Anal Bioanal Chem (2009) 394:1233–1236
DOI 10.1007/s00216-009-2793-x

ABCs OF TEACHING ANALYTICAL SCIENCE

Science outreach: an important endeavor for active scientists

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Published online: 24 April 2009

Introduction

High-technology industries are currently key drivers of world economic growth. For more than 20 years, production in high technology has grown at over twice the annual rate of any other manufacturing area [1]. Since 2003, the US high-technology industry has generated more high-technology value added to domestic production than any other country or the European Union [2]. While this has positively impacted the world economy, this capability may not be maintained owing to possible lack of availability of enough science and engineering college graduates. The USA currently ranks 16th (out of 18) among the industrialized nations for the number of higher-education degrees in science and engineering produced per 100 24-year-olds [2].

The proficiency of US students in science further threatens the economic growth of science and technology in the USA. The most recent data on science proficiency in the USA show that no improvement in science proficiency in the USA occurred across this entire period of international comparisons (from 1996 to 2007) [3]. Another compelling component of those data is that the percentage of students proficient in science does not reach values higher than 30–32%. Figure 1 shows a comparison of the number of industrialized countries with students performing below, equal to, or above the USA in science proficiency as a function of progress through the K-12 system [1]. US students become less competitive relative to their international peers as they move through the K-12 education system. The American Competitive Initiative was established to improve science and engineering education in the USA through numerous funding initiatives. The funding of these initiatives continues to be under discussion.

In 2005 C.F. Rutherford, retiring Chief Education Officer of the American Association for the Advancement of Science, cautioned that little progress in science education has been made in post-World War II America. Rutherford suggests that this lack of progress is not due to a lack of effort in science education reform in terms of either applied human or financial capital. He argues that the causes of these disappointing data are that the US education system is complex and efforts made at the national level do not necessarily translate into changes at the local level because education is primarily controlled at the local and state levels [4]. Therefore, grassroots efforts to affect change combined with a national framework for that process would likely be more productive. The USA has nearly four million scientists with advanced degrees who might be able to contribute to such grassroots efforts.

A grassroots program that works

The Wonders of Our World (WOW) is a grassroots science outreach program that takes the excitement of scientific discovery into elementary schools. Designed to help teachers learn how to incorporate experiments into their lessons, WOW partners teachers with volunteer scientists to conduct hands-on science in kindergarten through fifth grade classes. WOW, currently in its tenth year of programming, has inspired enthusiasm for science in more than 10,000 elementary school students and hundreds of teachers in central Ohio, and has given schools the

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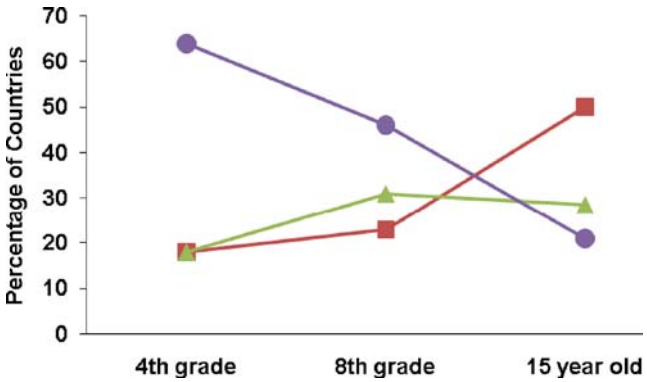

Fig. 1 International comparison of science performance of K-12 students (*red* above USA, *green* equal to USA, and *blue* below USA)

knowledge and equipment to continue implementing inquiry-based science lessons in the future.

The goals of the WOW program are to (1) bring the excitement of science discoveries into the classroom; (2) supplement the existing science programs in elementary schools; (3) increase the science materials that elementary school teachers are comfortable presenting to their students; (4) increase the involvement of local scientists, parents, and undergraduate and graduate science students in this important community project; (5) generate a pathway which gives school teachers easy access to scientists at Ohio State University (OSU) and other local science enclaves; (6) generate a model that can be used by other scientists to assist science programs in other elementary schools.

The structure of the WOW program centers on teacher and scientist collaboration in the classroom. Interactive professional development workshops are conducted throughout the year at participating schools. In these workshops, teachers learn background information about a science topic and they try a wide range of experiments they can use in their classroom to teach related concepts to their students. Then, WOW trains volunteer scientists and college science students to help the teachers facilitate the experiments in their classes. WOW provides all of the supplies and an array of resources for the teachers to enrich their science teaching. At each school six topics per year are covered in depth; this collaboration continues for a 2-year period as the WOW school adoption period. The fourth year involves "mentoring," where the teachers are doing the experiments no longer assisted by the volunteers but consultation with the WOW staff on experiments continues. These continuing efforts have made a deep impact on the way science is taught and learned. The passing rates on science proficiency/achievement tests have improved dramatically at participating schools and more time is devoted to engaging science instruction in schools once they begin working with WOW.

Expected outcomes

WOW is expected to fulfill a school's needs that result from lack of resources, such as teacher training, skilled volunteers, and science materials. Scientists are available in the classroom and any content deficiencies are expected to be addressed through the workshops with the teachers. Teachers who participate in these workshops are acquiring science content knowledge as well as greater confidence in their ability to successfully teach science. By training all teachers of an entire elementary school, we anticipate that the WOW program will have a lasting effect on science education at that school. The schools receive 18–20 WOW kits for their permanent use. These kits include complete materials and supplies for classrooms, the lesson plans, and also donated elementary-science-related children's literature. OSU science students are able to test their interest in teaching while performing a significant service to the community. The program allows OSU faculty members and volunteer students to work together closely outside the classroom environment. Local-area scientists are mentored by the program staff on elementary school science standards so that they are more able to assist local teachers with appropriate-level experiments. The program facilitates the development of a strong science-education support group within schools through the interactions between the parent volunteers.

Performance to date

Program

Strong positive responses have been obtained from all stakeholders. The teachers are enthusiastic about having the new material available and also about having the added help. Suggestions from teachers and volunteers on how experiments can be improved are taken seriously. The students' scores on the Ohio Science Proficiency/Achievement Test have improved by 30–40% on average, but some schools have had remarkable improvements of more than 300%. The principals of the schools, especially the inner-city schools, are very pleased with the level of support provided by WOW. Multiple school principals have noted lower student absences in classrooms when the students know WOW is visiting. WOW leaves a strong team of enthusiastic community volunteers who are trained and available to work further with the schools.

Impact of WOW on OSU student volunteers

The performance of most of the volunteers has exceeded expectations. Volunteers invest significant time and effort to

prepare for the projects. We documented more than 2,500 h of service from the volunteers on an annual basis. Both the local scientist volunteers and the OSU student volunteers come back to the next training sessions with enriching stories about how their classroom visit positively impacted them personally. We have had OSU science majors completely change their career plans as a result of volunteering for WOW. For example, an honors chemistry major decided to become a high-school chemistry teacher in inner-city schools as a direct result of WOW. Other WOW-involved undergraduates have decided that they like teaching and are choosing to go to graduate school to become faculty members.

Impact of WOW on teachers

WOW is a tool for teachers to use, and although some teachers were reluctant to begin teaching more science, they all thoroughly enjoy the hands-on activities and experiments after participating in WOW program for 1 year. At almost every participating school, during the first year, some teachers openly express their dislike of science and discomfort in teaching the subject. Over the 3 years of WOW, as they became more comfortable teaching science on their own because WOW showed them they could, those teachers transformed into science enthusiasts. Also, as the years progressed, the teachers began to bring in other (non-WOW) science experiments on their own. All of the schools involved in the WOW program were previously provided with hands-on science kits by their school districts, and the teachers were trained by the school district staff on how to use the kits. However, almost universally, the teachers stored the kits instead of implementing them. Interestingly for almost every school, at the end of the first year of WOW, the teachers decided to find, organize, and begin to use the kits that were stored in the basement or in a closet of the school.

During academic year 2004–2005, we asked an external evaluator (J. Upton, Institutional Research Consultants, Powell, OH, USA) to provide feedback on the teachers' impressions of WOW. High percentages (87%) agreed that the WOW program gave them ideas on how to effectively present science concepts to their students, improved their understanding of science concepts (84%), and increased (84%) their use of inquiry learning.

Impact of WOW on elementary school students

The success of the program is measured in many ways; the primary quantitative tools have been analyzing the results of the Metropolitan Achievement tests and the science portion of the State of Ohio Fourth Grade Proficiency Test. Every school involved in the WOW program has had improvements in their science proficiency test scores. Two elementary schools more than doubled their test scores after 1 year in WOW.

In 2004, a statistical analysis of the students' progress on the science components of the national standardized tests was undertaken (standardized test score data were collected from the school districts involved in the program). Student performance improved as a function of time in the WOW program to the point that average scores of students in their last year of WOW (third year) had improved by 65%.

The external evaluator also collected data on student performance through the questionnaires given to the teachers. Ninety-three percent of the teachers thought WOW had increased their student's interest in science and 94% thought WOW made their students more enthusiastic about science. Ninety percent thought WOW helped give students a better understanding of essential science concepts.

There have been numerous situations where volunteers and teachers have noticed that not only did the students learn the science presented but they also applied the concept to another situation correctly. A favorite example is a student who after doing experiments on the properties of light commented to his fellow students at recess that "A kickball works just like light. It only moves in a straight line." Women volunteers have reported that they were pulled aside by young girls who asked them what it was like being a scientist. One volunteer reported back that a young girl came up to her and said, "I am not very good at math now, but I really like the science experiments. Do you think I can still be a scientist?"

WOW receives letters from teachers attesting to its impact on his/her classroom. Here are quotes from two teachers describing their thoughts on what their students learned. "WOW was careful to align the topics with our graded course of study and took great pains to create lessons that were grade-appropriate. As a result, our standardized test scores have shown steady growth....the students gained a sense of both the importance of science in our daily lives as well as the value of working as a community of learners and explorers." "They [meaning the students] talk about what they have experienced for days and retained the knowledge that they have gained." During the summer of 2008, the WOW staff received a phone call from a summer day camp program offered for socioeconomically disadvantaged students emphasizing the long-term recall of the WOW science the child had learned that year. The child described in great detail many science experiments that had been done during the year and discussed the science of the experiments.

For most of its tenure WOW has collaborated with teachers in socioeconomically disadvantaged communities

in central Ohio. The schools specifically targeted are ones with very low average scores on science proficiency/achievement tests. It has also functioned successfully in regions of economic advantage. The gains in terms of performance from the disadvantaged students are greater than those for the economically advantaged students. However, significant improvements have been observed in all types of school environments. The WOW volunteers are excellent role models for disadvantaged students who may have not known what a scientist does on a daily basis. The university volunteer pool is racially diverse, with both genders well represented. Allowing young children whose parents did not attend college the opportunity to interact with this group of college students also provides an opportunity to expand the children's thoughts on the future education pathway that they might want to consider.

Impact on families

The WOW program was designed to improve schools' overall science programs. This includes elevating levels of excitement for science between students and teachers. In all of the WOW schools, students overflow with excitement when volunteers enter the classroom to begin new experiments. Students have actually chased groups of OSU volunteers down the school hallway, begging the volunteers to come into their classroom again soon. The students take their enthusiasm home with them, sharing experiences with parents and siblings, and often repeating and furthering their explorations with the help of their parents. Many participating schools asked WOW to help with family science nights so parents could learn more about the experiments their children had conducting with WOW. Attendance at family science nights was far greater than expected by school personnel, showing that WOW really is helping students take the excitement of science home with them. The inner-city schools had previously not attempted family nights because of very poor attendance at previous attempts.

The enthusiasm that is being generated is not just for WOW science activities, but for all science. At one elementary school before WOW began, 100 of the 600 students participated in the science fair, which the school holds every 3 years. The year after the WOW program finished, nearly 200 students entered projects.

Documented interest in WOW

Over 40 groups (including school districts) have requested information on how to begin something similar to WOW at their sites or have requested expansion of the OSU WOW program to their location during the past year. The Department of Chemistry of Muskingum College adopted the WOW program 3 years ago. This group serves primarily rural elementary school students near their location. The WOW Web site (http://www.wow.osu.edu) receives well over 150,000 hits per month from teachers and scientists around the world. Because of this reach, visitors from across the globe have visited the WOW program in action as well.

Summary

Science and technology innovations are likely to continue to be of utmost importance for maintaining a vibrant economy. Adequate science education is vital to populating the science and technology sector that drives this portion of the economy. Most scientists are quite enthusiastic about their area of expertise. A collaboration that joins the strength of the classroom teachers and the strengths of the scientists provides rich opportunities for intellectual growth for the teacher, K-12 students, and the scientist volunteers. Others are strongly encouraged to join science outreach efforts like WOW.

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