Despite national guidelines to reform K-12 science education, our students are not learning science any better. Conducted under the auspices of the American Association for the Advancement of Science, a symposium examined several programs where professional scientists interact with classroom teachers to improve science education. Symposium participants described their projects and discussed the factors that contribute or detract from each project’s success. The events of this symposium are critically analyzed. Four themes emerged as issues that affect the successful implementation and continuation of science education reform projects: scientific literacy as a primary goal, personal characteristics and commitment of project partners, curricular change built on social and developmental goals, and the incentive/reward structures in universities and school systems. This review of the emergent themes places the opinions of the symposium participants into the larger context of a growing science education research literature to inform others about synergy between professional scientists and classroom teachers. Our aim is to help others learn about the characteristics of effective partnerships to improve science education.

Key words: inquiry; scientific literacy; reform
and scientists representing the disciplines of chemistry, physics, mathematics, and physiology.

This AAAS symposium report examines the cumulative experience of those convened who described partnerships that address problems in K-12 science education. As former science teachers who now hold faculty positions in research science departments, the authors were invited to organize the symposium by the AAAS Pacific Division. Nancy Pelaez was a biology teacher when the American Physiological Society Frontiers in Physiology summer research program inspired her to seek a Ph.D. in vascular physiology from Indiana University School of Medicine. Barbara Gonzalez was a chemistry teacher before she completed a Ph.D. in education while working on educational projects in the UCLA Chemistry Department. The symposium speakers were selected on the basis of sustained scientist-teacher partnerships recognized by substantial national grant support.

One pattern that emerged was that concerns about students who are poorly prepared or who fail to find science interesting, or concerns about their own children and grandchildren being bored with school science, instigated the efforts of scientists who now work with schools. Because of their status as researchers, school teachers and administrators opened their doors to scientists such as Barbara Goodman, Robert DeHaan, and James Bower, providing opportunities for the scientists to satisfy their curiosity about K-12 science programs. These scientists and the teachers who work with them cared enough to ask, “If the kids are bored, but science is such an important and fascinating area, then what can we do and how can we change that?”

Some of the partnerships presented conflicting approaches to reform. But the AAAS symposium presenters provided evidence that professional scientists and classroom teachers who are predisposed to working at the interface between theory and practice converged on solutions with similar themes. Our aim here is to review the emergent common themes with reference to the science education research literature. Scientists who have joined the national trend to work with K-12 students, teachers, and schools are the beneficiaries of expert opinions about the characteristics of effective partnerships.

SYMPOSIUM GOALS

Speakers shared insights gained in the course of working in partnership efforts in diverse settings across the nation. All but one of the speakers are tenured university faculty members and principal investigators on a partnership project. Joseph Wise, a secondary school administrator and science teacher, offered an uncommon perspective to the symposium: that of a secondary educator who has participated as principal investigator, consultant, and participant in various projects that involve university partners. The speakers emphasized the importance of building a true collaboration between university scientists and the teachers and students in the K-12 classroom.

SYMPOSIUM AGENDA

American Association for the Advancement of Science
Pacific Division 82nd Annual Meeting
June 19, 2001
University of California, Irvine

**Calibrated Peer Review™: A Cross-Institutional Tool for Science Writing Assessment**

Symposium speaker: Orville L. Chapman, Professor of Chemistry and Associate Dean for Educational Innovation, UCLA Department of Chemistry

Teachers: science teachers of Crossroads School, Santa Monica, California and science teachers of Los Angeles Unified School District

Project outcome: Web-based curricular tools to improve writing in science.

http://www.molsci.ucla.edu/

**W. M. Keck Math/Science Institute: A Catalyst for High School Science in the Community**

Symposium speaker: Joseph A. Wise, Newroads School

Scientists: Walter Gekelman, UCLA, Gilbert A. Clark, Jet Propulsion Lab Telescopes in Education (TIE), and William Hamner and Steve Strand, UCLA Marine Science Center (Ocean Globe)

Teachers: Los Angeles Physics Teacher Alliance Group (LAPTAG)

Project outcome: community resources enhance secondary student participation in science research projects

http://www.ciel.org
A PERSONAL VIEW

Semi-Virtual Advanced Placement Chemistry: A University of California College Preparative (UCCP) Initiative

Symposium speaker: Arlene A. Russell, UCLA Senior Lecturer SOE in Chemistry
Teacher: Jeanette Coburn, Clovis High School Chemistry Teacher
Project outcome: The UCCP initiative broadens equity of access to improve rural secondary students’ eligibility for admission into the University of California through a hybrid course in advanced placement chemistry
http://www.uccp.org

Local Outreach Team (LOT) Approach to Outreach Activities for K-12 Teachers in a Large Rural State

Symposium speaker: Barbara E. Goodman, Associate Professor, School of Medicine, University of South Dakota
Teachers: Science teachers near Vermillion, South Dakota who serve educationally, financially, or socially disadvantaged students
Project outcome: development and field testing of inquiry-based physiology modules to teach K-12 students
http://www.usd.edu/~bgoodman

Elementary Science Education Partners (ESEP): Every Child a Scientist

Symposium speaker: Robert L. DeHaan, Candler Professor of Cell Biology Emeritus, Emory University Medical School
Teachers: approximately 1,700 teachers in 70 Atlanta K-5 elementary schools
Project outcome: teacher professional development as a means of improving science instruction through inquiry-based pedagogy in the Atlanta Public Schools
http://www.emory.edu/COLLEGE/ESEP/

Caltech Precollege Science Initiative (CAPSI): Multiple Scientist/Educator Collaborations

Symposium speaker: James Bower, Professor of Neurobiology, California Institute of Technology
Project outcome: teacher professional development as a means of improving science instruction through inquiry-based pedagogy in California school systems
http://www.capsi.caltech.edu/

EMERGENT THEMES

Although each project had its own unique goals, stakeholders, and context, four themes emerged as issues that affect the successful implementation and continuation of each one of the projects:

Scientific literacy as a primary goal
Personal characteristics and commitment of project partners
Curricular change built on social/developmental goals
Incentive/reward structures in universities and school systems

This review of the emergent themes attempts to place the opinions of the symposium participants into the larger context of a growing science education research literature. The opinions are not necessarily those of the authors. The ideas presented come from symposium speakers who were chosen for their experience and success with scientist and teacher partnerships.

Scientific Literacy as a Primary Goal

Science educators and national science education reform documents view scientific literacy as a primary learning goal. The general qualities of science defined in national science education standards parallel the constructivist view that knowledge is the result of a dynamic mental process for building conceptual understanding. AAAS reform documents emphasize that science ideas are subject to change, science demands evidence, and science is a complex social activity (15). Similarly, science educators report that “knowledge is a human construction rather than something that has always existed . . . scientific knowledge is constantly evolving rather than static, [and] scientists
and their ideas are influenced by the technology and social and political forces of their time” (Ref. 18, p. 387).

Orville Chapman, in his introductory talk, confirmed and expanded this view of scientific literacy with the idea that students must be able to articulate science ideas on paper and orally to be scientifically literate. Concerns about literacy question the approach of some scientists who treat learning as transmission of enough science information into the students. If learning is regarded, instead, as a process where science knowledge “is not discovered but rather constructed within communities of like-minded people” (Ref. 7, p. 475), then learning science must be treated as a process that requires critical thinking, the evaluation of information, synthesis of ideas, the testing of ideas and data through comparison against preexisting models, and the development of new models.

Calibrated Peer Review originated in September 1997, by Orville Chapman as an Internet-based learning and assessment tool. Built on the scientific model of peer review of writing, it also reflects the “writing across the curriculum” teaching reform movement that came from K-12 teachers. A problem in science education is that students are given only limited practice writing about science. Calibrated Peer Review makes it easy for teachers to create assignments where students must write to demonstrate their understanding through analysis and clear, concise expression, supporting their ideas with evidence. Social interaction remains an important part of the process as each student constructs scientific understanding. But Calibrated Peer Review adds another dimension in the form of individual accountability and assessment. Each student must organize thoughts and write scientific ideas with logic. Once students complete a writing task and the responses are submitted, they get three calibration essays to review for feedback on their performance as reviewers. Then three documents are peer reviewed before they finally return to their own document for self-review. Although not yet officially released commercially, Calibrated Peer Review has attracted funding from the National Science Foundation Division of Chemical Education and the Howard Hughes Medical Institute for life science applications. Both teachers and scientists have written assignments on topics that include physiology, evolution, chemistry, physics, and science education.

Writing as a means to reach the scientific literacy goal can be viewed as a form of teaching by inquiry. Michael Fullan defines inquiry as internalized “norms, habits, and techniques for continuous learning” (8). Like Calibrated Peer Review, the Ocean Globe, LAPTAG, LOT, CAPSI, and ESEP programs use an inquiry approach to learning in which students acquire knowledge and understanding of scientific ideas as well as first-hand experience with how scientists study the natural world. The emphasis is on learning by doing and discussing, and the priority is on scientific thinking skills and conceptual understanding. Large-scale efforts, particularly important for less affluent students across the country, are vulnerable because of the expense and demands on teachers. The AAAS symposium speakers agreed with the view that the current nationwide emphasis on accountability, with a bias toward easily tested factual knowledge, pressures schools away from inquiry-based science despite its emphasis in the national standards (1, 10, 15).

Joseph Wise, formerly of the Keck Math/Science Institute at Crossroads School, added the insight that teaching science through inquiry shifts expectations of a student’s role in learning from that of consumer toward that of producer: sharing in the excitement of creating knowledge through science. Wise’s view is that topics in print are the history of science, not science per se. Wise works with scientists in his community on projects such as Ocean Globe to help teachers open doors for students to become producers of scientific knowledge, not just consumers of science history. Robert Reich contends that, in the 21st century global economy, the nation will need many knowledge producers or symbolic analysts (13). Successful partnerships between teachers and university scientists can bring authentic science into schools in a manner beneficial to students. The context can be any topic under investigation by a local scientist willing to make science real by extending the work in directions that secondary students can do well. In contrast to real scientific investigations, school science experiences are usually set up with the equipment ready for predefined outcomes. But science happens when experiments produce unexpected re-
results. The subsequent potential for discovery makes science interesting for students.

**Personal Characteristics and Commitment of Project Partners**

Reform depends significantly on whether work is done by isolated individuals or whether groups exchange ideas, receive support, and share their feelings about their work (9, 14, 16). The group theme cuts across the range of strategies described by the symposium presenters. The structure of the UCCP Advanced Placement Chemistry course is quite different from the open inquiry used at the Keck Math/Science Institute. Both projects demonstrate benefits for students interested in science. Although Barbara Goodman’s LOT and Orville Chapman’s Calibrated Peer Review projects mainly impact teachers motivated to teach science, the ESEP and CAPSI projects target systemic reform through professional development aimed at all teachers. Regardless of the scope or aims, groups of scientists and teachers working together are key aspects common to all of these projects.

Substantive, meaningful contact between academia and schools requires a thoughtful process. Results do not simply stem from scientists’ approval of a standardized curriculum. One of the barriers that scientists encounter in developing effective programs is “failure to understand and take into account site-specific differences among schools” (5). Public schools experience unequal access to financial support from the government. According to Arlene Russell, “digital school” was not a reality for students from rural California schools in the San Juaquin Valley who enrolled in Semi-Virtual Advanced Placement Chemistry through the UCCP initiative. UCCP helps students at urban and rural schools eliminate disadvantage by providing access to advanced placement and honors courses. Online courses with a cybermentor are meant to reach students who do not have the opportunity to take advanced placement courses in their home schools.

Students from seven schools with seven different class schedules were enrolled in UCCP Semi-Virtual Advanced Placement Chemistry. The course was a traditional program with content organized by weeks. It became necessary to individualize the schedule, because schools with a large number of field workers start in August to provide for a long Christmas break when families travel to Mexico, whereas urban schools start in September. Lab was scheduled for Saturdays. When some students had band practice on Saturdays, make-up labs were established on Thursdays for those who missed a Saturday lab.

To complete the virtual chemistry course, students needed daily access to the Internet. For some students, the computers were across campus at the elementary school. Students who enrolled were required to have access to a computer with a CD-ROM, but two had computers that could play only music CDs. Two months into the program, it became clear that the students needed computers at home. Computers were provided with University of California support. The Internet-based course was very expensive. Some thought it would be cheap, but reaching the students was the goal. The cost of a computer is only a small part of the total costs.

The UCCP project described by Russell was actually a second effort. In the first attempt, students were given a videodisk but no teacher. The result was aversion to chemistry. Russell ascribes recent success to Jeanette Coburn, a chemistry teacher from Clovis High School, who understood and helped take into account the site-specific differences among schools. With a teacher as a personal contact to identify problems, the students developed positive attitudes toward chemistry.

The partnership between Russell and Coburn illustrates the power of personal commitment. Reflection via e-mail is easy, but Coburn needed to know that Russell would respond. The UCCP project worked only because Russell recruited the funding needed to solve problems that arose. These two individuals dedicated their time to help students understand the level of knowledge that colleges would require of them. Students in low-performing schools are isolated from the demands of academia. These students from rural schools benefited from exposure to the standard of excellence demonstrated by precollege students in other schools.

Wise identified three groups of high school students on the basis of their commitment to science projects: those who are inherently interested in science and...
make a serious commitment of their time, those who are friends of the inherently interested in science but whose commitment of time is tenuous, and those who are not interested in science and won’t commit their personal time to science projects. To justify funding to work with a few students, Wise used the data generated by the few and made that part of the curriculum for all students. The self-selected students committed to investigating science questions of local relevance collected data that were shared. For example, data generated through projects (e.g., LAPTAG, TIE, and Ocean Globe) were placed on the Internet so that other teachers and students could use the data to supplement classroom instruction. In some cases, teachers wrote Calibrated Peer Review assignments with guiding questions to help students analyze the data and perform at a higher level (12).

Goodman learned about commitment through 10 years’ experience with the American Physiological Society LOT program. A LOT is a science education partnership grant award that forms scientist-teacher teams, training both the scientist and the teacher partners. A LOT team consists of a biomedical researcher, local middle/high school teachers with support from their school administrator, and representatives from the local school system. Seven physiology teaching modules developed by LOTs have been approved by both scientists and teachers (3). Each module is inquiry based and includes assessment. The teacher partners who worked on the modules were self-selected and interested in science. Most did research in a biomedical lab with support from the American Physiological Society Frontiers in Physiology summer research program. Teachers worked with scientists for the production and improvement of new materials with the potential to be used by large-scale reform projects (8).

Some teachers feel uncomfortable around the expert scientist. Goodman commented on some differences in various LOT scientist-teacher relationships. She noted that some physiologists find it hard to stop talking long enough to listen and find out what the teachers have to offer. Scientists who continue with LOT acknowledge that they learn from the teachers. Effective LOT projects consider each partner as an equal: everybody is valued. Goodman notes that her South Dakota LOT teacher partners are secure in their knowledge and abilities as reforming science teachers. To work with teachers who are less secure in their feelings about science, scientists must demonstrate a willingness to learn. According to James Bower, “watered down lectures only reinforce in teachers the sense that they are not really capable of understanding scientific principles, reinforcing insecurity that many elementary teachers feel about science” (4). Caltech’s CAPSI and ESEP in Atlanta are two systemic reform initiatives that purposely place scientists in a context where they know very little, so that they model “investigation, critical thinking, imagination, and thinking on your feet with your hands, skills that are essential to success in scientific research” (4).

Symposium presenters agreed that both students and teachers enjoy interacting with scientists when the interaction is structured appropriately. Seeing a scientist struggle with a problem makes science fun. The scientists learn to communicate with the public and get regional and national recognition. Students get a better science education, and scientists learn about “the negative effect that poor teaching of science in colleges and universities has on the rest of the educational system” (4). Direct involvement improves programs and enlightens the project participants.

Curricular Change Built on Social/Developmental Goals

Curricular change is often directed at cognitive-academic goals, but a better solution may be to work toward achievement of personal/social/developmental goals (9). Cognitive-academic goals can be concrete and measurable, but some believe that such reforms are elitist and are aimed only at the academically talented. Developmental training is a key for programs that target reform aimed at all teachers in service to all students. Social/developmental goals target four groups of science education reform stakeholders: the students, the scientists, the teachers, and the administrators.

Perhaps the most important stakeholders in the science education reform effort are the students. All of the AAAS Symposium projects intended to produce an improved quality of science instruction that would lead to gains in students’ cognitive-academic and affective understanding of science. Although at first
glance the Semi-Virtual Advanced Placement Chemistry project appears to serve an academic elite with the least need for science reform efforts, the project really served as an example of how science can be the impetus for changing the opportunities of students. Even the best students from the San Juaquin Valley are at a disadvantage when applying for entrance to the University of California or other highly selective universities, because they have few honors or advanced placement courses listed on their transcripts. Russell soon realized that the impact of her project could not be judged solely on the number of students who successfully passed the AP Chemistry examination. The project was a vehicle for students to discern the possibility that they could study science at a highly competitive University of California campus.

Scientists who reform science teaching also demonstrate social-developmental growth. The ESEP and CAPSI programs demonstrate that scientists learn how to reform science teaching from other scientists. Bower’s development as a science education reformer started when, as an untenured Caltech faculty member, he visited Mesa, Arizona, where inquiry-based curriculum developed using National Science Foundation funding in the 1960s was in place in the elementary schools. Change begins with “disequilibrium,” or a realization that current practices cannot achieve current educational goals. Then, exposure to other methods broadens “awareness of possibilities for change and fosters a sense that alternatives are available” (Ref. 7, p. 443). Such awareness of the Mesa program led to the Pasadena Unified School District’s importing the CAPSI curriculum from Mesa. Caltech’s contribution was the personal involvement of scientists in the project.

Robert DeHaan studied several projects, including CAPSI in Pasadena, when he decided to develop ESEP into a project for science faculty to help improve science education in Atlanta schools. But when the Atlanta teachers were approached with the ESEP idea, there was discomfort. Teachers were afraid that scientists would impose upon them in their classrooms. One of the teachers suggested college science students. In 1995, e-mails were sent to scientists at Emory University, and 70 undergraduate students responded to the call to help teachers explore new ways to teach science. Focus groups provided feed-back showing the need for ESEP college student volunteers to be trained to support teachers. Undergraduate student ESEP volunteers now receive 12 hours of training before they enter a classroom. A commitment to an hour-a-week discussion section with a teacher leader and a scientist is part of each ESEP student volunteer’s semester-long relationship with one teacher. Symposium presenters agreed that learning from other projects and focus group discussions provides good mechanisms for developmental training of the scientists.

Programs must recognize teacher needs and expertise if they are expected to change school science education. This view, derived from ESEP’s focus group discussions, was confirmed by other AAAS symposium presenters and in the research literature on curricular reform efforts: “Science teachers must make the final decisions about the use of science materials in their classroom . . . based on unique aspects . . . including the basic needs of students . . . available resources, background of the science teacher, . . . the teacher’s understanding of science, and assumptions about students’ learning” (Ref. 7, p. 495).

To foster science education reform in a manner consistent with the need to achieve social/developmental goals, teachers need time for professional development, a supportive community, and the necessary materials (4). The ESEP idea of assisting in science instruction by partnering teachers with an undergraduate science major for three to four hours per week during a semester-long relationship was an acknowledgment of teachers’ need for time and support from the scientific community. The undergraduate science partner was an effective agent for change. Teachers who had a science partner to assist them were more ready to try new ways to teach science than teachers who did not have such a partner. But, although undergraduates helped, ESEP was built upon the premise that teachers with “...a greater sense of efficacy ... take action and persist in the effort required to bring about successful implementation” (Ref. 9, p. 84). So the teachers who were early adopters, the Science Knowledge Inquiry Leader (SKIL) teachers, received more than 180 hours of special professional development to run science teacher development sessions as mentor teachers. Kathryn Kozaitis, a cultural anthropologist, helped ESEP teach-
ers manage the change process. She was able to validate the culture of the teachers and schools while providing the nurture and support for the teachers to manage the process of reforming science education. The result was professional development of all 1,700 Atlanta Public Schools elementary teachers.

School administrators and district staff are the gatekeepers of reform and the fourth set of stakeholders for whom the goals are intended. They have the power to foster the professional learning communities that support teachers in their efforts to reform science education. Although some of the scientists who spoke at the AAAS symposium entered into their respective projects through the back door as parents when grants for the programs were developed, the principals and superintendents were approached as major players. In South Dakota, the Vermillion school superintendent created a program called “Scientist in Residence” to help teachers do more science. As a result, Vermillion students learned physiology: second graders walked to Goodman’s lab, fourth graders learned about lungs, sixth graders did electrocardiograms and heart dissection, and the Advanced Placement Biology class used actual red blood cells to demonstrate diffusion. But programs must be institutionalized to survive when superintendents, principals, and other curriculum leaders change. Without sustained support, even effective programs crumble because of rapid teacher turnover. ESEP and CAPSI project leaders learned this lesson. These projects now include a research component to evaluate and report on efficacy as part of the institutionalization process.

Incentive/Reward Structures in Universities and School Systems

Science faculty members in universities and colleges desire excellence in science education at all educational levels. However, most scientists place little value on their colleagues studying science education or working with teachers and students. The formal incentive and reward structure in academia does not always acknowledge this activity. According to the AAAS Symposium project leaders, incentives and rewards are needed to promote science education reform.

Given the status quo, only scientists like Chapman and DeHaan, who reach the top of the promotion hierarchy before becoming involved in science education outreach, are in good positions to advocate for teachers. AAAS Symposium participants cited several examples of junior faculty whose job status was compromised due to K-12 outreach. Goodman got tenure before she made K-12 outreach an official part of her academic endeavors. Then she negotiated with the University of South Dakota School of Medicine to get promotions based on her K-12 outreach work. But although her dean is supportive and allowed her to focus on education in place of bench research, problems persist with evaluation of her work. Other scientists do not recognize the work involved. Writing grants to work with schools takes time. Starting July 1, 2001, Goodman moved into a new position, where she will also be evaluated by the dean of the University of South Dakota Graduate School, with the expectation that this dean will be better able to recognize effort for promotion to full professor.

Others are also exploring ways in which science education can be recognized, evaluated, and rewarded within institutions. In May 1999, the American Physical Society adopted the position that “physics education research can and should be subject to the same criteria for evaluation (papers published, grants, etc.) as research in other fields of physics,” and that “the usefulness of physics education research is greatly enhanced by its presence in the physics department” (2). Mathematics offers more examples. The University of Tennessee at Knoxville hired an “Outreach Mathematician,” who will be evaluated on the quality of professional performance with measures that include “contacts with mathematics teachers and students, which improve the quality of mathematics learning” (Ref. 6, p. 1172). The University of Arizona College of Science adopted “procedures for evaluation of faculty members who play a substantial role in precollege mathematics and science education” with a Science Education Promotion and Tenure Committee to evaluate the impact on “the teaching and learning in mathematics and science. . . . Both the magnitude of the impact and its direction” are to be considered (11). A clear outcome of the AAAS Symposium was consensus on the need for measures of contributions in K-12 science education to be counted not as “service” but as “scholarly and creative activity.”
Teachers also need incentives and rewards for working with scientists. Support for the teacher could come from the school administration or from grants. Scientists have the “grant-writing and communication skills . . . often lacking in school systems” to support teacher partners (4). Teachers’ expertise must be acknowledged. Through community luncheons with students and scientists, Wise realized that students could build a scanning tunneling microscope, resulting in a grant from Research Corporation. Although only 17 students at 7 high schools built one, one of Wisec’s rewards was that, at his school, all students knew about scanning tunneling microscopes. His comment exemplifies a reward commonly mentioned by teachers as “the times I reached a student or group of students and they have learned” (Ref. 9, p. 119). Another reward from the change process is that teachers who partner with a scientist advocate a sense of professional empowerment. They no longer “feel like puppets—people pull our strings” (Ref. 9, p. 123). What is needed is “the process of creating and fostering purposeful learning communities” with integration of “development and accountability . . . in new cultures of improvement” where “everyone is implicated” (Ref. 9, p. 136).

Benefits of Science Education Reform

Many of the scientists involved in science education reform agree on a point expressed by Bower: “The most important personal consequence of my involvement with science education reform has been a growing awareness of how poorly I have taught my own students . . . I have become profoundly aware of the negative effect the poor teaching of science in colleges and universities has on the rest of the educational system” (4).

Bower also challenged the view that good K-12 science teachers are those who take more science courses. Teachers who have taken more science courses may be more likely to teach using the lecture-based approach (4). In contrast, teachers with fewer lecture-based college science courses may be more ready to change to inquiry-based science teaching methods, and comfort with science inquiry leads teachers to seek the additional science content knowledge needed. Scientists can model inquiry-based teaching and become better teachers for students who get by on rote memory. According to Goodman, active learning—learned from the teachers—helped medical students remember what was taught. Colleges and universities set the standards for the entire educational system. Curriculum controlled by faculty should be easiest for them to change, so the most important consequence of teacher-scientist partnerships may be a change in the way college science is taught.

RECOMMENDATIONS

In conclusion, scientists should be good listeners about science education issues to build relationships with schools and to take a stand. “To the extent that each side is ignorant of the subjective world of the other, reform will fail—and the extent is great” (Ref. 9, p. 86). Structures that allow scientists to work with teachers in ways that lead to long-term relationships are needed. Long-term relationships depend on equality of roles and on respect. Work with school administrators to institutionalize science education reform should be valued as more than just a service component of some scientist’s functions. With the Frontiers in Physiology program and LOTs, the American Physiological Society is taking steps toward establishing and recognizing important partnerships. Scientists who are finding ways to work with K-12 schools may make the most significant contribution of this involvement for students. Awareness of the characteristics of both good teaching and effective partnerships should improve science education at all levels.

Address for reprint requests and other correspondence: N. J. Pelaez, Dept. of Biological Science, College of Natural Science and Mathematics, California State University, Fullerton, 800 North State College Bl., Fullerton, CA 92834–6850 (E-mail: npelaez@fullerton.edu).

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