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Sandia Scientists Enhancing K-12 Education:

How We've Done It and What We've Learned[1]

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Sandia National Laboratories became seriously involved in the science education reform movement in 1989 in response to a Department of Energy directive:

> "We must expand our involvement in science education to inspire the youth of America to either enter or feel more comfortable in the fields of math, science, and engineering. With our labs and facilities we are uniquely well positioned to provide major assistance in strengthening science and engineering motivation and education, making it "come alive" for the main body of students who too often fear these disciplines or who cannot relate to them" (Admiral James D. Watkins, U.S. Secretary of Energy, September, 1989).

Sandia's initial effort, the School Partnership Project, contributed Sandia technical staff members to several pilot schools in Albuquerque for the purpose of improving student attitudes toward science. Scientists and engineers with experience in coaching, scouting, and other types of youth work were selected for this project. They conducted monthly in-class science demonstrations and hands-on activities with students on topics currently being covered by their teachers. In addition, they provided tutorials for teachers, assistance with science fairs, and tours at Sandia.

The impact of this effort was assessed by giving identical questionnaires to about 700 participating students (in grades one through seven) before and after one semester of School Partnership activities. The results showed the following:

1. Incoming student attitudes toward science are very positive in first and second grades (more than 90 percent favorable), but declined steadily from third to seventh grade (less than 35 percent favorable by seventh grade).

2. Student attitudes improved substantially as a result of one semester's involvement in the School Partnership Project (the percentage of fourth through seventh grade students with gen-

erally favorable attitudes toward science increased from 42 percent to 65 percent).

Based on these encouraging results, a decision was made to greatly expand the Sandia effort. The next step was to involve more schools with the more potent goal of system-wide reform of elementary and middle school science education in Albuquerque and surrounding New Mexico communities. In addition, the focus of this expanded effort shifted from students to teachers for the following reasons:

1. Leverage – each teacher works with many students, resulting in greater impact.

2. Duration of benefits – enhanced teaching skills would continue beyond the period of Sandia's direct intervention.

3. Ease of communication – Sandia scientists and engineers are, for the most part, more adept at communicating with other adults than with children and adolescents.

A high percentage of Albuquerque public elementary and middle schools, as well as rural and Bureau of Indian Affairs schools in the northwest quadrant of New Mexico, indicated interest in being part of this Science Advisors Project. Over 150 Sandia staff members were recruited, and a master science teacher was engaged to help prepare them for their task. These individuals were given pre-service training in the hands-on, inquiry-based approach to science education that we wanted to foster, and to help them understand how to interact effectively with students, teachers, and administrators.

In addition, a Sandia Science Education Resource Center was established to provide access to activity ideas, supplies for various topic areas, and extra Sandia equipment that could be loaned to the schools. Each Science Advisor (or SCIAD, as they came to be known), was then assigned to a school, and authorized to spend up to one day each week at the school.

The SCIADs were directed not to go out to their school with "a suggested program or solution," but rather with the question, "How can we help you?" SCIADs met with teachers, principals, and counselors to learn about the strengths, dreams, and problems of their schools, and to develop plans for how Sandia and their SCIAD might help.

Because initiatives were tailored to the *expressed* needs of each particular school, individual SCIADs adopted different approaches. Many presented in-class activities with students, similar to those

done in the School Partnership Project. Others familiarized teachers with hands-on activity ideas, served as liaisons to help teachers find activity kits, or developed their own activities. Some helped organize, repair, and update science supplies and computers at their schools. Others organized science nights for parents, provided science tutorials for teachers, organized and judged science competitions, or served their schools in a host of other ways.

In the following year, additional initiatives were added. The Science Advisor Project expanded to include in-service and summer workshops in hands-on science activities for elementary and middle school teachers. Afterschool projects were begun in which African American, Hispanic, and American Indian middle and high school students engage in exciting science activities with ethnic minority members of the Sandia staff. A high school speakers program was initiated. Efforts were begun to help other communities begin their own Science Advisors Projects, some via telecommunications and distance learning for remote American Indian communities from Maine to Arizona.

Substantial efforts have been made to assess and improve each of these projects. Questionnaires were given to the Sandia project participants and their school "customers." External assessment groups were hired to conduct in-depth interviews and to make recommendations for project modification and improvement.

Several findings stand out regarding the overall impact of the Sandia K-12 Program:

1. Teachers, particularly elementary school teachers, now feel much more comfortable teaching science than they had previously.

2. Teachers are increasingly engaging their students in hands-on inquiry-based science. Loans by our Resource Center have increased substantially each year, topping 10,000 in the 1993-94 school year.

3. Students exposed to positive technical professional role models have developed much more positive attitudes toward science.

4. Following several years of Sandia activities in most Albuquerque elementary and middle schools, Albuquerque third, fifth and eighth graders scored higher in science than any other subject area in the 1993 Iowa Test of Basic Skills.

5. In a broad survey of community attitudes toward Sandia, 70 percent of Albuquerque residents indicated that Sandia was having a positive effect on schooling and education.

What We Learned

Through our experiences of the past five years, we have learned a number of important lessons about science education. First and foremost, we learned that technical professionals can make substantial contributions to K-12 science education, provided they are supported by their employer, are appropriately trained, and have access to high quality educational resources.

Second, we learned that, in order for education programs to be effective, local teachers and principals must have a sense of ownership that comes from having a significant role in establishing the program directions and approaches.

Third, we learned that the characteristics and needs of students and teachers, as well as the degree to which technical professionals can be effective, all vary substantially with grade level in a variety of ways.

Elementary schools (especially third through sixth grades) provide particularly good opportunities for interventions conducted by scientists and engineers. These are the years during which student interest typically declines most precipitously. But programs like those outlined above can make a significant difference.

Elementary students are enthusiastic, respectful, and easy to work with, making it possible for adults without a great deal of training or experience in youth work or education to interact quite effectively with them. In addition, elementary school teachers frequently know very little about science and are in great need of help. They are typically open and eager for any help that proves to be useful.

Perhaps most importantly, only a very basic level of science content knowledge is required at the elementary school level—virtually anyone with a science or engineering background can provide helpful assistance with the *entire range* of topics being covered, i.e., physical science, life science, and earth science. This facilitates *repeat visits* and the establishment of *continuing relationships* between particular scientists, teachers, and students. It would be difficult to overestimate the degree to which effectiveness increases as these relationships develop.

Middle school students and teachers also have great needs, but are much more challenging. Student interest continues to decline, and the onset of adolescence makes working with them more difficult. A significantly higher level of understanding and experience with the youth culture is required. They are self-conscious and very concerned about their standing in their peer group. They begin to "try on" alternative behaviors and positions, and often alternate between fairly mature and outrageously immature behaviors suddenly and frequently. Despite being boisterous and unruly, they have great needs for positive adult role models who simply like them—the most important question they're asking is, "Am I O.K.?"

Middle school teachers vary widely in their knowledge of science. Some have been certified in elementary education and may have very little science background. Others are certified in secondary education and have substantial science backgrounds. Regardless, they are identified as *science* teachers, implying that they *should be* knowledgeable in science. This makes them significantly more guarded. Unfortunately, those who most need help are often the most defensive.

The level of content and applications knowledge required of the scientist is somewhat greater than in elementary schools, but remains basic enough to enable the same individual to assist with all topics *within* a given area. A physician, nurse, microbiologist, or game and fish worker would be best qualified to assist throughout the life science topics. A geologist, oceanographer, civil or mining engineer, or meteorologist could assist throughout the entire earth science course. Because working with middle school students and teachers involves additional challenges, the establishment of continuing relationships is even more important than at the elementary school level.

High school programs are considerably different, and require different objectives and approaches than elementary and middle school efforts. Student interest tends to be bi-modal. Some students are beginning to develop serious interest in science and need positive role models and mentors to encourage them and help them deepen their level of understanding. Others are turned-off to science and math—it is very difficult to regenerate their interest.

Teacher knowledge of subject matter is usually adequate, but they frequently need motivational examples of how science is applied to interesting real world problems. Perhaps most significantly, a higher level of specialized knowledge and experience is required, making it much more difficult to develop continuing relationships. Within a given course, physics for example, a mechanical engineer might be well qualified to assist in the area of force and acceleration, but a laser physicist would be much better in the area of optics, and an acoustical specialist better in the area of sound.

Finally, we have learned several key principles which scientists and engineers need to know and follow in order to either conduct or promote quality science education activities. These are listed in Figure 1. Space constraints do not permit these to be discussed in detail here, but these points have been fleshed out in a training

guide, which can be obtained by contacting the author.

To date, we at Sandia have made significant inroads in introducing a hands-on approach to science in many New Mexico schools, and engaging the technical professional community in the science education process. Building on this, we now hope to work with others towards a national movement of technical professionals enhancing science education in their local communities.

The key organizational units in this movement should be local. Local alliances should serve as focal points to bring together all community stakeholders in the science education process: teachers, principals, technical professionals, museums, businesses, and others. Through these alliances, local needs can be assessed, and goals and methods established for addressing them. The community's technical professionals, an interdisciplinary group of physicists, engineers, medical workers, and others, can then be trained and equipped for their roles in the educational process.

While the key organizational units will be local, national groups also have important roles to play. Professional societies can make their members aware of the needs and opportunities for involvement, publicize the activities being conducted by their members, recruit interested volunteers, connect them with the appropriate local alliances, and provide support for K-12 efforts by their local chapters.

There will also be a strong need for a support structure to provide things that are jointly needed by all of the local alliances, such as: advice on local alliance formation and maturation, information on national reform initiatives, training materials to help technical professionals interact effectively with students and teachers, publicity and recruiting materials, information to help win employer support for employee involvement, and access to educational resources and activity ideas.

We have found that the technical community can make a positive difference in science education in our schools. We have seen it happen in Albuquerque. We now stand ready and eager to help the national community of technical professionals become productively involved in enhancing science education in other communities across the country.

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Strategies for Quality Science Education Activities

- **Support and collaborate with teachers**
  - Don't be arrogant
  - Do activities that integrate with and enhance curriculum
- **Recognize your need for planning and preparation**
  - Technical knowledge isn't enough—plan to engage students
  - Take advantage of existing materials and resources
- **Employ sound learning principles**
  - Include excitement and fun
  - Involve students in hands-on activities
  - Provide opportunities for discovery experiences
  - Use applications to stimulate interest in principles
- **Do age-appropriate activities**
  - Concrete versus abstract
  - Applications relevant to age group
  - Consistent with student background and vocabulary
- **Engage numerous senses and learning modalities** of hearing, seeing, touching, kinesthetic, rhythm, group interaction, and problem solving.
- **Balance science process and content**
- **Hypothesize and test by experiment**—develop critical thinking skills and ability to reason logically
- **Demonstrate concern for safety and environment**
- **Build relationships**
  - Be excited and fun
  - Demonstrate that you like them
  - Give lots of positive feedback
  - Avoid one-shot visits
- **Solicit feedback from teacher and students**

Figure 1