967, 6). Barnard wrote this in the heyday of the alphabet science curricula (ESCP, BSCS, CHEMS, CBA, PSSC, and

HPP), when there was considerable choice between the inquiry-oriented alphabet texts and the confirmation approach of traditional textbooks. Some would argue that there is no choice today because all textbooks have been more or less homogenized by textbook publishers, who are more interested in market share than engaging learners in exciting science exploration. Parents, too, often equate learning vast quantities of factual information with quality education and, indeed, the 1100-page science textbooks not only contain the facts, they illustrate them beautifully.

The science educator, however, has a choice. The science textbook can be put in its proper place: at the back of the room and in the library, and the remaining textbook money can be spent on *doing* science. "From the very first day in school, students should be actively engaged in learning to view the world scientifically. That means encouraging them to ask questions about nature and seek answers, count and measure things, make qualitative observations, organize collections and observations, discuss findings, etc." (Project 2061, 6) Or, in the words of Louis Agassiz, our nation's first great naturalist, "Study nature, not books" (Woodburn, 1965, 200).

One of my former students, a high school science teacher in a "Bible Belt" school, was assigned to teach an advanced biology course. He felt that a significant treatment of evolution had to be included in the course, yet knew that if he did he would be "raked over the coals" by parents and the local press. Dilemma? Yes! He started the class with a question, "How ought we teach evolution?" (Zimmerman, 1999, 2). Some of his students aspired to be lawyers; others, doctors; some, homemakers, etc. Groups were



**...the induction period should run on real, paid time, not on the backs of overburdened science supervisors and mentor teachers.**

arranged according to interest, and the students were charged with the responsibility to finding out how people in these respective areas of interest thought evolution should be taught and then to present this information to the class. The class troublemaker, who thought he might avoid doing any work, asked if he could research The Pope and his opinion on evolution. He proved to be the busiest student in the class, surprising everyone. The student researchers learned a lot about, and the teacher received praise instead of criticism.

The question of how ought we teach evolution is ill-structured; it is not well defined, and it has several correct answers (King, 1994, 11). Classes organized around ill-structured problems, like the example, are far more likely to engage students in learning than classes that proceed from chapter to chapter. We must step away from the “read a chapter, do the problems, and take a quiz” mentality if we expect students to become scientifically literate. Literacy comes from *doing* science, not reading about science, and science can be done everywhere, with or without expensive equipment.

Problem-based instruction is a promising innovation. It’s really not new; it is “classic 1896 laboratory school Dewey.” However, problem-based instruction is new to the moribund textbook/worksheet teacher,

who won’t believe it will work until successfully experiencing it. Creating situations in which tradition-bound textbook teachers are successfully implementing problem-based instruction is one of our greatest challenges. It calls for a paradigm switch, accepting a new definition of teacher. It calls for believing that teachers can only facilitate; they cannot give.

### **Selection of Curricular and Technological Innovations**

“Almost 2000 students offered their opinions. One of the findings: Many of our students are just plain bored. (Jacobson, 1986, 59). My students call it “raging apathy” and worry extensively about ever engaging students in serious studies of science. The apathy and boredom highlight the fact that we need to do some serious thinking about the curricular and technological innovations being placed before students; this was the third point made by Barnard (1967,6).

A technique that has piqued much interest is the practice of having students make content presentations to their peers. A small group of students is assigned a textbook chapter or some other area of study. They are assigned the task of becoming experts on a subject and given the responsibility for making hyper-card, power point, or web-site presentations. I have encouraged my preservice teachers to involve their students as teachers. I point out to them that they will learn more science during their first year of teaching than they learned in college, and that their students will also learn more if they are engaged in teaching. However, **there are situations in which younger students get so wrapped up in the technology and making of fancy presentations that science learning does not occur.**

Learning to use the technology, rather than the science content, becomes the priority; thus, the teacher’s objectives are subverted. It is important for the teacher to ask whether the teaching strategy selected is engaging the students in meaningful dialogue and scientific inquiries on the path toward the achievements desired.

The World Wide Web can also be a double-edged sword. One edge is the almost infinite quantity of correct and potentially useful information; the other edge is a blunt reminder that the web does not have any publishing standards, referees, or editorial boards. Discovering inappropriate and absolutely incorrect items on the web is an everyday occurrence.

Another web problem is created by the mentality that seems to suggest that everything should be put on the web. One of my first assignments as a college instructor was to serve as the grader for a science methods course offered through correspondence. I worked very hard trying to establish good interaction with the correspondents; however, the quality of the interaction never reached the height of my on-campus courses. Furthermore, because the correspondents were “out there by themselves,” they did not have the opportunity to interact with and



**...there are situations in which younger students get so wrapped up in the technology and making of fancy presentations that science learning does not occur.**

learn from each other. I am very proud of the science teachers graduating from Indiana University, and I regularly tell them that I hold the “bragging rights” for their achievements. However, I know that they learn more from each other than from me, and my greatest contribution to their success as teachers is establishing the opportunity for them to interact with and learn from each other. Such interaction and learning cannot be “canned and sent out over the wires.” Yes, the web should be used to deliver some courses. Participants in science methods should also use the web, to seek information and share it with others. The web can supplement and enhance the quality of science methods instruction. However, I think a web-based science methods course would be a poor substitute for a regular methods course featuring face-to-face interaction and shared hands on experiences.

Finally, as science educators, we teach three student populations: middle school, secondary school, and introductory college courses. These populations differ significantly; they have different needs, interests, and motivations. Yet we persist in serving them the same repetitious fare year after year: covering the same content, adding at each level a bit more factual information in the rhetoric of conclusions that has turned off learners since the beginning of time. Are we, as a profession just like the textbook companies: unwilling or afraid to change?

A former student in whom I have great confidence moved with her husband to a new state. Not being immedi-

ately successful in locating a teaching job, she applied for an editorship in a company that produces one of our best selling science textbooks. She reported having an excellent interview until she asked the wrong question: “What is being done to make sure that your book is consistent with the *National Science Education Standards?*” (National Research Council, 1995) The editor’s response, paraphrased, was that the so-called National Standards were written by a bunch of idealistic college professors who know nothing about teachers or textbooks. We, on the other hand, know about both teachers and textbooks and will continue to develop books that sell. That statement ended her interview.

### Summary

In 1967, J. Darrell Barnard presented three important problems that have been well solved in many educational settings. However, situations change and when they do, new solutions are needed for the problems. I have suggested a few solutions; I don’t expect everyone to agree with them. I might not like them tomorrow either. As an afterthought, the following resource should be required reading for every science educator:

Peddiwel, J. A. (1939). *The Saber-Tooth Curriculum*. McGraw-Hill.

### References

Collins, A. GPC Box 330. Vanderbilt University, Nashville, TN 37203.  
Council of Chief State School Officers (CCSO). One Massachusetts Ave, N.W. Washington, DC 200001-1431.

Fine, C. (1997). *Learning with technology*. 1997, North Central Regional Educational Laboratory.  
Griffiths, P. A. et al. (1997). *Adviser, teacher, role model, friend*. National Academy Press.  
Harbeck, M. B. Ed. (1967). *A sourcebook for science supervisors*. National Science Teachers Association.  
INTASC, One Massachusetts Ave, NW, Suite 700, Washington D.C. 200001-1431, 202/336-7048.  
Jacobson, W. J. & Doran, R. L. (1986, May). What do our ninth graders think of science and school? *The Science Teacher*.  
King, P. M. & Kitchener, K. S. (1994). *Developing reflective judgment*. Jossey-Bass.  
National Research Council, (1995). *National science education standards*. National Academy Press.  
National Council for the Accreditation of Teacher Education. (n.d.) Teacher preparation: A continuum. In *The new professional teacher project*. NCATE.  
Project 2061, (1993). *Benchmarks for science literacy*. Oxford University Press.  
Woodburn, J. H. & Obourn, E. S. (1965). *Teaching the pursuit of science*. Macmillan.  
Zimmerman, C. (1999). How ought we teach evolution: Problem-based learning strategy? Unpublished Manuscript.

---

Hans O. Andersen is Professor of Science Education, School of Education, Indiana University, Bloomington, IN 47405.