Challengi

Questioning common myths about science education

M**YTHS ARE PRESENT IN EVERY CULTURE,** and the culture of science education is no different. As in other cultures, our myths explain phenomena, use a common language, and are plausible. Unfortunately, some of our myths adversely influence classroom practice and limit our understanding of science education. Those that affect instruction and curriculum should be a concern to science educators. While there are many myths of which science educators should be wary, I have found five to be especially problematic.

MYTH 1: IT IS EASY TO CHANGE

A myth exists among educators that changing one's instructional pattern from a current instruction model to a reform-based practice can be easily accomplished. While science educators may recognize the need to modify their practices to benefit students, changes are not easily made.

Early educational studies on change are as pertinent today as they were more than 20 years ago. Research shows that teachers experience different levels of concern when using innovations. They begin with concern for themselves in the classroom, progress to concern about the task, and finally move to concern about the impact of the strategy on students. Prior knowledge of a strategy and the extent of strategy use in the classroom contribute to a teacher's progression through the various levels of concerns (Hall, Wallace, and Dossett, 1973).

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Researchers have recently found that science teachers who are committed to changing their instruction make some changes readily while other changes take more time (Luft and Pizzini, 1998; Martens, 1992). Some changes, such as using materials differently, observing students more frequently, questioning students more, or enacting different management strategies, can be readily accomplished. Other changes, such as asking more higher-order questions, placing greater emphasis on the student-centered nature of a class, or modifying beliefs and attitudes, are more difficult to implement. The variety of changes teachers make represents the highly personal process of change and the need to provide adequate time for the change process.

Science teachers who are excited and willing to use reform-based curriculum and instruction should give themselves ample time (at least three to five years) to reflect on and assess their progress. Additionally, science teachers should develop study groups or find peers to assist in their continual reflection on practice and progress. They should also inform administrators of current instructional or curricular changes and share their successes with peers, parents, and administrators. Creating an environment that allows for and supports change is as important as engaging in the change process.

MYTH 2: STUDENTS LEARN THROUGH LABS

This myth suggests that as students participate in laboratory investigations they will construct their own knowledge about emphasized concepts. Specifically, many teachers believe that when students manipulate materials, collect data, and answer conclusion questions, they learn the essential concepts inherent in the investigation. Unfortunately, most laboratory experiences are highly structured, confirmatory, and teacher-directed and they offer little opportunity for students to construct their own knowledge (Gabel, 1994).

In order for students to learn science concepts, they need to have experiences that reveal and build upon their current cognitive schemas. When a student experiences a difference between an expectation and an observation, disequilibrium occurs and the student's schema can be modified to represent the experience (Saunders, 1992). If disequilibrium does not occur, students may not fully understand the concept. Creating disequilibrium requires that students' prior concepts be revealed and challenged with evidence relevant to the concept. When students confront the evidence, they must make an explanation that expands or refines their current idea. Typical laboratory experiences do not account for students' prior knowledge, nor do they force students to confront their current scientific ideas.

Alternatives to traditional laboratories include a variety of inquiry practices. For example, learning cycles require students to explore and explain phenomena, use appropriate terms, and apply the learned concept (Lawson, 1995). Extended inquiries urge students to identify researchable questions, collect data that will help answer questions, and share their findings (Luft et al, 1997). Conceptual change instruction encourages students to challenge current beliefs about science by collecting and analyzing data (Stepans, 1994). Unlike traditional laboratories, these investigations are student-centered, encourage divergent thinking, and provide opportunities for students to construct their own understanding of concepts through events that challenge preconceived ideas.

MYTH 3: WELL-PLANNED ACTIVITIES REQUIRE MINIMAL TEACHER ASSISTANCE

This common myth assumes that students learn important concepts through inquiry-based investigations, activities, or laboratories. Well-planned activities skillfully guide students through steps that provide an understanding of a concept. Yet students' prior knowledge influences their understanding of any investigation. To facilitate an investigation, science teachers must interact with students to advance their conceptual knowledge.

Teachers play important parts in the construction of students' scientific knowledge (Driver et al, 1994). Teachers guide students in constructing the meaning of science and science concepts. The questions teachers ask, the contrasts and contradictions teachers provide, and the ongoing dialogue between teachers and students are critical to students' construction of scientific meaning. Being an effective teacher is more than planning activities—it is engaging in meaningful verbal interactions.

One way to facilitate a meaningful interaction is to not interact. Wait time (pauses of 3 to 5 seconds after a teacher or student comment) is important during verbal interactions. Teachers who use wait time demonstrate greater response flexibility, ask fewer but more appropriate questions, and develop higher expectations for students (Rowe, 1986). Students react to wait time by increasing the length of their answers and volunteering more unsolicited responses.

Another way to create meaningful interaction is to develop a questioning hierarchy. Science teachers create hierarchies for questioning in order to ensure a variety of questions are asked (Gilbert, 1992). A developed hierarchy results in students experiencing knowledge, comprehension, application, and synthesis questions during their investigations; these are a variety of questions not commonly asked of students.

MYTH 4: STUDENTS LEARN THROUGH CLASSROOM INVESTIGATIONS

This myth suggests that students understand the nature of science and develop good habits of mind as they observe phenomena, collect and analyze data, and draw conclusions. In reality, however, students often learn science knowledge without an understanding of the nature of science.

A study of 9- to 16-year-old students that explored the images students had of science showed many science curricula to be limited in providing students with an understanding of the major ideas about science. Specifically, students often did not fully understand the relationship of society to science, did not demonstrate views of science that involved the testing of models and theories, and did not coordinate explanation and theory building. Such knowledge is important for students as they become scientifically literate adults (Driver et al, 1997).

The *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996) state that students should learn more than science content. Ideally, they should also learn about the nature of science, the influence of society on science, and the change in science over time. To achieve this view of science, the history and philosophy of science should be incorporated into science classes (Matthews, 1994). Others have suggested developing a curriculum that unifies science, technology, and society (Yager, 1993). Ultimately, to help students achieve an in-depth knowledge of science, educators need to spend more time on a few topics and include specific instruction about the scientific endeavor.

MYTH 5: SCIENCE ASSESSMENTS SHOULD DETERMINE COMPETENCY

Throughout their science careers, students answer multiple-choice, fill-in-the-blank, and short-answer questions so teachers can assess their understanding of science.

These assessments are primarily summative and assist instructors in assigning grades. Unfortunately, these common assessments reveal limited information about the student and less about the learning context.

To combat the limited assessment experienced by most science students, teachers should create and use assessments that are summative, formative, educative, and evaluative (Hodson, 1992). A summative assessment reveals what students know about concepts. A formative assessment provides information to students about how they can become better learners. An educative assessment assists students in learning how to learn. An evaluative assessment furnishes teachers with knowledge about their science instruction.

To move our current assessment beyond a competency measure, teachers should use concept maps, vee diagrams, portfolios, and rubrics. Concept maps represent students' understandings of science topics, while vee maps are representations of the conceptual and methodological components of knowledge; both help students learn how to learn (Novak and Gowin, 1984). Portfolios are purposeful collections that allow students to represent their knowledge and growth (Arter and Spandel, 1992). Rubrics are constructs or matrices that define the expectations in a learning situation and provide specific feedback about a level of performance (Luft, 1997). These forms of assessment provide specific feedback to the student while informing both students and teachers about the learning process, curriculum, and instruction.

BEYOND THE MYTHS

The five myths explained above have the potential to limit instruction in science classrooms. As long as we perpetuate them (directly or indirectly), we will continue to confine ourselves to the margins of effective science teaching and our students to the margins of success in science. It is not enough to challenge these myths; we need to transform them so that future teachers will have an accurate portrayal of the teaching of science.

To begin transforming the myths in the culture of science teaching, we first need to acknowledge that they exist, then commit to their revision. Next, we need to provide ourselves with ample time for change and to surround ourselves with colleagues who are also in the process of challenging these myths. Finally, we must always remember that the only myth that does not change is the myth that goes unchallenged. ✧

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