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Teachers Make Exemplary Programs

Results from the Search for Excellence in Science Education show how exceptional teachers develop programs that result in enthusiastic, active learners.

Photographs by John J. Skrocki, Jr.

Students in John J. Skrocky Jr.'s first year physics class at Northwest High School, Omaha, experiment with the refraction of light in water by spearing a "fish" (actually a suspended washer in a fish tank). Until they learn the necessity for relational adjustment, the "spear" passes above the "fish," although their aim appears to be perfect as they look through the sighting tube.

Teachers do make a difference. While many of us have known that for years, the National Science Teachers Association Search for Excellence in Science Education has now provided more evidence than ever before about how teachers make the difference. And, more important, we now have extensive data about who these teachers are, their goals, their expectations, their strategies, and the results they obtain with students.

From the beginning of the Search for Excellence, we knew that programs being identified throughout the nation were vastly different from traditional science programs. These programs offered at every grade level a wide variety of content topics and approaches to the broad field of science. We found exemplary science programs in large schools and small, rich and poor, and with various ethnic and racial compositions. They have been well described in a variety of publications, including the 13 volumes of the *Focus on Excellence* series from the National Science Teachers Association.[1]

Not surprisingly, we have also found that teachers in these programs are unlike science teachers in general. From Iris Weiss' (1978) monumental study of characteristics of science teachers throughout the United States in 1977, we gained an exceptionally useful baseline of teacher demographic characteristics and the knowledge of just who the science teachers are.

With these data for comparison, we administered the Weiss questionnaire to 221 teachers who represented 50 exemplary programs as identified by the National Science Teachers Association (Bonnstetter et al. 1983). Various association members also spent 110 days visiting 6 sites in districts that were deemed especially exemplary because they were selected for programs in more than one search category. In addition, we met with another 100 teachers of exemplary programs at professional science teacher meetings in various locations and at National Science Foundation-sponsored honors workshops at the University of Iowa during the summers of 1984, 1985, and 1986. From both the concrete, specific data of the Weiss questionnaire and the more anecdotal data we gained from personal meetings with these teachers, we have compiled a profile and description of these teachers of exemplary programs.

In a tense contest that pits Campbell's Minestrone against Campbell's Consommé, physics students learn about the conservation of energy, translational kinetic energy, and relational kinetic energy. The consommé can reaches the bottom of the ramp first, but the minestrone rolls farther on the horizontal plane before stopping. "Surprised!" is the word Sterocky uses to describe his students' reactions—particularly those students who have placed friendly bets on the consommé.

To demonstrate Newton's Third Law (the conservation of momentum), Sterocky rolls a ball bearing down a ruler. The ruler and the boat it is attached to move in the opposite direction from the ball bearing.

A Profile of the Teachers

From the questionnaire, narrative data gathered from each program, and interviews with teachers, we found that teachers of exemplary programs:

- are older and have taught longer than teachers in general;
- stay in the same district for most of their careers;
- tend to have more hours and degrees beyond the B.S. than teachers in general;

- attend and make presentations at professional meetings and inservices;
- lecture far less than teachers in general;
- stress process-approach science;
- use professional journals in their teaching;
- feel more enthusiasm for science teaching now than when they started;
- gain inspiration from other teachers, their students, professional publications, professional meetings, and involvement in project development activities;
- are aware of national curricular materials;
- feel well qualified to teach science;
- put in far more than minimal time;
- are involved in extracurricular assignments; and
- have high expectations for themselves and their students.

But, while this profile may outline *who they are*, it does not adequately describe *what they do*. One critical component, these teachers tell us, is the relatively unusual set of goals they have for the science classroom.

Classroom Goals

While all teachers tell us they are concerned with students learning the traditional aspects of science, they see this learning as taking place under four broad and general goals. Interestingly enough, these goals match the desired state goals outlined by Project Synthesis (Harms and Yager 1981).

1. *Students will see science as it relates to a variety of careers, not just the traditional careers of science, medicine, and engineering.*

Rather than teaching a one-week unit on science careers, we find teachers introducing careers at various times and in assorted ways. Some teachers use commercially developed materials such as *Comets*, others use current events to introduce careers in their classrooms, and many invite community resource persons to visit. These visitors, representing a variety of science and science-related careers, interact with students in debates, forums, and the more traditional lectures. Students often go into the community, surveying citizens about science-related social issues. In the process they learn much about peoples' ideas on science and social issues and identify still other ways that individuals use science in their everyday lives.

2. *Students will apply their knowledge of science.*

Most teachers recognize that using knowledge requires greater understanding than mere memorizing and repeating. Applying knowledge requires, in addition, the ability to manipulate ideas in new contexts. In applying knowledge, teachers in exemplary programs have students use their knowledge of science to offer resolutions for problems, both physical and societal, which are often identified by students themselves. In identifying and resolving the problems, students must collect data, make decisions, test ideas, and communicate results. A key feature is the learning that knowledge itself is only the beginning; applying that knowledge is the next step for citizens in an educated society.

In Wallingford, Connecticut, students saved their community more than $550,000 by applying their knowledge of energy gain and loss to area school buildings. Even more money was saved as they analyzed 18 public buildings in Wallingford. These students are learning that science can be applied to resolve issues and problems that directly affect them and their community.

Photograph by Sam Chattin

Guided by teacher Sam Chattin, Scottsburg, Indiana, students worked with a Burmese python given to the school by a pet store owner. The owner found that the animal was so aggressive that he couldn't sell it, but under students' care it became extremely gentle in about three weeks. Students gave the snake an appropriate name: Julius Squeezer.

3. *Students will take action.*

These teachers stress that while knowledge itself is a useful goal, a truly concerned citizen must be prepared to take action. Over and over again we have heard from teachers that they are not content for students merely to collect data and write reports; they want students to present these reports in appropriate ways. We have found numerous instances of students giving testimony and presenting information and ideas at school board and city council meetings, writing letters to editors, and writing articles for general publication.

Students in Eva Kirkpatrick's physical science class in Imperial, Missouri, collected information on a proposed landfill in their community. Armed with information and ideas, these students became convinced that a landfill did not belong in their community. Their action? They took their own city council to court. Not only did students have to use their knowledge for proof, they had to use community resources such as people, libraries, and businesses. In the process they found their knowledge stressed to the very limit. They had to learn more, and they had to expend far more than the usual effort. In addition to learning a great deal, they won their suit. These students now have direct and personal knowledge that few adults can claim—you *can* fight city hall and win!

Students participating in a program entitled Energy and Us in Casper, Wyoming, testified before the city council and even in front of the hearings of a Senate subcommittee.

4. *All students will be science literate.*

For teachers this means having students understand the tentative nature of science, the man-made aspects of all scientific knowledge, and the role of science in society. Students gain science literacy by being encouraged to question facts, teachers, and authority while developing alternative ideas and solutions rather than by passively accepting existing ideas. Teachers in exemplary programs see a need for students and adults who recognize the utility of science now and in the future; who see science not as a cause and not necessarily as a solution to all problems, but as a way of investigating, proposing, and testing solutions and ideas. As the National Academy of Science Convocation report (1983) stated so well, science literacy should be a key goal for science education at all levels.

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In school after school, we find truly incredible numbers of students enrolling in elective science courses. At the Porter-Gaud School in South Carolina, students at every grade level overwhelmingly rate science as their favorite subject. In addition to its regular physics courses, Omaha Northwest High School in Nebraska now has 13 physics sections for students who are not the usual high achievers. Many other schools report that over half of their students complete physics before graduation. These students should continue to value science in the future.

Expectations

As might be expected, teachers in exemplary programs have exemplary expectations. They do not wait for something to happen; they know they have the power and the necessity to bring it about. These expectations, for both themselves and their students, are the single most important reason these programs exist, have grown, and continue to evolve. These are not teachers with an interest in the status quo—they approach teaching as they would science. In doing so, they analyze, suggest new alternatives, and test and evaluate, constantly looking for the most effective strategies, materials, and ideas. Following are some of their expectations.

1. *They want the best curriculum for their students.*

So does everyone. But these teachers realize that the best curriculum for their particular situation might not be readily available on the shelf of their bookstore. They know that to have the best they must analyze their needs, their students, and themselves. They know that only the best raw materials will work. In this case, the best raw materials may include community resource persons; commercially available materials; the ideas and inspiration of science supervisors, administrators, students, and other teachers; and the influence of professional science teacher associations. These teachers know that excellence is not accidental; it is something they must strive for, gain, and nurture with great effort and diligence.

2. *Students can succeed at science.*

With science literacy as a significant goal, these teacher-developers know that they must develop programs for *all* students, not just the elite few who are traditionally served. And, at the same time, they want to enhance the success of those same elite science-oriented students who are often said to learn in spite of us. Providing such success becomes a function of the interaction of curriculum, teacher, and students, requiring considerable knowledge and expertise on the part of the teacher.

We found teachers seriously studying cognitive psychology, topics in science, and other outstanding school science programs. As a result, we noted a variety of new and innovative programs coming into being. For example, while Henry Gunn High School in Palo Alto, California, has the most successful advanced physics course in the nation as measured by success on advanced placement exams, it also has two lower-level physics courses, one of which is almost nonquantitative and designed for students who would not normally take physics. At Omaha Northwest High School, those relatively average students filling 13 sections of physics

learn concepts of physics to which they would normally not be exposed. In Fort Lauderdale, Florida, we found primary-level students pursuing inquiry, studying how learning takes place, and teaching a chicken some small skills. Teachers in these schools know that students have great capacity if presented with the right learning environment.

3. *Students will question facts, teachers, and knowledge.*

An inherent part of science is questioning—not just the questioning that seeks ordinary answers, but questioning that includes healthy skepticism, a seeking of evidence to justify explanations. While most students are encouraged to question facts, few persevere to the extent of questioning teachers, patterns of learning, and societal implications. The Contemporary Issues in Science program in New York actually provides a forum with community leaders designed just for this purpose. Other programs, such as Energy and Us in Casper, Wyoming, encourage students to formulate questions and seek answers in the community itself. In the process, students come face-to-face with adult ideas, motivations, and logic. Often students are surprised by this logic, or the perceived lack of it.

4. *Students need stimulating environments for learning.*

Teachers go out of their way to create challenging environments. In Scottsburg, Indiana, students can look up to see snakes climbing around tree branches suspended from the ceiling. At Clarkstown South High School in West Nyack, New York, students are stimulated by an ongoing debate between their two teachers, an anthropologist and a biologist, over which is the superior discipline for explaining the nature of man and society.

At Wausau West High School in Wisconsin, general science students attend a large-group lecture once a week at which science faculty members dress in stereotypical costumes representing environmentalists, lawyers, construction workers, and others. As the lecture unfolds, these teacher-actors play a definite, though stereotypical, role that leads to the presentation of a variety of viewpoints. Here, teachers recognize that a stimulating environment captures students' imagination, producing a willingness and an eagerness to learn.

5. *Students must make decisions and take action.*

While learning science might be an adequate goal to an ordinary teacher, teachers of exemplary programs insist that the ultimate goal for an informed citizen is decision making and action. Yet, in most classrooms students make few decisions beyond the trivial, and little room exists for meaningful action. If a classroom is truly to be the training ground for adult society and citizenship, however, students must learn the skills necessary to function in society and produce changes beneficial to all. In Imperial, Missouri, students made critical decisions and took serious action in suing their city council over the location of the proposed landfill, while at Scottsburg Junior High School, students make difficult decisions about how to best preserve the lives of injured wild animals. At the Houston School for the Health Sciences in Texas, students work closely with health professionals and witness life-and-death decisions on a daily basis. Even in that primary school in Fort Lauderdale, students decide what to teach their chicken as well as how to do it. But they don't stop with just formulating the "how to," *they actually do it,* testing the results and gathering evidence to prove in fact that it has happened.

At Toledo High School in Quilscene, Oregon, students designed a solar home that the trades class proceeded to build. The home economics class designed and installed appropriate interior decorations for the energy-efficient scenario. The end result here is quite real; they knew they would have to sell the house when they were finished. These are not trivial decisions, but decisions that each and every student must live with.

6. *Teachers will be very professional.*

While only about 10 percent of all science teachers belong to a professional science teachers' association, an amazing 46 percent of exemplary teachers have actually made presentations at meetings of such associations. And, although these teachers are at the top of their salary scale, they continue taking courses for college credit. Professional activism and interest in continued learning combined with significant reading of professional journals give these teachers a sound knowledge base and successful models for inspiring, developing, and evolving exemplary programs. These teachers view themselves as learners, not merely transmitters of knowledge.

7. *Teachers must develop their own programs.*

Over and over again, from large schools to small, from single teachers to entire school districts, the action is the same. Beginning with a commercial text, programs evolve purposely until they virtually become a locally developed and oriented curriculum. In the process, the text becomes less and less central and more and more supplemental to the curriculum as a whole. While this takes considerable time (often years), teachers and developers seem to work steadfastly toward a vision of excellence that they know they can produce.

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Instructional Strategies

Exemplary teachers do more than just set goals and expectations; they have carefully analyzed where they want to be and where they are, developing means of moving their students and

programs to new levels of achievement. Their instructional strategies are consistent, comprehensive, and effective. And, interestingly enough, these strategies have a number of common elements across all of the exemplary programs we have visited. These strategies include:

1. *Science materials play a key role.*

Hands-on science is a daily occurrence in these exemplary programs. While they don't always have true laboratory activities for the entire class period, almost without exception these teachers at every grade level have some type of hands-on activity each day. They tell us that students are far more interested in the laboratory aspects of their courses, and they use this motivation to propel students into reading, discussing, writing, and looking seriously at issues. By doing so, students have more concrete experiences to which they can relate and plenty of opportunities to test their own creativity and ideas while interacting with fellow students. And "hands-on" does not mean just test tubes; it also means designing surveys for use in the community, manipulating ideas as well as objects, and being deeply involved in their own personal studies.

2. *Teachers encourage applications of student knowledge.*

Almost without exception, teachers in these exemplary programs tell us they are not content for students to merely know; they want students to use their knowledge actively to resolve problems they have identified. At Scott High School in Madison, West Virginia, students drew on their knowledge of environmental awareness in biology to create a series of nature trails near the school. Now, these trails are used by students of different age levels from a variety of schools. At Toledo High School in Oregon, remember, students not only designed an energy-efficient house, they built it!

Potential for application of science concepts is endless when teachers look beyond the science classroom itself into the community and the world of ideas beyond.

3. *Flexibility counts above all.*

Teachers consistently speak of the need to remain flexible, taking advantage of incidents, phenomena, and issues when they arise. In the human ecology program at Brandywine High School in Delaware, students work in local human service agencies, finding out about the community directly. To take advantage of this, teachers must be prepared for whatever might happen in the agency in a given week. While teachers have a written curriculum, they use it more as a framework than a guide. In the Topics in Applied Science course in Jefferson County, Colorado, for example, students analyze the water supply of the Denver area at a discreet time during the program. When water becomes a topic of public interest during other parts of the program, students return to past studies, relearning certain aspects about water distribution and remembering prior discussions.

Students who have flexible teachers become flexible themselves and soon recognize that being a scientist requires the ability to take advantage of the moment without losing sight of the past or the future.

4. *Questions are motivators, not examinations.*

Students who are motivated by their own interest and by their success at learning are far more likely to contribute both as students and as adults and to continue learning science. Questions are not only pursued by the teacher but by the students, and questions and answers become the domain of both. At Henry Gunn High School in Palo Alto, Art Farmer gives no written exams in his qualitative physics class. Students are questioned orally until they answer enough questions correctly for him to give them a positive grade. His students regard oral evaluations as fun, and he complains of having to chase students from the classroom.

Sometimes questions can be used when discussing current events, as at South Rowan High School in China Grove, North Carolina, where Dorothy Helms thinks nothing of dropping the present topic in chemistry to study whatever news event seems to have a strong relationship to chemistry. As students identify questions they find exciting, she helps them find answers by bringing in outside resource persons and ideas and, most important, by giving them opportunities to pursue answers on their own. At Merritt Island High School in Bevard County, Florida, students in the science research program are often given keys to the school because they refuse to go home at night. What more can we ask for than to have to chase our students out of the classroom because they wish to continue questioning and learning science?

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5. *Students do the work.*

As Harry Wong has so aptly put it, "Why not let the workers do the work?" These teachers are doing exactly that. When you enter their classrooms, you find teachers acting in a supervisory, management, resource-person role while students are busily doing the work of learning. At the Kampsville Archeological Center in Illinois; in classrooms in Sunburst, Montana; or in the Rochester, New York, Community School District, we find teachers who have figured out how to get students to do the work. When students do the work, they also do the learning. And these teachers' strategy is relatively simple. They have ways to make the work palatable, relevant, and suited to the needs, interests, and perspectives of students. Teachers are now committed less to teaching as we have always known it and more to creating an environment where learning can take place. Such a learning environment requires a high level of trust, rich resources, time for thinking

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as well as action, and an independence of thought on the part of students. When these elements are in place, according to teachers in these exemplary programs, you can't stop the students from working and learning.

6. *Teachers are models of active inquiry.*

If we want students to pursue ideas actively, question knowledge, and propose new solutions, teachers must do the same. That is exactly what we find in these innovative programs. The teachers continue to question, to learn, and to develop their own ideas as well as themselves. And they don't hide it from their students. When Wayne Browning and Albert Orlando of Clarkstown South High School in West Nyack, New York, spend their lunch periods arguing about the innate superiority of biology or anthropology, students realize this is an honest intellectual debate.

When teachers at Wausau West High School play their stereotypical roles for the large-group general science class, students once again get to see teachers debating issues, questioning, and indicating some fixed patterns of thinking. But, at the same time, others are questioning that. When Dave Tucker teaches about alcoholism in his chemistry class in Deming, Washington, he doesn't purport to know everything about it. He, like his students, must research and investigate to find the answers. As Elizabeth Horsch and Roxie Deever let students choose a topic to study in their Energy and Us program in Casper, Wyoming, they don't steer students only in a direction in which they are already knowledgeable. They are quite confident that no matter what area students choose, they are just as competent as their students at studying, learning, and developing new knowledge about the area. And, not surprisingly, students respond quite well to this.

Results

With these unusual goals, high expectations, and clearly defined strategies, it is not unexpected that these exemplary teachers obtain rather phenomenal results. Westinghouse Science Talent Search winners abound, International Science and Engineering Fair finalists number in the dozens, scholarship recipients are numerous, and science fair projects are most rigorous and unusual. But the true result of these programs is not easily measured by such classical academic performance, for although many of these students will go to college, only a few will become scientists or even major in a science area.

The most important result is developing a population of citizens who are scientifically literate—citizens who understand the tentative nature of science, the man-made nature of science, and science as a way of looking at life and problems. These are students who are quite comfortable applying science to problems around them and have no difficulty meshing science with society in a positive and useful way. At the same time, they are in a position to appreciate more theoretical aspects of science and possibilities that might never be reality.

These science-literate students are exactly the types of citizens we need if we are to maintain a free and rational society capable of using intelligence, accumulated knowledge, and community resources to focus on and resolve issues and societal problems.

Equally important as a result is a cadre of teachers who look forward to Monday morning, who want to be with their students, and who realize the true nature of teaching and learning. These teachers are the antithesis of burnout and perfect examples of excitement, enthusiasm, and professionalism. Although 25 percent of all science teachers polled by the National Science Teachers Association said they would leave teaching if they could do anything else, more than 80 percent of the teachers in these exemplary programs indicated that their level of enthusiasm for teaching is higher now than it was when they began teaching an average of 16 years ago.

These are the kinds of teachers we need now and in the future if our schools are to remain successful and become all they can be for our students and for our citizens.□

1. The 13 volumes of the *Focus on Excellence* series are entitled *Earth Science; Elementary Science; Inquiry; Physics; Biology; Chemistry; Science in Middle/Junior High; Physical Science; Science/Technology/Society; Energy Education; Centers of Excellence: Portrayals of Six Districts; Exemplary Programs in Physics, Chemistry, Biology, and Earth Science;* and *Science in Non-School Settings.* They are available from the National Science Teachers Association, 1742 Connecticut Ave., N.W., Washington, DC 20009.

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