Scientists in Science Education

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Introduction

As schools prepare today's students to live in the highly globalized and competitive 21st century, the need for *every* student to receive a good science education has never been more pressing. All students, not just those destined for a scientific, technical, or health-related career, can benefit from the skills that science education can provide—such as critical thinking, data analysis, working in teams, and oral and written communication. The need for scientists to share their unique skills and understanding with their own local school or school system has also never been more pressing.

Schools today are under enormous pressures and constraints that were not present as few as 10 years ago. To maximize your effectiveness as a scientist playing a role in education, it is important to learn something about the forces at play in American education today. This report is intended to help you make the most of the time you have decided to dedicate to improving science education, whether that is a single hour spent conducting a lab demonstration or a hundred hours spent reviewing your state's science education standards.

Many scientists find it rewarding to share their passion for science with their community. Their interest in science education often originated in a memorable personal experience. While each person has a novel story about what prompted them to get involved, scenarios like these seem to be common:

- Worrying about the education that your son or daughter is receiving in science class.
- Being approached to talk to a local classroom about science or "being a scientist."
- Being invited to run a workshop about science for teachers.
- Being asked to serve in the position of "scientist" on the school district's education reform or textbook selection committee.
- Choosing to volunteer at a local science museum.

Very few scientists get involved in all of these areas. One of the objectives of this document is to increase involvement by helping you decide how and where to get started. It is also important for you to understand something about the rationale for improving science education, what kind of science education is needed, and some of the pressures on school systems today. This document will provide information on each of these topics as well.

Why Improve Science Education?

It is important to understand why improving science education is necessary. Most scientists would argue that science is an important tool for understanding the way the world works, for comprehending some of the critical issues of the day, and even for improving citizenship. For many parents, however, the most compelling rationale might be to develop the skills their sons and daughters will need to prosper in a 21st-century workforce.

How can this be? We certainly do not mean to imply that everyone in the 21st century will be working as a scientist or engineer. Far from it! Depending on how strictly we define science, only 3 to 8 percent of our workforce is employed as scientists or other similar technical professionals. When we look at the skills valued by employers, however, it becomes apparent that scientists have a lot to offer in preparing students to meet these proficiencies. We will briefly discuss some of the skills valued by today's employers and examine how well students in the United States are learning these skills.

Schools need to prepare students for the 21st-century workforce. In the 1970s, students could attain a middle-class lifestyle with only a high school diploma. Over the past 30 years, however, the skills needed to obtain a job and make a middle-class salary have changed dramatically. During this time, the advent of advanced technology, especially in manufacturing industries that had formerly paid high wages, along with the increasing international trade competition for low-skill jobs have made things much more difficult for students with only a high school diploma. It is becoming clear that even people with a college degree, or more, may not be immune from the forces of globalization.

These difficulties are compounded by the fact that the skill set taught in schools has remained the same over this time period. The education that was effective in the 1970s has stayed the same while the workplace has changed dramatically. In the early years of the 21st century, there is a substantial gap between the skills of graduating high school seniors and the skills valued by employers.

In *Teaching the New Basic Skills*, Richard Murnane and Frank Levy (1996) describe a new set of skills important to employers and work practices in firms paying middle-class wages. The New Basic Skills are those abilities needed to obtain at least a middle-class position. They include:

Hard skills

- The ability to read at the ninth-grade level or better
- The ability to do math at the ninth-grade level or better
- The ability to solve semi-structured problems where hypotheses must be formed and tested

Soft skills

- The ability to work in groups with people of various backgrounds
- The ability to communicate effectively, both orally and in writing, at the ninth-grade level or better

Other skills

- The ability to use personal computers to carry out simple tasks like word processing

In today's advanced technological world, many employers are willing to teach knowledge specific to their industry, as long as potential employees are proficient at the New Basic Skills. In addition, these skills are needed by all students, regardless of whether they attend college or enter the workforce directly after high school. Murnane and Levy describe why specific jobs, such as working on an auto assembly line or for an insurance company, require skills that were not needed 30 years ago and are not possessed by most applicants today.

Recent assessments of grade 12 students in the United States show that they are lacking in preparation for these basic skills. According to findings from the 2005 National Assessment of Educational Progress (NAEP), the number of students performing at a basic level in reading dropped by 7 percent between 1992 and 2005. In addition, just over half of students performed at a basic level in mathematics. The Organization for Economic Cooperation and Development's (OECD) Programme for International Student Assessment (PISA) found that, in 2003, 58 percent of students surveyed in the United States scored only as basic problem solvers or below. Further-more, the United States ranked 29th out of 40 countries surveyed in this study. To read more about how these assessments were conducted, how students in the United States scored, and how they compare with students in other countries, see Appendix I.

Science Education in Today's Schools

To make your experience in science education a positive one, it is important to understand a few issues in today's educational system. This is not meant to be an exhaustive explanation of schools, but rather, to briefly familiarize you with terminology you may encounter.

Teaching Science as Inquiry

Inquiry may not be a term you have heard before in relation to science education, but you surely know what it is! On the most basic level, inquiry refers to the process of doing science. Inquiry-based learning engages students in the investigative nature of science. Using inquiry to teach science helps students put materials into a meaningful context, fosters critical thinking (Narode et al., 1987), engages students so they develop positive attitudes toward science (Kyle et al., 1985; Rakow, 1986), and improves their communication skills (Rodriguez and Bethel, 1983). Inquiry shifts the focus of education to cognitive abilities such as reasoning with data, constructing an argument, and making a logically coherent explanation.

Using inquiry to teach science can, we believe, serve to develop a number of the New Basic Skills and help students prepare for the world of work. Inquiry-based science can give students practice reading and understanding the rich scenarios and activities that typify this mode of teaching. Inquiry-based science activities frequently ask students to create and test hypotheses; use math, graphs, and other approaches to analyze data; work as part of a problem-solving team; and communicate findings and conclusions orally or in writing.

To be certain, science class is not the only place that students can learn these skills. If students are exposed to a set of rich, inquiry-oriented science lessons over the years, though, they will have a great deal of practice developing the skills and abilities that are highly prized in the 21st-century workplace, whether or not they plan to attend college. Unfortunately, inquiry-based teaching is not the norm in most classrooms. To read more about the features of inquiry-based learning, see Appendix II.

Why should scientists be involved in inquiry-based science education? The simple answer to this question is, Who better to teach students about how to think like a scientist than the people who do just that every day? The parallels between the way scientists learn new information through research and the way students learn through inquiry-based teaching are striking (Figure 1).

It should be clear from this comparison that the fundamental process of science has direct links to inquiry-based science teaching. Scientists' knowledge of the scientific process makes them invaluable in facilitating student education. As you contemplate the role you would like to play in science education, consider the information on practicing science versus teaching science and consider how you might incorporate this knowledge into what you do.

No Child Left Behind

A piece of national legislation that has had a dramatic impact on education in the past few years is the No Child Left Behind Act (NCLB), passed in 2001. The purpose of this legislation was to ensure that all children in the United States receive a high-quality education. The act has led to higher standards and accountability in school systems across the nation. NCLB has placed the responsibility for children's learning in the hands of the teachers and schools by holding school districts accountable. Parents receive information on the schools in their district about which ones are succeeding and why. Because students and schools are evaluated each year for progress in particular areas, teachers must be aware of the state education goals at all times.

Under NCLB, a school must make Adequate Yearly Progress (AYP), which is based on student performance, with at least 95 percent of students participating in the NCLB student assessments, and continued progress over time. If a school does not make AYP, it is subject to mandated school improvements, corrective actions, or restructuring. This puts a great deal of pressure on teachers and schools. For this reason, it is important that you ensure that the role you play and the information you provide in science education fits with the goals of the teacher, the school, and the school district. To read more about NCLB, see Appendix III.

Figure 1. Practicing science versus teaching science.

Scientific research approach	Inquiry-based teaching approach
Raise fundamental question of interest that is addressable via scientific investigation.	Engage student interest; guide the development of questions (i.e., establish basis for **inquiry**) in a specific area of content.
Research what is already known.	Discuss with students what they already “know” or think they know (**prior knowledge assessment**) to help address the question(s).
Make a prediction or hypothesis in answer to the question of interest.	Ask students to make a prediction or hypothesis in answer to the question of interest.
Plan and implement an experiment to test the prediction.	Plan and implement an experiment to test the prediction (**hands-on activity**).
Reflect on the results of the experiment and how they affect what was known before. Be alert for how the new data do or do not readily fit into the existing structure of scientific understanding.	Reflect with students on the results of their hands-on activity or investigation and use their predictions to assist them with gaining new and deeper understanding of content. Be alert for any shifts from “prior knowledge” as students integrate their new experiences.
Communicate new knowledge via talks and papers. Science community judges the validity and value of the results. New questions are raised.	Communicate new knowledge via presentations, papers, demonstrations, exams (**means of student assessment**). Teachers judge students’ learning and guide them to apply it to new circumstances.

Courtesy, Association of Universities for Research in Astronomy, Inc., and the Space Science Institute.

Standards and Assessment

Another concern for teachers is the content taught to students. To help guide the curriculum, a voluntary set of *National Science Education Standards* was released in 1996 by the National Academy of Sciences. Many school systems have referred extensively to these national standards, while others use state or district standards. Standards help improve science education by providing guidance on content and assessment in a particular area.

Before making a decision about what your role in science education is, determine which set of standards is used by teachers in your area. In most places, the standards are available online. Read through them, determine how your ideas fit into the curriculum presented there, and discuss your ideas with your collaborators in education. In today’s environment of accountability, teachers are reluctant to spend time on information that does not relate to their state standards. See Appendix III for more information about standards in today’s schools.

Thinking about Your Role

By now you likely have some understanding of why science education should be improved, how inquiry-based learning is an important part of that reform, and why scientists must be involved in this effort. To look more specifically at the role you can play within science education, consider the following questions.

- Do you want to do presentations to students or teachers, or work behind the scenes?
- Are you comfortable speaking in front of an audience?

- Do you have already-established relationships that you could use as a point of entry into the educational system?
- Would you prefer a long- or short-term commitment?
- Would you prefer to work as an individual or as part of a team?
- Are you interested in learning more about educational issues?
- With whom do you want to interact—students, teachers, administrators, policy makers?

These questions, Figures 2 and 3, and the descriptions in Box 1 will help you determine avenues for involvement in science education. As you investigate different options, please take some time to look into local science education efforts that may already exist in your community or at your university. These efforts might include programs funded by the National Institutes of Health, the National Science Foundation, or Howard Hughes Medical Institute. Joining a program that is already under way is often an efficient approach.

You can become involved in many ways. You might consider your interests, time, and talents. Traditionally, most scientists think about visiting schools, doing demonstrations, and serving as role models. We certainly encourage this. We hope you will consider other ways that your expertise can contribute to science education, too. Figure 3 presents a variety of opportunities that vary in time and level of involvement. The roles are grouped under advocating, serving as a resource, and becoming a full partner.

Figure 2. Characteristics of different roles in science education.

Role	In the classroom	Professional development (training)	Informal education	Parents and school boards	Developing instructional materials
Make live presentations	✓	✓	✓	✓	
Speak in front of an audience	✓	✓	✓	✓	
Tap into relationships	✓	✓	✓	✓	✓
Make a short-term commitment	✓	✓			
Work as an individual	✓	✓	✓		
Learn about educational issues		✓		✓	✓
Interact with students	✓				
Interact with teachers		✓			
Interact with administrators				✓	✓
Interact with policy makers				✓	

Figure 3. A sampling of roles for scientists in education.

Level of involvement	Advocate	Resource	Partner
K-12 students	• Participate in PTA. • Talk to school board about the importance of science education.	• Judge a science fair. • Answer student e-mail. • Give a tour of a research facility.	• Mentor a student in your laboratory. • Partner with students in a research project.
K-12 teachers	• Speak out in support of appropriate professional development, or training, opportunities for teachers.	• Answer teacher e-mail about science content questions. • Present in teacher workshop on some aspect of science.	• Work with a teacher to implement curriculum. • Hire a teacher intern.
Schools of education (pre-service teachers, graduate students, faculty members)	• Speak out in your department or organization in favor of closer ties with colleges of education. • Speak favorably of teachers and the teaching profession in your undergraduate classes.	• Teach a science course or workshop segment for pre-service teachers. • Collaborate with education faculty to improve courses on teaching science.	• Hire a graduate in education to work as evaluator or co-developer of education project. • Develop a science course or curriculum for teachers-to-be.
Systemic change (change throughout a district, a state, or the country)	• Speak out at professional meetings about the importance and value of scientist involvement in systemic change. • Speak out in your district for better science education.	• Review science standards for science accuracy. • Review the state framework for science education.	• Collaborate on writing or adapting science standards. • Participate on state boards for adoption of standards, instructional materials, or teacher certification.
Educational materials development (BSCS, NSRC, EDC, Lawrence Hall of Science)	• Speak out at a school board meeting for adopting exemplary science-rich educational materials.	• Agree to serve on an advisory board for a science education project. • Review science educational materials for science accuracy.	• Collaborate on creating exemplary science education materials.
Informal education (Science centers, scouts, planetaria)	• Speak out in your community on behalf of the importance of informal science education at science centers, museums, planetariums, etc.	• Review science content of scripts for science exhibits, planetarium shows, or environmental programs. • Give a talk at a science center.	• Collaborate on creating a museum exhibit or planetarium show. • Serve as science coordinator for a scout troop. • Participate on the board of a science center, planetarium, environmental center, or museum.

Source: Improving Science Education: The Role of Scientists, by Rodger W. Bybee and Cherilynn A. Morrow. Printed in the Fall 1998 *Newsletter of the American Physical Society Forum on Education*. The complete article is available at http://units.aps.org/units/fed/newsletters/fall98.pdf. Reprinted with permission from the American Physical Society Forum on Education.

Box 1. Some roles for scientists in science education today

Visit a Science Classroom

Traditionally, demonstrations and presentations have comprised the work of scientists in the science classroom. These can be valuable means of interacting with students, but when planning your visit, remember to keep the essential factors of inquiry in mind. Try to include hands-on activities and encourage students to discuss *how* or *why* something occurred. Take things a step further by encouraging students to answer questions that start with, What if? and, How would you explain?

For example, think of the classic liquid nitrogen demonstration. A scientist might arrive at a classroom with a Dewar flask of liquid nitrogen and a number of objects, such as a banana, a flower, an apple, and a tennis ball. The scientist can awe students as she freezes each object in the nitrogen and then smashes it on the floor. Although this demonstration might generate some temporary positive excitement and attitudes toward science, it doesn't contribute much to substantial, long-term science education.

How could this demonstration be reworked to include scientific inquiry? Our scientist might now start the demonstration by freezing the banana and shattering it on the floor. She might ask students what they saw and why the banana shattered. She might then freeze a paper towel and try to shatter it on the floor. In this case, not much happens. She might ask students what results they observed and how they would explain the difference. The students might be allowed to "experiment" further by choosing the next few objects to freeze and observe, based on their hypothesis. From their observations of these additional objects, students may find their hypothesis to be incorrect or to be supported.

Objects like bananas shatter well in this experiment due to a high water content. The water in the banana freezes into ice crystals that are not attached to one another very well because they begin forming at many different places. In addition, cell membranes and walls freeze, making them weak. When thrown on the floor or hit with a hammer, the crystals separate easily. Think of breaking apart ice cubes that have become stuck together. Because a paper towel has a low water content, it is relatively unaffected by being frozen and dropped on the floor. Depending on the age of the students, they may not be able to discern this particular characteristic, but they should be able to define the characteristics that make an object likely to shatter.

This scenario demonstrates another important point about visiting a classroom. It is not necessary that you talk about your area of research! Presumably, the scientist in this scenario is not researching which objects shatter after being frozen in liquid nitrogen, but she recognized that she could use an inquiry-based version of this demonstration effectively in the classroom. She was able to bring her experience to students by modeling the scientific process, connecting science to a real-world event, and sharing a general passion for science. She might have augmented the science background of the teacher and students and helped end the stereotype of scientists as "nerds." There might have been a discussion about the nature of good questions that help reach the goal of answering a particular question. These important contributions help students learn critical, stepwise thinking and introduce the world of a scientist. This type of introduction to the scientific world is more valuable in science education than a detailed, content-based presentation about one's research, not to mention more fun and flexible for you.

Classroom involvement can be short- or long-term. You may choose to spend just one afternoon in the classroom. On the other hand, you may be able to visit several times while students study a particular topic, or periodically over the course of the year. The more closely you are able to work with the teacher to understand her goals, objectives, and problems, the better you will be able to help design activities that will help achieve them.

Advice

As a guest in the science classroom, your collaboration with the teacher is very important. Start by meeting with the teacher before you plan what you want to do. You might ask questions such as, What are the topics that seem to be difficult for students? or, What are the big ideas you might like a scientist to cover in the classroom? Teachers often have particular lesson plans for particular topics, so it is best to narrow down the subject of your visit in cooperation with the teacher.

As part of meeting with the teacher, discuss the standards your visit will meet, as well as ways to assess your impact. Have the goals of your visit in mind when you plan, as well as how you will determine what students learned. You might also spend some time discussing the general scientific literacy of the students, age-appropriate content and vocabulary, and the diversity of students. You can also use this time to determine what, if any, technology will be available to you during your visit. If possible, spend some time observing the class. The more information you have before your visit to the classroom, the more effective you will be and the more smoothly things will run during your presentation.

Many professional societies provide educational resources that might be useful in planning your visit. These range from activities and lesson plans to collections of resources. Appendix IV is a list of links to the educational resource pages of a dozen professional societies.

6 Six things to think about

- To get started, contact the school principal or, perhaps, a teacher you know, identify yourself and explain that you would like to get involved, and then ask who you might speak to.
- Ask the science teacher about ways you can contribute to his or her goals.
- Listen for concerns or problems the science teacher is trying to solve.
- Learn about the science curriculum and the students’ understanding of science.
- Be clear about the students’ level of understanding and what you want them to learn.
- Make sure your presentation has a clear beginning, middle, and conclusion.

Provide Professional Development, or Training, for Teachers

You may have a desire to be involved in science education but choose not to work in classrooms with students. There are many other opportunities to help with inquiry-based education. One of the challenges for classroom teachers is staying current on the latest advances in science or in topics that may fall outside the teacher’s expertise.

One way you might choose to be involved is through providing classroom support. You could serve as a resource for a teacher or school simply by answering e-mails or phone calls about particular topics. In this role, you might also be able to offer suggestions about hands-on activities or real-world situations that would enhance particular topics.

Workshops are a great way to allow teachers to learn more about science topics. You might serve as a teacher or facilitator for this type of workshop. Some workshops take one day and help teachers or schools with a specific activity. Other workshops may cover a broader topic and last several weeks or months. The workshops may take place at a school, a department of education, or your own professional setting.

Take, for example, a college workshop on environmental education. This workshop could take place over two weeks during the summer, during which teachers are placed in an intensive, but fun, setting where they can learn basic principles of ecology, how to apply these ideas to lesson plans, and how to develop their own school yards for environmental education. Although you may not choose to do a workshop as demanding as this one, the same principles may apply to shorter workshops. If you can help teachers learn about a science topic and connect this topic to hands-on activities or real-world examples that could be used in the classroom, the benefits will be widespread.

Finally, some scientists are in a position to invite a teacher to spend the summer participating in research in their own professional environment. Becoming immersed in research for a 10-week period provides teachers with examples of how science is applied in real life, models of scientific thinking, and practice at effective science communication. Teachers often have trouble translating the lab experiences back into their classroom, however. You could help overcome this by collaborating with the teacher on a lesson plan based on laboratory activities to take back to the classroom. Universities often have programs set up to involve local teachers in laboratories. These programs can be a valuable resource to you on how to best collaborate with a teacher, so it is worth contacting local institutions for possible information. If no such program exists in your area, try to find a mentor who has successfully hosted a local teacher in his or her laboratory in the past. By using the knowledge of other programs or individuals, you will have a greater chance of a successful experience in your own collaboration.

Advice

The goal of professional development workshops for teachers is to provide them with information they can use in the classroom. Work with your contact at the school, school district, or state organization to ensure that you will be addressing an issue, problem, or topic that is significant in science and of interest to teachers. Throughout their careers, teachers are continually building on their knowledge, so plan a way to assess their current understanding and abilities. By doing this, you will be able to present a workshop at an appropriate level. While you are planning, keep in mind the impact you hope to have and how you will evaluate your effectiveness.

During the workshop, try to actively involve teachers in an investigation, and provide resources such as scientific literature or technology ideas to enhance the teachers' background information. Keep in mind, though, that the time teachers have to prepare is limited, so a few excellent resources are more effective than a pile of papers they have to sort through. If you are able to and feel comfortable doing this, provide your contact information to teachers so they can continue to use you as a resource as questions arise later.

6 Six things to think about

- The contact person for arranging a workshop may be in the school, the school district, or a state organization. If you do not know the proper person to contact, ask the school's principal.
- Ask the organizer about the science curriculum and teachers' needs, then offer to design a presentation to fit with these.
- Build the teachers' understanding of science from their current knowledge.
- Help the teachers translate your presentation to their students' level of understanding.
- Model teaching strategies that are more than, and different from, lecturing.
- Incorporate your understanding of inquiry and the nature of science into your workshop.

Support Informal Science Education

Some of the most effective places at incorporating inquiry-based education into their goals are the science museum, children's museum, planetarium, and history museum in your area. Although these informal education settings do a good job of using hands-on activities and other means of exploring science, there is still a role for you in them. Volunteering as a docent may be the first thing that comes to mind, but there are several other ways that you could be involved.

You could participate on the advisory board of one of these museums. If you would prefer to be more involved in the science aspects, you might choose to review the science content of scripts for the science exhibits, planetarium shows, or environ-mental programs. You could even collaborate on the creation and development of a new exhibit at a museum.

Advice

When thinking of informal education settings, we hope that the word "fun" comes to mind. The goal in informal education is to provide current, accurate scientific information to the public. It should complement, supplement, and enhance what is learned in the classroom. Whether you are serving as a docent or planning an exhibit, be conscious of how you are going to engage patrons—both adults and children—and what sort of investigations can occur related to your topic.

Collaboration is key when you are involved with informal education. Be sure you have an understanding of the goals of the museum or center and the demographics of the expected visitors. There is an emphasis on creativity in this type of setting, as well as on appealing to a variety of learning styles, ages, socioeconomic backgrounds, abilities, and cultures, so keep these in mind during your planning. If you are helping design an exhibit, you might also spend time thinking about ways to make the science accessible to patrons with disabilities. Although the museum will have staff members to work on accessibility issues, by collaborating with museum personnel, you can ensure that scientific content remains accurate while all visitors are accommodated.

6 Six things to think about

- The point of contact should be the volunteer coordinator for the museum or center. You may also talk to the director of education if you want to help plan an exhibit.
- Find out about the goals of the museum and how you can support those goals. You may consider offering your skills as a grant writer to assist with proposal development.
- Be aware of the audiences with whom you interact as well as their under-standing of science.
- Make connections between experiences in the informal and school settings.
- Write up a brief description of your role so that you and your contact are clear about the form and function of your involvement.
- Help identify ways that exhibits could be made accessible to disabled patrons while still showing scientifically accurate information.

Work with Parents and School Boards

Some scientists are more interested in reforming science education at the level of their local school system. This type of change involves scientists working with school districts to restructure and redefine science education. Long-term strategic planning is necessary, and it should be understood that this is a very complex political process. In the case of systemic reform, the goal is to introduce changes that are implemented to become a new "standard operating procedure" within the relevant school system.

At the most basic level, this involvement could be participation in parent-teacher organizations or speaking to the school board about the importance of science education. A larger commitment could be reviewing local science education standards for scientific accuracy or helping evaluate the state framework for science education. Each of these would require working as part of a team.

It may be that the school district in your area is already involved in improving science education. If this is the case, there may be a number of opportunities in which to take part. You might collaborate on writing or adopting science education standards for the area. As a district works to adopt new standards and materials, there is a need for scientists to evaluate textbooks and other resources to ensure that they are accurate, are inquiry-based, and will make a substantial contribution to science education.

Advice

Working on systemic reform requires commitment and collaboration. This is not a role for someone who is only interested in spending a few hours to improve science education. This is a political process, so constant communication, a clear position, and friendly pressure may be necessary at times. It will be important to keep in mind the local, state, and federal pressures on the school district. Organization and long-term planning are also important. Business or administrative experiences are often helpful for this type of role.

Becoming educated about science education is also essential. When engaged in systemic reform, scientists need to be able to evaluate current conditions and then develop goals that support a clear vision. From there, it is important to create step-by-step plans for how to reach the goals within the education framework. It is also necessary to determine what the measure of progress will be and to review plans periodically. In addition, think about how you will evaluate the impact of your work at the end. Throughout this process, remember that you are working as part of a team and that collaborating with others is vital to reaching the goals.

6 Six things to think about

- To become involved with parent organizations, contact the school to find out whom you should talk with. To help evaluate science education standards, contact the person in your state who oversees science standards.
- Communicate effectively without excessive scientific or educational terms.
- Understand the concerns being addressed.
- Listen for and differentiate among issues that are policies, programs, and classroom practices, and align your response to the appropriate issue.
- Be insightful about obligations such as union contracts, state assessments, local priorities, and national policies.
- Practice effective strategic planning by setting clear goals and a stepwise plan to reach those goals.

Select and Implement a New Science Program

As important as teaching methods are, it is also important that teachers have appropriate instructional materials to support their efforts. Some scientists may choose to get involved in science education through helping schools select materials. Like the systemic reform efforts, selection of instructional materials involves a long-term commitment and collaborating with others to create an effective product.

In this role, you might review for scientific accuracy materials that are being developed by others. Much like the review of scientific journal articles, this may be sporadic and time-sensitive. The Biological Sciences Curriculum Study (BSCS) and the National Institutes of Health have developed 16 curriculum supplements covering a variety of topics. Printed copies of these supplements are available for free online at science.education.nih.gov/supplements. BSCS has also developed a number of textbooks and other materials that focus on different areas of science. Other organizations that are involved in developing innovative new materials are the National Science Resources Center (NSRC), the Education Development Center (EDC), and Lawrence Hall of Science.

Advice

Teamwork is very important for this role. To select instructional materials, input is obtained from classroom teachers, administrators, scientists, and others. To assist in this selection process, you should feel comfortable reviewing materials for scientific accuracy, appropriate technology, and authenticity of the scientific process, then providing an evaluation. As with the other roles, think of how you will evaluate your impact once you have completed the process.

6 Six things to think about

- Contact the school or the superintendent's office to ask about the appropriate person with whom to speak. Selecting instructional materials may happen at the school, district, or state level.
- Identify a set of criteria for analyzing curriculum materials.
- Help review materials for the accuracy of scientific content and a balance of major concepts and facts.
- Classify conceptual development and progressions of student learning from the beginning to the end of the textbook.
- Point out essential connections between the narrative text and laboratory experiences.
- Be sure there are appropriate technologies associated with the program.

Final Note

The single most important thing you can do before becoming involved is to contact the appropriate person and spend time discussing your role. Make sure that you have common goals and ideas about your involvement. In some cases, there may be some flexibility, while in others, you will need to fit into a curriculum or team already in place. While you may be an expert in a particular field, remember that the school personnel are specialists in education. By working together, you can determine the most effective way to contribute your experience

Did You Have an Impact?

Throughout your involvement in science education, you should think about your impact and effectiveness. Once you have undertaken a role, we encourage you to take time for reflective evaluation. This is key for continuous improvement of science education. Consider the following questions, as appropriate:

- What did the students learn?
- How do you know what they learned?
- Was the curriculum effective? (This is a question for classroom visits, work-shops for teachers, and selection of instructional materials.)
- If you participated in teacher training of some kind, did the teacher include the experience in his or her program?
- Are there things you could have improved?

Once you have spent time considering these questions, and any others you feel are important, communicate with your collaborators, offer your feedback, and ask for their opinions. By reflecting on your experience and discussing it with others, you are continuing to contribute meaningful information about the interactions between scientists and science education.

Summary

If you have made a decision to participate in science education, congratulations! You are undertaking an important role that will have widespread benefits. Whether you have chosen to volunteer in a classroom, to help with professional development (or training) workshops, or to evaluate science education standards, you will find that a rewarding challenge awaits you. Remember that this is a new experience for you, and possibly for your collaborators, so be flexible. You may experience some rough spots along the way, but don't let this discourage you from remaining involved. As with any partnership, communication is the key, so don't hesitate to ask questions or clarify information as necessary.

Remember that the goal of your involvement in science education is to improve the learning and thinking processes for today's student. By helping improve the education process with a focus on inquiry, you are affecting the development of students' lifelong skills. In doing so, you are helping set a foundation for policies, programs, and practices needed to prepare the 21st-century workforce.

Appendix I. How Well Are U.S. Students Doing?

The National Assessment of Educational Progress (NAEP) periodically tests math and reading skills. These standardized tests are given to a representative sample of students in grades 4, 8, and 12 across the country. The 2005 tests assessed about 21,000 high school seniors from more than 900 schools and presented performance as both a scale score and an achievement level.

To achieve a *basic* performance level on the NAEP in reading, the lowest of the three achievement levels, students are expected to be able to demonstrate understanding of and make some interpretations about a text. Furthermore, they should be able to identify overall meaning, extend ideas through simple inferences, relate ideas in the text to personal experience, and draw conclusions. Seventy-three percent of students performed at or above the basic level on the reading portion of the NAEP. This represented a decrease from 1992, when 80 percent of students scored at or above the basic level. (For descriptions of the *proficient* and *advanced* achievement levels, see the *12th-Grade Reading and Mathematics 2005* report from NAEP (2007).)

In mathematics, a *basic* achievement level represented the ability to solve problems requiring a direct application of concepts in familiar situations. In addition,

> These students should also be able to estimate, calculate, and compare measures and identify and compare properties of two- and three-dimensional figures, and solve simple problems using two-dimensional coordinate geometry. At this level, students should be able to identify the source of bias in a sample and make inferences from sample results, calculate, interpret, and use measures of central tendency and compute simple probabilities. They should understand the use of variables, expressions, and equations to represent unknown quantities and relationships among unknown quantities. They should be able to solve problems involving linear relations using tables, graphs, or symbols; and solve linear equations involving one variable. (NAEP, 2007, p. 18)

For the mathematics assessment, only 61 percent of high school seniors scored at or above the basic achievement level. Twenty-five percent of these students scored at or above the proficient achievement level. (For descriptions of the *proficient* and *advanced* achievement levels, see the *12th-Grade Reading and Mathematics 2005* report from NAEP (2007).)

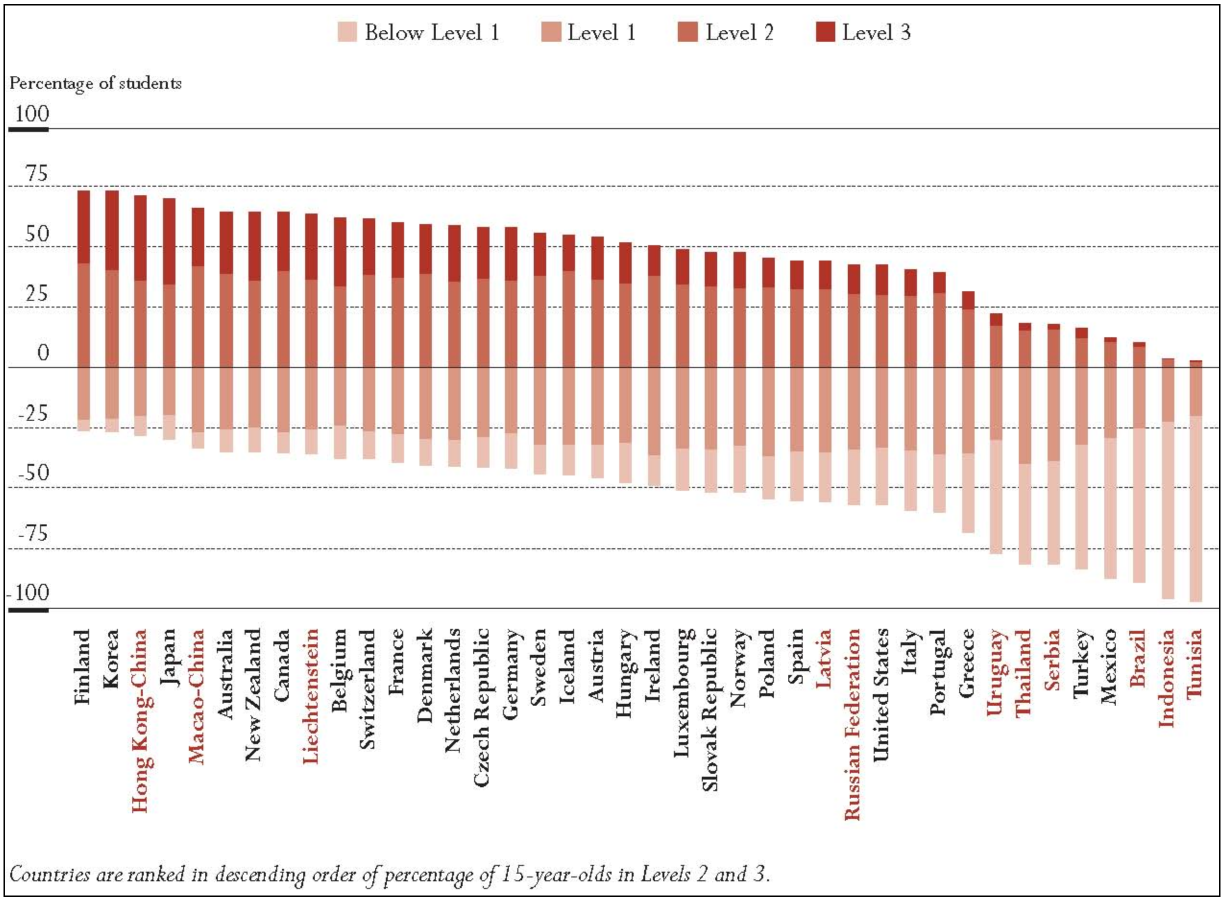
Students' problem-solving skills are not adequate. In addition to reading and mathematics, problem-solving skills were recently evaluated in high school–aged students. In 2003, the Organization for Economic Cooperation and Development's (OECD) Programme for International Student Assessment (PISA) surveyed student knowledge and skills of 15-year-olds in 40 countries. More than 250,000 students were assessed. These students were assigned an achievement level based on a raw score, with levels defined as follows:

Level 3: Reflective, communicative problem solvers
Level 2: Reasoning, decision making problem solvers
Level 1: Basic problem solvers
Below level 1: Weak or emergent problem solvers

In the United States, 24 percent of students fell below Level 1 in their problem-solving abilities, and an additional 34 percent fell into the Level 1 category. Some labor economists fear that this 58 percent of students are at great risk in our 21st-century workforce.

Of even more concern is how students in the United States compare with those in other countries. As Figure A.1 indicates, of the 40 countries assessed in the PISA study, the United States, once a leader in education, ranked 29th in the percentage of students achieving Level 2 or 3 in problem-solving abilities. This suggests that current methods of education are not effectively teaching our students about this skill. You can help by showing teachers and students how to develop problem-solving skills through inquiry-based activities in the science classroom.

Figure A.1. Percentage of students at each level of proficiency on the problem-solving scale.



Source: *Problem Solving for Tomorrow's World: First Measures of Cross-Curricular Competencies from PISA 2003*, © OECD, 2004.

The strength of the PISA data is such that it allows for the elimination of some of the potential hypotheses that might be offered to explain the United States' poor performance. It is known that the United States has a relatively nonselective school system in order to provide all students with the same opportunities. In this way, U.S. schools must address all levels and abilities within a school. Other countries use high-stakes tests as early as the fifth grade to form groups of students with similar abilities (e.g., college vs. vocational track) within or between schools. If PISA were to compare all students in the United States with only the college-bound students from other nations, it could explain the higher performance of these countries. However, because PISA proportionally samples all students in each country and not just the elite students tracking towards a college education, "selection bias" is not an explanation for the poor performance of U.S. students.

Another argument that has been made to account for the poor performance of U.S. students is that other countries have more homogeneous populations. While this may be true of some of the top-scoring countries (Finland #1 or Japan #4), this is not the case in others. Hong Kong–China placed #3 in the number of students placing into Levels 2 or 3. In China, significant proportions of the population speak different languages, while the United States has only one official language. It could be argued that many parts of Asia are as heterogeneous as the United States.

It is also not the case that “the best U.S. students are the best in the world.” When the data from the PISA 2003 problem-solving study are plotted to rank countries with respect to the scores of the number of students at the 95th percentile, the United States moves from 29th place to 24th. While this is certainly a move in the right direction, it is not where most Americans imagine our best students ranking.

Finally, it has been suggested that the performance of students in the United States is simply a function of students with dramatically differing abilities. The PISA data, however, not only compare the mean results for each country, but also the disparity between the highest and lowest performers. In some countries, not only is there a high average performance, but also a smaller gap between the highest- and lowest-performing students, while other countries, such as the United States, show lower mean performance as well as a large disparity between highest- and lowest-performing students. The fact that some countries have been able to overcome differences in innate ability and bring students to a more comparable performance level suggests that changes in education in the United States may be beneficial.

The fact that students in the United States are underperforming in reading, mathematics, science, and problem solving (think: inquiry in science classrooms) creates a clear role for research scientists’ involvement in science education. The basic skills needed for all students entering today’s workforce include some of those that are the very expertise of scientists! Whether critically reading a journal article, making a chemical solution, or analyzing the results of an experiment, scientists use these skills every day. Your skills can be useful in science education and in helping to prepare today’s student for the 21st-century workforce.

One of the most important ways students can learn about education is through working together—another of the basic skills needed—to tackle real-world problems. In doing so, students can gain the skills they need to analyze and apply information to diverse situations. This type of inquiry-based learning is the foundation of current science education reform (AAAS, 1993; NRC, 1996, 2000).

Appendix II. What Is Inquiry and Why Is It Important in Science Education?

In 1996, the publication of the *National Science Education Standards* presented inquiry as a prominent theme. It stated,

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world. (NRC, 1996, p. 28)

The specific standard states, “As a result of activities in grades 9–12, all students should develop both abilities necessary to do scientific inquiry and understandings about scientific inquiry.” The *Standards* shifted the implementation of the “science as inquiry” theme from an emphasis on the processes to a focus on developing cognitive abilities such as reasoning with data, constructing an argument, and making a logically coherent explanation. Further, the *Standards* made it clear that the aims of science education include students’ understanding scientific inquiry.

It is important to realize, however, that these abilities are not important only to students planning to attend college and major in science. Critical thinking and problem-solving abilities, as well as the application of information to real-world problems, are important to all students as they enter the workforce.

How does one’s physician arrive at the correct diagnosis? A physician considers the symptoms and laboratory results, analyzes this information, and employs clinical judgment that comes from years of experience before reaching a conclusion. Furthermore, the physician must be able to justify the diagnosis to the patient, to other healthcare professionals, and even to the insurance company.

How might an air traffic controller use inquiry-based skills? Not only must she be familiar with advanced technology, she must integrate her various sources of information, from the pilots, the radar, and the other air traffic controllers, into a mental picture of what is happening in the sky. Recognizing that any given piece of information could be in error, she must also be able to skeptically “test” each bit of data as she reasons her way through any emergency situations in order to find a safe solution. The split-second decision to order an errant aircraft into a new position can mean the difference between life and death for many passengers.

Assembly-line workers in a modern auto factory are expected to provide a quality-control function that was not the responsibility of earlier generations of similar workers. When some aspect of the production drifts “out of specification,” these workers form impromptu problem-solving teams, create hypotheses, and test their ideas, until the source of the problem is identified and corrected. Few people realize the extent to which these workers are expected to apply inquiry in their daily jobs. And those who are highly proficient at this skill can accumulate sufficient bonus points to eventually merit a free car!

Even the airline agent must solve problems by examining options, ticket prices, schedules, and available seats. She will have to use logic and information to get you to your destination on time and at a price you can afford.

What Are the Essential Features of Inquiry?

For you to understand how you might incorporate inquiry into the role you take in science education, it is important to consider the five essential features of inquiry outlined in *Inquiry and the National Science Education Standards* (NRC, 2000). These are:

1. Learner engages in scientifically oriented questions.
2. Learner gives priority to evidence in responding to questions.
3. Learner formulates explanations from evidence.
4. Learner connects explanations to scientific knowledge.
5. Learner communicates and justifies explanations.

Let's take a look at what each of these statements means according to *Inquiry and the National Science Education Standards*.

Essential Feature 1: Learner engages in scientifically oriented questions. Scientifically oriented questions center on objects, organisms, and events in the natural world; they connect to the science concepts described in the content standards. They are questions that lend themselves to empirical investigation and lead to gathering and using data to develop explanations for scientific phenomena. Scientists recognize two primary kinds of scientific questions. Existence questions probe origins and include many "why" questions. Why do objects fall toward Earth? Why do some rocks contain crystals? Why do humans have chambered hearts? Many "why" questions cannot be addressed by science. There are also causal and functional questions, which probe mechanisms and include most of the "how" questions. How does sunlight help plants grow? How are crystals formed?

Students often ask "why" questions. In the context of school science, many of these questions can be changed into "how" questions and thus lend themselves to scientific inquiry. Such change narrows and sharpens the inquiry and contributes to its being scientific.

Essential Feature 2: Learner gives priority to evidence, which allows the learner to develop and evaluate explanations that address scientifically oriented questions.
As the *National Science Education Standards (NSES)* notes, science distinguishes itself from other ways of knowing through the use of empirical evidence as the basis for explanations about how the natural world works (NRC, 1996). Scientists concentrate on getting accurate data from observations of phenomena. They obtain evidence from observations and measurements taken in natural settings such as oceans, or in contrived settings such as laboratories. They use their senses; instruments, such as telescopes, to enhance their senses; and instruments that measure characteristics that humans cannot sense, such as magnetic fields. In some instances, scientists can control conditions to obtain their evidence; in other instances, they cannot control the conditions, or control would distort the phenomena, so they gather data over a wide range of naturally occurring conditions and over a long enough period of time that they can infer what the influence of different factors might be. The accuracy of the evidence gathered is verified by

checking measurements, repeating the observations, or gathering different kinds of data related to the same phenomena. The evidence is subject to questioning and further investigation.

You can help students with some of these new skills. In their classroom inquiries, students use evidence to develop explanations for scientific phenomena. They observe plants, animals, and rocks and carefully describe their characteristics. They take measurements of temperature, distances, and time and carefully record them. They observe chemical reactions and moon phases and chart their progress. Or they obtain evidence from their teachers, instructional materials, the Internet, or elsewhere to "fuel" their inquiries.

Essential Feature 3: Learner formulates explanations from evidence to address scientifically oriented questions. This aspect of inquiry emphasizes the path from evidence to explanation, rather than the criteria for and characteristics of the evidence. Scientific explanations are based on reason. They provide causes for effects and establish relationships based on evidence and logical argument. They must be consistent with experimental and observational evidence about nature. They respect rules of evidence, are open to criticism, and require the use of various cognitive processes generally associated with science—for example, classification, analysis, inference, and prediction—and general processes such as critical reasoning and logic.

Explanations are ways to learn about what is unfamiliar by relating what is observed to what is already known. So, explanations go beyond current knowledge and propose some new understanding. For science, this means building upon the existing knowledge base. For students, this means building new ideas upon their current understandings. In both cases, the result is proposed new knowledge. For example, students may use observational and other evidence to propose an explanation for the phases of the moon, for why plants die under certain conditions and thrive in others, and for the relationship of diet to health.

Essential Feature 4: Learner evaluates his or her own explanations in light of alternative explanations, particularly those reflecting scientific understanding. Evaluation, and possible elimination or revision of explanations, is one feature that distinguishes scientific inquiry from other forms of inquiry and subsequent explanations. One can ask questions such as, Does the evidence support the proposed explanation? Does the explanation adequately answer the questions? Are there any apparent biases or flaws in the reasoning connecting evidence and explanation? Can other reasonable explanations be derived from the evidence?

Alternative explanations may be reviewed as students engage in dialogues, compare results, or check their results with those proposed by the teacher or instructional materials. An essential component of this feature is ensuring that students make the connection between their results and the scientific knowledge appropriate to their level of development. That is, student explanations should ultimately be consistent with currently accepted scientific knowledge.

Essential Feature 5: Learner communicates and justifies his or her proposed explanations. Scientists communicate their explanations in such a way that their results can be reproduced. This requires clear articulation of the question, procedures, evidence, and proposed explanation and a review of alternative explanations. It provides for further skeptical review and the opportunity for other scientists to use the explanation in work on new questions. Having students share their explanations gives others the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations. Sharing explanations can bring into question or fortify the connections students have made among the evidence, existing scientific knowledge, and their proposed explanations. As a result, students can resolve contradictions and solidify an empirically based argument.

Source: Olson, S., and S. Loucks-Horsley, Editors, and the National Research Council. 2000. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning.* Washington, DC: National Academy Press.

Appendix III. Understanding Today's Schools

To have a positive experience in science education, you should understand some of the terminology you may encounter. This includes terms surrounding the No Child Left Behind Act, science education standards, and student diversity. The following is meant to provide enough information to familiarize you with each of these topics.

No Child Left Behind

The No Child Left Behind Act (NCLB) was passed in 2001 with a purpose of ensuring that all children in the United States receive a high-quality education. Because of NCLB, there are higher standards and accountability in classrooms across the country, and the responsibility for children's learning has been placed in the hands of the teachers and schools. Parents receive information in the form of a report card on the schools in the district, so they can see which ones are succeeding and why. The report card includes information about whether the school made Adequate Yearly Progress (AYP) based on student performance, with at least 95 percent of students participating in NCLB assessments, and continued school progress over time.

To obtain this information, NCLB relies on testing children each year in reading and math during grades 3 through 8, and at least once in high school. Science is not currently included as an area that counts toward a school's AYP. The testing allows states to compare not only a particular student's progress, but also to compare schools with one another and determine which schools need improvement.

If a school does not make AYP, it is given two years to make improvements. If there is not sufficient progress by the end of two years, the school is subject to corrective action. Examples of corrective actions include replacing the school staff relevant to the failure, extending the school day or year, decreasing the management authority in the school, or restructuring the internal organization of the school. If, after one additional year, adequate progress is not made, the school is subject to restructuring. This may include such actions as replacing all or most of the school staff, including the principal; reopening the school as a public charter school; or having the state take over the school. These possible actions underscore why many teachers feel their positions are at risk and are thus focused on ensuring that students are able to successfully complete the NCLB assessments.

Because students and schools are being evaluated each year for progress in reading and math, teachers must be aware of the state goals at all times. This emphasizes the importance of meeting with teachers before you become involved in the classroom to ensure that your ideas fit into the time frame and curriculum available to teachers. A teacher may also help refine your plans so that they are as effective as possible.

National, State, and Local Standards

Another concern for teachers is the content taught to students. To help guide the curriculum, the voluntary *National Science Education Standards* were released in 1996. Some school systems follow these national standards, while others use state or district standards. Standards help improve science education by providing guidance on content and assessment in a particular area.

Before making a decision about what you plan to do in the classroom, determine which set of standards teachers in your area use. In most places these standards are available online. Read through them and determine how your ideas fit into the curriculum presented there. This is another topic that should be discussed with your collaborating teacher, as she may have other plans for a particular topic, or may choose to fit your ideas into a different area. Teachers are obligated to teach all the standards listed and should be able to explain how any given lesson plan fits the standards, so it is important to clearly define the goals of your participation beforehand.

Should you choose, instead, to participate in systemic changes to science education (changes throughout a district, a state, or the country), you will find that the standards are equally important. Obtain a copy and evaluate what is already in place. Are there items that you feel should no longer be taught or that should be included? Consider your justification for any standard you feel is out of place. Be aware, however, that even if you find a standard that is in scientific error, the district may have to clear its changes with the state department of education—a time-consuming process. Fortunately, in most cases, the standards provide a good baseline and are only slightly revised from time to time.

Diversity among Students

Finally, to contribute effectively, it is important to remember that students have diverse learning styles, and the most effective teachers and presenters can appeal to more than one style. Students may have preconceptions about your topic, and it is important to spend some time discovering what information students already know or think they know. Following that, it is important to present information in a way that appeals to different learning styles. Some people are visual learners, meaning that they learn best from pictures and text, while others are auditory learners, who learn best when information is presented out loud. Younger students learn best by doing something rather than just listening or watching. Some learners understand topics better when the “big picture” is presented first, followed by the details, while others prefer starting at the bottom with the details and working up to global understanding. Students also have diverse backgrounds from which they have gained knowledge, and it is important to respect that.

By working closely with teachers and other collaborators, you will find that you each contribute to an idea to make it a success. Do not hesitate to ask questions. By considering factors in today’s education system and working closely with those involved with it, you will be able to have a positive and rewarding experience.

Appendix IV. Educational Resources

These resources are links to the education sites of professional societies. Many of the sites have activities and plans you could use in the classroom or as a starting point for your own ideas. The list is not meant to be exhaustive, so if your professional society is not listed, you may want to take a few minutes to explore the society's Web site to see if it has an education section.

American Chemical Society, Educational Resources
http://www.acs.org/education

American Physiological Society, Teaching Resources
http://www.the-aps.org/education/edu_teachingres.html

American Society for Cell Biology, *Cell Biology Education—A Journal of Life Science Education*
http://www.cellbioed.org

American Society for Cell Biology, Educational Resources
http://www.ascb.org/index.cfm?navid=6

American Society of Human Genetics, GenEdNet
http://www.genednet.org/

American Society for Microbiology, Resources for K–12 Teachers
http://www.asm.org/Education/index.asp?bid=1229

Biophysical Society, Educational Resources
http://www.biophysics.org/education/

Ecological Society of America, EcoEdNet
http://www.ecoed.net

Geological Society of America, Education and Teacher Resources
http://www.geosociety.org/educate/

Society for Developmental Biology, Education Section
http://www.sdbonline.org/index.php?option=com_content&task=section&id=6&Itemid=62

Society for Neuroscience, Brain Awareness Week Educational Resources
http://www.sfn.org/baw/bawresources.cfm

Society of Toxicology, Education Outreach
http://www.toxicology.org/ai/eo/education.asp

Appendix V. References

American Association for the Advancement of Science. 1993. *Benchmarks for Science Literacy*. New York: Oxford University Press.

BSCS. 2006. *Why Does Inquiry Matter? Because That's What Science Is All About!* Dubuque, IA: Kendall/Hunt Publishing Company.

BSCS. 2007. *A Decade of Action: Sustaining Global Competitiveness.* Executive summary. Colorado Springs: BSCS.

Bybee, R.W. 1998. Improving precollege science education—The involvement of scientists and engineers. *Journal of College Science Teaching* 27(5):324–8.

Bybee, R.W. 2003. The Teaching of Science: Content, Coherence, and Congruence. The 2003 Paul F-Brandwein Lecture. National Science Teachers Association, Philadelphia, PA.

Bybee, R.W. 2006. *Science Teaching in the 21st Century: Five Themes for Educational Leaders.* Dubuque, IA: Kendall/Hunt Publishing Company.

Bybee, R.W., and B. Fuchs. 2006. Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching* 43(4):349–52.

Bybee, R.W., and C.A. Morrow. 1998, Fall. Improving science education: The role of scientists. *Newsletter of the American Physical Society Forum on Education*.

DeBoer, G. 1991. *A History of Ideas in Science Education.* New York: Teachers College Press.

Kyle, W.C., Jr., et al. 1985. What research says: Science through discovery: Students love it. *Science and Children* 23(2):39–41.

Laursen, S., C. Liston, H. Thiry, and J. Graf. 2007. What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K-12 classrooms. *The American Society for Cell Biology* 6:49–64.

Morrow, C.A. 2000. What Are the Similarities between Scientific Research and Science Education Reform? Online at www.scientistsineducation.org.

Murnane, R.J., and F. Levy. 1996. *Teaching the New Basic Skills: Principles for Educating Children to Thrive in a Changing Economy*. New York: The Free Press.

Narode, R., et al. 1987. *Teaching Thinking Skills: Science.* Washington, DC: National Education Association. ED 320 755.

National Academies of Science. *Roles for Scientists and Engineers in the Schools.* Online at www.nationalacademies.org/rise/roles.html.

National Assessment of Educational Progress. 2007. *The Nation's Report Card: 12th-Grade Reading and Mathematics 2005.* W. Grigg, P. Donahue, and G. Dion. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office. Online at nces.ed.gov/nationsreportcard/pdf/main2005/2007468.pdf.

National Research Council. 1996. *National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council. 2000. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington, DC: National Academy Press.

Programme for International Student Assessment. 2003. *Problem Solving for Tomorrow's World: First Measures of Cross-Curricular Competencies from PISA 2003.* France: OECD Publications. Online at www.pisa.oecd.org/dataoecd/25/12/34009000.pdf.

Rakow, S.J. 1986. *Teaching Science as Inquiry.* Fastback 246. Bloomington, IN: Phi Delta Kappa Educational Foundation. ED 275 506.

Rodriguez, I., and L.J. Bethel. 1983, April. An inquiry approach to science and language teaching. *Journal of Research in Science Teaching* 20(4):291–96.
U.S. Department of Education. *Facts and Terms Every Parent Should Know About NCLB.* Online at www.ed.gov/nclb/overview/intro/parents/parentfacts.html.