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Feature

Points of View: Effective Partnerships Between K–12 and Higher Education

Note from the Editors
CBE *is pleased to present "Points of View," a series designed to address issues faced by many people within the life sciences educational realm. We present several differing points of view back-to-back on a given topic to promote discussion of the topic. Readers are encouraged to participate in the online discussion forum hosted by* Cell Biology Education *at www.cellbioed.org/discussion/public/main.cfm. We hope op-ed pieces on Points of View will stimulate thought and dialogue on significant educational issues.*

In this issue, we address the question "How do we construct effective partnerships between K-12 education and higher education?" K-12 educators and college/university faculty share many interests, and need to work together to ensure effective teacher education and that curricula are articulated. Yet, we work in different settings; some would say different cultures. In Points View, we examine the needs and the responsibilities of our institutions of higher education to support K-12 science education, and examine how we can build interactions that recognize the strengths and help remedy the weaknesses of each partner.

The points of view we present in this issue provide a number of responses to those questions. We invite you to share your ideas, experiences and insights on the discussion board.

Building Successful Partnerships Between K–12 and Universities

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When I was a high school science teacher, my interactions with university faculty members were limited. Occasionally, depending on the district in which I was teaching, university faculty members in the region or state would send us letters inviting us to summer workshops and classes. My science teaching colleagues and I generally valued these opportunities because we believed the classes kept us up to date in our fields and knowledgeable about contemporary ideas and big questions in biology. We viewed these occasions largely as opportunities for ongoing professional development. Our relationship was based on our perceptions that the university faculty had expertise and knowledge from which we could benefit.

However, partnerships today between university faculty and K–12 teachers imply something more than an instructional relationship based on a one-way flow of information from an expert to his or her novice students. The construct of "partnership" implies direct benefits for all parties involved. Partnerships involve two or more people, each with expertise or skills to contribute, working toward a common goal. The idea is that something is there to be gained by everyone, an idea that is at the heart of the National Science Foundation's Mathematics and Science Partnerships (MSP) program, which is offered as a special initiative by the Directorate for Education and Human Resources. The common goal of the large MSP projects is to improve the science and mathematics learning of all students, K–12 through university. Today, partnership models are replacing one-time summer courses and workshops as vehicles for improving science, technology, engineering, and math (STEM) education in the United States. However, the ways in which partnerships between schools and universities become established and are maintained is not well documented.

One developing partnership that I have been observing with interest is at North Dakota State University. The project is called NDSU GraSUS: A Graduate Student-University-School Collaborative. I am the external evaluator for the National Science Foundation–funded GK–12 project. The GraSUS project involves placing graduate students in the STEM disciplines in year-long fellowships with practicing middle or high school science and mathematics teachers. One of the goals of the project, now in its fourth year of operation, is "increased collaboration between NDSU scientists and mathematicians and area middle and high schools." Thus, this led to the evaluation questions for my work, "What comprises the collaboration to which the project aspires?" and "Does the project collaboration represent a partnership between K–12 and university scientists, and if it does, how do we know it when we see it?" In its first year of operation, I was somewhat critical of the degree to which this project was advancing toward the goal of increased collaboration and partnership. Early on, the project was designed so that STEM graduate students, with input from classroom teachers to whom they were assigned and with supervision from university faculty, were to develop in-class activities at the university that could be transported, as it were, to middle school and high school classrooms. The idea was to enhance the science curriculum with inputs created at the university.

However, the GraSUS project leaders quickly recognized that the one-way flow of activities from the university to middle and high school classrooms created little reason for teachers to take ownership of the project or to consider using the activities that had been developed in the curriculum. The GraSUS project was modified so that teachers, rather than faculty and graduate students, originated the ideas for the curriculum enhancements. Teachers knew which units of instruction needed upgrades, and they were also aware of which areas in which they felt weak. The shift resulted in a substantial increase in interactions among the graduate students in the project, the teachers, and the supervising university faculty members. To document the increased collaboration, the project director began keeping records of all interactions and the reasons for them. The GraSUS project changed in less than 1 year from one with few interactions between faculty and teachers to one in which dozens of interactions occur each year.

I believe the GraSUS project is successfully documenting collaboration and growth of a partnership because the university-based project leaders realized early on that reasons for a partnership must be grounded in the needs of the teachers who will be making the decisions about how and whether to use the "products" that are created. High-quality activities and curriculum enhancements make a difference only if individual teachers regularly use them. With the GraSUS project, each graduate student fellow works on a different project. Yet, each fellow is involved in improving the educational experiences of the middle and high school students with whom they work. They accomplish this through activities the fellows create or revise in response to what a teacher specifically needs.

I also believe the GraSUS partnership is enabled by the presence of the graduate student fellows who serve as conduits between the university and school cultures. In other words, I do not believe the collaboration and resultant partnership would happen without the graduate student fellows. Their presence allows teachers' needs to be interpreted and then communicated to faculty members at the university. Because the graduate student fellows spend a significant amount of time directly involved with the teachers in their classrooms, they gain knowledge of the K–12 learning environment, which is largely invisible to many university faculty members. The fellows occupy a unique position in the project in that they can confidently communicate with teachers as well as with the university faculty members.

Finally, there is some evidence in my project evaluation data to suggest that the partnership is working both ways. Graduate students report that the year-long fellowships spent working with science and mathematics teachers in their classrooms and on curriculum enhancements has resulted in their own greater awareness and understanding of student learning and teaching. Some of the graduate student fellows I interviewed also reported changes in their own instructional approaches to laboratory courses they often teach at the university. As these graduate students are just now beginning to graduate and pursue academic or industry careers, we have only been able to speculate about how the project will affect their thinking and actions. A goal for the next several years is to document the ways in which the GraSUS project has affected the fellows and their careers.

In sum, successful K–12/university partnerships do not begin with what university faculty members believe must be changed in K–12 classrooms. Rather, successful partnerships develop in response to needs identified by practicing teachers for their specific classrooms and curricula.

Furthermore, curricular needs are best articulated by individuals who have dual knowledge of the science and the school learning environments in which the improvements will be implemented. Finally, successful partnerships involve university faculty members asking how involvement with K–12 schools and teachers can enhance the education of their own students.

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Science Education Partnerships: Being Realistic About Meeting Expectations

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Much of our science education professional literature is filled with detailed prescriptions of how to implement successful partnerships to enhance K–12 school science. These resources provide well-grounded recommendations about earning the support of administrators, teachers, and parents before beginning a new science program in schools. Quality curricula, adequate materials, and other physical resources, as well as professional development for teachers and appropriate evaluation strategies, are also identified as important elements in K–12 science education programs. Most science organizations and their representatives incorporate these elements to greater or lesser degrees into the school partnership they undertake. Certainly, in our work at the Center for Educational Outreach at Baylor College of Medicine (BCM), we apply the recommendations of the National Science Education Standards (National Research Council, 1996) and other similar resources to every extent possible in our partnerships with teachers, schools, and districts. We work closely with our colleagues in K–12 schools and strive to address mutual concerns and needs. In numerous cases, our partnerships have achieved measurable successes in developing teacher content knowledge, facilitating student achievement, promoting changes in teachers' science teaching practices, or fostering the emergence of local science education leaders (Moreno, 1999; Moreno and Tharp, 1999; Moreno, *et al.*, 2001, 2004). I suspect, however, that our experiences are not unlike those of many others who work as school partners within their local communities. In most situations, our partnership efforts yield sustainable outcomes. In a few cases, however, despite our best, well-informed and skilled efforts, we do not achieve the predicted changes in science teaching and learning. Which leaves us asking, "Why do partnerships sometimes fall short of expectations?"

The answer to this question is different in each instance. In some cases, intrinsic factors in schools work against innovations in science teaching and learning. In others, elements of the partnership itself prove to be inadequate for the challenges that arise during implementation. Based on our experiences, partnerships that do not meet expectations may have experienced one or more of the following pitfalls.

1. The partnership is one-sided. Even experienced science partners will sometimes fall into the trap of trying to be Superman. Unidirectional partnerships, in which one partner (Superman) single-handedly tries to rescue the other, rarely achieve their goals. Much more desirable is the Batman and Robin model, in which a more-experienced partner mentors a newer, or less-experienced partner; or the Superfriends model, in which each partner makes equivalent, but different contributions, based on needs and individual resources of the partners. These models are valid at all partnership levels, from individual scientist/teacher partnerships to institutional partnerships. The Baylor Science Leadership Program summer institute, which we conduct with HULINC, the Urban Systemic Initiative of the Houston Independent School District, is an example of a Superfriends-type partnership. This model evolved from a typical higher education summer institute offered to local elementary teachers to a true collaboration. The school district identifies critical content areas to be included in the institute curriculum, recruits and enrolls participants, pays stipends, conducts the technology training portion of the program, and holds school-year follow-up sessions. BCM plans the curriculum, manages purchases and logistics, provides all instruction using master teachers and scientists, and designs and conducts short-term and long-term evaluations. This combined program, provided to more than 800 teachers, has been much more effective in terms of increasing teacher content knowledge and science teaching efficacy beliefs than professional development delivered primarily by one or the other partner.
2. Science education is not given equal priority by all partners. Science research institutions sometimes assume that science teaching and learning should be of the highest priority in all K–12 schools at all times. Unfortunately, teachers and administrators are challenged daily by issues related to student test scores; inadequate facilities; parent concerns; drop-out rates; student mobility; needs of at-risk and disadvantaged students; students who speak English as a second language; and vast socioeconomic, racial, and ethnic diversity. It is not surprising that 29.5 percent of public school teachers surveyed by the National Center for Educational Statistics (2003) indicated that students come to school unprepared to learn. Thus, even when schools genuinely want to participate fully in a given science education initiative, administrators and teachers may have to divert their attention to other more immediate and pressing concerns. We have learned not to be disappointed when a scheduled meeting or teacher workshop has low attendance because, in many cases, teachers are unable to attend due to last-minute meetings or schedule changes at schools. For important in-service sessions, we schedule make-up days or work one-to-one with teachers.
3. Partnership activities are viewed as an add-on in schools. Within the current climate of accountability and high stakes assessments, schools feel pressured to focus on topics within the curriculum that will appear on student assessments. The challenge to science partners is to identify science themes that will engage students in real issues, but also build skills and basic understandings of content areas that will appear on standardized tests.
4. Minimum physical resources for science instruction are not in place. Many elementary schools, in particular, do not have adequate classroom or laboratory facilities for conducting hands-on science activities. A standard joke among elementary science teachers is, "Oh yes, I have running water in my classroom . . . I run down the hall to bring back a bucketful." Middle and high schools usually have laboratory-style classrooms, but may have outdated equipment or lack funds to buy needed consumable materials and supplies. Thus, a science education partnership that provides hands-on, inquiry modules or kits to teachers, for example, also should

develop mechanisms for the refurbishment of consumable supplies, so that the kits may be used for instruction year after year.

5. Professional development does not match the needs of teachers. Recent studies have shown that, nationally, 24 percent of secondary school classes in core subjects are taught by teachers lacking even a college minor in those subjects. In the nation's high-poverty schools (more than 50 percent of students eligible for free or reduced lunch), the percentage of teachers teaching out-of-field increases to 34 percent (Jerald, 2002). As a result, science partners who provide professional development need to be prepared to address differing levels of knowledge and preparation among participating teachers. Over time, we have found that preassessments can help identify areas needing special attention during workshops or teacher institutes. Feedback from teachers about what works in classrooms also can be very helpful.
6. Mismatch between professional practices of scientists and K–12 teachers. As noted by Tanner *et al.* (2003), scientists and teachers work in environments that encourage different kinds of behaviors and require different kinds of knowledge. Scientists are highly specialized, with access to abundant scientific and academic resources, and are accustomed to providing critical or skeptical feedback to colleagues. Teachers, on the other hand, have broad knowledge, work in environments with limited or scarce resources, and typically provide encouragement or constructive feedback in their interactions with learners or colleagues. As a result, partnerships in which scientists and teachers are expected to work together can be diminished by clashes between these two cultures unless the differences are appropriately anticipated and addressed. Otherwise, scientists may be disappointed in the lack of appropriate equipment in schools, or teachers may find scientists' probing style of asking questions intimidating or offensive. At BCM, we conduct two programs that partner local teachers and scientists. The Howard Hughes Medical Institute–funded Science Education Leadership Fellows program teams elementary teachers and BCM graduate students or postdoctoral fellows. Our GK–12 program, which is funded by the National Science Foundation, partners high school biology teachers with BCM graduate students. In both programs, members of the most productive teams have learned to appreciate each other's expertise and learn to build on each other's strengths. Strategies that we have found to be effective in promoting productive teams include 1) having scientists co-teach under the guidance of teachers in K–12 schools, 2) allowing teachers to experience the world of science through short research projects at BCM, and 3) requiring scientists and teachers to work together to develop a specific product, such as a curriculum unit or an instructional video.
7. No time to develop a culture of professional learning and improvement in schools. Many K–12 teachers feel overwhelmed by the demands placed on their time by students, parents, and increased accountability and paperwork requirements in schools. This leaves no time for professional and collegial activities such as co-planning or mentoring. Further, in many cases, teachers must use their personal time after school or on weekends to complete professional development requirements. In order to collaborate effectively, science partners need to be sensitive to existing demands on teachers' time and energies.
8. Partnership is not sustained long enough to achieve results. Educational reforms take time. Some partnerships require 10 or more years to achieve desired outcomes in teaching and student learning. Unfortunately, most grants for science education partnerships provide support for only three to five years. Finding ways to nurture and sustain partnership activities beyond the initial grant period is one of the greatest challenges and obstacles to the success of partnerships.

Being aware of some of the pitfalls is the first step in building productive partnerships. Some of the following approaches can be useful.

1. Value all partners. Superman saves the day only in Hollywood. Real partnerships are much more productive when the contributions of all participants are valued and recognized. Effective partners jointly identify needs, and plan and work together to solve issues such as those related to resources in schools or to find appropriate times for teacher professional development.
2. Involve only those who want to participate. Unwilling partners are not effective. In projects involving individual teachers, enroll only those who are willing to participate. Often, more reluctant teachers will join in once other teachers begin to experience success. At the levels of schools or districts, administrative cooperation and buy-in is essential if partnership goals are to be achieved.
3. Pitch your teacher professional development to the appropriate level. Many teachers, particularly in elementary schools, have been trained to teach reading or language arts. As a result, teachers may feel nervous about teaching science because they have had few opportunities to experiences science inquiry for themselves. Being aware of the current teaching practices and knowledge levels of partner teachers is an important part of providing appropriate teacher professional development.
4. Deliver what you promise. If you promise kits, make sure they arrive on time. If you provide a workshop, make sure it meets the needs that teachers and students identified.
5. Stick around. K–12 education is plagued by programs and instructional strategies that last a couple of years and disappear. In order to be taken seriously, partners from science institutions need to collaborate consistently over time.
6. Focus your efforts where you can make a difference and do not be afraid to go elsewhere. Every so often, partnerships come up against intrinsic or extrinsic factors that will make achieving project goals almost impossible. When this happens, do not be afraid to acknowledge the situation and reallocate your limited resources to where they will be more effective.
7. Create a winning environment. Teachers, scientists, and their institutions have a lot in common. They have chosen a service profession and focus on making things better for society. It's hard work and little recognition ever comes their way. Open and frequent communication, in addition to shared credit for accomplishments, works to build trust and friendships.

Finally, and most important, sometimes it is necessary to adjust the definition of "success." Thus, while partnerships sometimes may fail to meet original expectations, they may generate successes in ways that were unanticipated. For example, not all teachers may become enthusiastic science instructors after one professional development program—but that one teacher who did get excited may some day become a science specialist and influence curriculum decisions for an entire school district. We have learned that it is not realistic to expect immediate changes in teaching and learning as a result of science education partnership activities. Change can happen, but it takes time.

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REFERENCES

Jerald, C.D. (2002). All talk, no action: putting an end to out-of-field teaching. Based on data analysis by Richard M. Ingersoll, University of Pennsylvania. Original analysis for the Education Trust of the 1999–2000 Schools and Staffing Survey. Education Trust, August. http://www.edtrust.org/main (accessed 18 November 2004).

Moreno, N., Griffin, R., Denk, J., and Jones, W. (2001). Real-world science: achieving better returns in student learning. School Business Affairs *67*(8), 17–19.

Moreno, N. (1999). K–12 Science education reform: a primer for scientists. Bioscience *49*(7), 569–576.

Moreno, N., Tharp, B. (1999). A national interdisciplinary project developed at Baylor to make science exciting for all K–5 students. Acad. Med. *74*(4), 345–347.

Moreno, N., Denk, J., Roberts, J., Tharp, B., Bost, M., and Thomson, W. (2004). An approach to improving science knowledge about energy balance and nutrition among elementary- and middle-school students. Cell Biol. Educ. *3,* 1–9.

National Center for Educational Statistics. (2003). Digest of Education Statistics, 2003. Teacher perceptions about serious problems in their schools, by control and by level of school: 1993–1994 and 1999–2000. http://nces.ed.gov/programs/digest/d03/tables/dt072.asp (accessed 15 November 2004).

Tanner, K.D., Chatman, L., and Allen, D. (2003). Approaches to biology teaching and learning: science teaching and learning across the school–university divide: cultivating conversations through scientist–teacher partnerships. Cell Biol. Educ. *2,* 195–201.

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Modern Genetics for All Students: An Example of a High School/University Partnership

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Teaching laboratory science in a high school setting has never been easy. Time is available in short blocks; laboratory facilities are often quite limited. In most American high schools, teachers are responsible not only for preparation of their lesson plans, but also for ordering and preparing any materials to be used in a lab, with little or no technical support. Nonetheless, there is an expectation that science instruction will be inquiry-based, giving students opportunities to carry out their own investigations of the natural world. In biology, the challenge is compounded by the fact that the field is changing rapidly, with new information, experimental approaches, and social issues arising at an increasing rate.

With these concerns in mind, a group of Washington University (WU) faculty invited the science teachers at a local high school, University City, to meet with us in 1989 to explore ways that we could work together to find ways that the strengths of the university could be used to support local high schools. Our brainstorming sessions concerning biology became focused with the opportunity to apply for a Science Education Partnership Award (SEPA) from the National Institutes of Health (NIH). A particular concern of the teachers was to find ways to incorporate DNA science into their curriculum while maintaining a grounding in genetics, but adding hands-on experiments that would help students to understand the science underlying developments such as personal identification through DNA samples, the sequencing of the human genome, and other recent advances with societal implications.

In preparing our grant application for NIH, we identified two important limitations that could be overcome by appropriate use of the funding. First, while both university and high school faculty come up with great ideas when brainstorming together on new teaching tools and labs, neither group has the time to render these ideas into well-written, lab-tested classroom materials. It is essential to identify individuals with good writing skills, a solid science background, and classroom experience to become "lead writers/organizers" for the project. This person must have salary support from a grant (or other sources) to allow him or her to devote appropriate time to the project. University and high school faculty will make essential contributions at every step, from first draft, to testing, to critique and review, but the lead writer is the person who then goes back and generates the revised text using the results from critique and discussion. Second, while university faculty generally has enough flexibility to be able to arrange meetings with colleagues, high school faculty frequently does not. To overcome this obstacle to a group effort in writing and implementation, we budgeted funds to provide an extra science teacher for the high school, allowing the high school administration to create a schedule with all biology teachers having an extra, common planning period to work together with us in creating *Modern Genetics for All Students*.

Our goal was to design curriculum materials that could be used throughout the St. Louis area, in any of the 30-plus public school districts, or in private or parochial schools. This creates a second set of challenges. Each district or school has its own curriculum, and several different textbooks are in use. Thus the unit needed to be sufficiently complete to be used as such, without other supporting materials, but also flexible enough to be incorporated into a wide number of different ongoing biology curricula. Thus the core of our curriculum development effort became the generation of a number of activities—wet labs, simulations, model building, discussions, or role playing—that would engage students and could be incorporated into any first-year high school biology class. Flexibility is critical; some schools will use all of the activities, some only a few, the decision often being driven by available time. As biology textbooks get thicker and thicker, one cannot simply add a new unit (e.g., "Molecular Genetics") to the curriculum. One must instead provide teachers with materials that allow them to strengthen the work in a given portion of their current curriculum. It is essential to provide a "guide" to *Modern Genetics,* showing where each experiment or activity can be used to advantage with any of the several textbooks commonly in use. More recently, we have also prepared a similar guide showing how the use of *Modern Genetics* allows schools to help their students meet the science standards for the state of Missouri.

Both high school and university faculty agreed that our curriculum project should be targeted to students taking their first high school biology course. While most high schools encourage taking more science, only two year-long science courses are required for graduation in Missouri (and many other states). Thus, if we are to reach all of our citizens, we must target the first-year biology course. The development of DNA science in the United States—the advent of methods of gene cloning and analysis, the sequencing of the human genome, and so on—has been fueled by tax dollars, and we felt it important that all citizens have an opportunity to learn about what their tax dollars had purchased. In order to exercise their right to genetic privacy, to make use of genetic information when it might help the family to make health care decisions, and to contribute to the dialogue on how DNA technology should be used, all students need to have a basic understanding of genetic principles and the availability of DNA sequence information. This decision, however, generated a further challenge: that of choosing language that was both scientifically accurate and accessible to this audience. Here the collaboration of university and high school faculty was absolutely essential. Accurate simplification requires a deep understanding of the science involved, while generation of accessible information requires the teacher's knowledge of the student. Careful work and many revisions are required to achieve the right balance—minimizing jargon while at the same time teaching vocabulary, providing guidance and examples while at the same time stimulating problem solving.

The current version of *Modern Genetics for All Students* is now available in print or on the Web (http://www.so.wustl.edu/) and includes both student and teacher materials. The four chapters are "DNA: The Hereditary Molecule" (which includes spooling DNA, modeling DNA structure, the gene expression dance, and transforming bacteria with *lux* genes to glow in the dark), "Passing Traits from One Generation to the Next" (which includes sea urchin fertilization, modeling inheritance with Reebops and other simulations, a genetic cross with yeast or Fast Plants, and an introduction to the chi-square test), "How Genes and the Environment Influence Our Health" (which includes inducing mutations with UV light, examining heart disease, and investigating human genetic disorders using gel electrophoresis), and "Controlling Our Genetic Futures" (which includes a discussion of the *Promise & Perils of Biotechnology: Genetic Testing,* from Cold Spring Harbor Laboratory Press, and an introduction to group decision making, with two case studies to challenge the students to resolve issues resulting from genetic testing).

In assembling *Modern Genetics,* we made use (with permission) of many excellent materials developed by others, creating de novo materials only as needed. The current version represents more than 10 years of testing in local classrooms, with several rounds of revision. Assessments to date show the materials are effective, as measured by average learning gains on pretests and posttests; a more intensive assessment is currently under way. However, DNA science continues to move ahead at a rapid rate, and we are now in the process of creating additional chapters that will provide material for either an honors first-year or a second-year biology class, including human genome sequencing and implications for health care, how plants are transformed and the implications for agriculture, and other recent developments. Both the materials developed for *Modern Genetics* and the "workshop" style of teaching commonly practiced by high school teachers are now being used in a course (DNA Science: A Hands-on Workshop) for nonscience majors at WU.

Developing curriculum materials is of no practical value if teachers cannot implement them, and again, our partnership between high school and university faculty has been essential in developing a practical implementation model. After development work with University City High School, the partnership was expanded to test the materials in urban, suburban, and rural high schools in the St. Louis area. Implementation of *Modern Genetics* is most effective if the "unit" for joining the project is the high school; specifically, all of the faculty teaching first-year biology need to agree to implement this change together. Administrative support is essential; we ask the principal, the science coordinator, and the superintendent for curriculum to write a letter of agreement as part of the partnership development. As the number of participating schools has grown (now more than 20 and adding 3–4 each year), recruiting new schools to the project has not been difficult. Teachers appreciate the opportunity to work together and to work with the university.

For a high school to implement *Modern Genetics,* three things are needed in addition to commitment: teacher training, start-up equipment, and classroom-ready supplies and support. Many current teachers received their formal training before DNA science was commonly taught to undergraduates. We provide a one-week (full-time) summer workshop to provide background in molecular biology, an opportunity to work through most of the *Modern Genetics* activities, and presentations and discussions with WU researchers and other users of DNA technology. The workshop (which can be taken for graduate-level academic credit) is a joint responsibility, engaging both current WU staff and high school teachers already using *Modern Genetics* who can speak knowledgeably about classroom implementation, providing coaching in this regard. To date, we have been able to support direct costs of the workshop from grant funding, but the school districts provide the stipends to support their participating teachers. Each school joining the project also needs a start-up set of equipment (pipettors, gel rigs, power supplies, etc.). A basic classroom set is provided from grant funding, and additional loaner equipment is available. In some cases (usually following the first year of implementation), an enthusiastic Parent-Teacher Organization (PTO) has provided additional funds to expand this base.

As noted above, most high school teachers do not have access to technical support, and many are with students almost all of their working day. Thus an experiment requiring sterile agar plates has required either a substantial supply budget to purchase these or a teacher willing to spend the weekend with a pressure cooker to prepare same. The sort of preparation facilities available at most universities can be used to overcome this problem, and provide economies of scale. We have prepared order sheets that allow teachers to specify when they need materials for a given lab, how many students are in each class, and so on. We then generate materials in a classroom-ready form—including those sterile agar plates, aliquoted samples of competent Escherichia coli and DNA, and so on—and deliver these to the school when needed. If a teacher would like support during the first year when implementing a new, technically demanding lab with his or her students, a member of the WU Science Outreach staff will arrange to be with the teacher in the classroom that day. If things go "wrong" (e.g., no transformation! no DNA bands on the gel! etc.), WU staff will troubleshoot, checking the materials and working with the teacher to identify the problem. Support is provided by dedicated Science Outreach staff, with faculty assistance as needed. This support helps teachers overcome a natural barrier to implementing new materials while working with large numbers of students, generally on a tight schedule. In teaching high school biology, there is no time to go back and do something over, so a high success rate in lab work is essential! The different venues of communication help us to develop a personal relationship with each teacher and each school. During the first two years of implementation, WU provides supplies at no cost to the school, using grant funds for this purpose. Starting the third year, we ask schools to pay the cost of raw materials for the supplies they order, while still using core grant support to cover the cost of preparing and distributing materials. Most of the experiments described in *Modern Genetics* can be implemented at a total cost of about $3 to $4 per student per year (for raw materials) under this scheme. The exception is sea urchin fertilization, a wonderful lab experience, but expensive in the Midwest!

On the whole, we count the *Modern Genetics* program a success. All of the partner high schools that have joined the program remain affiliated, and others are eager to join us, as resources become available. Our continuing dialogue with high school teachers has informed our efforts to improve beginning undergraduate instruction at WU, both for majors and nonmajors. The most significant problem in maintaining the program is turnover of staff, both at the university and at the high school. Depending on their backgrounds, new university contributors may have a steep learning curve as they develop the appreciation to embrace both the science involved and the committed teaching environment of the high school. Teachers new to a partner school may not "buy in" to the same degree as those making the original commitment, and they often need an opportunity to participate in the summer workshop. Without strong leadership within a high school, the original commitment can disappear, as a new superintendent, new high school principal, and/or new biology teachers arrive on the scene; in urban schools, such turnover can easily be in excess of 100% in 10 years.

Nonetheless, the partnership that forms the basis for *Modern Genetics* is now becoming woven into the fabric of the St. Louis educational community. The summer workshop has become a WU standard summer school course. While sustaining the *Modern Genetics* program represents only one way in which a university and its surrounding high schools can work together, it provides a cornerstone for us, creating a pool of university and high school faculty who know each other and are comfortable working together. This in turn can provide a foundation for many kinds of interactions, positions us as a group to take advantage of funding opportunities targeted to partnerships, and is building a stronger educational community for the St. Louis area.

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Moving from Outreach to Partnership: Striving for Articulation and Reform across the K–20+ Science Education Continuum

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> Scientists and engineers working in partnerships with local teachers represent an essential new force that will be required for effective science education reform... But to be effective, we scientists must first be willing to be educated about the opportunities and problems in our schools. This means that we must approach this problem with a humility that reflects how little most of us really understand about how children learn, as well as our respect for the tremendous energy, devotion, and skill required to be a successful K–12 teacher in today's schools.
> —Bruce Alberts, President, National Academy of Sciences

One would be hard-pressed to find a college or university in the United States without at least one outreach program designed to support science education in local K–12 schools. Over the last three decades, scores of thriving science education outreach programs have had significant and extraordinarily positive effects on K–12 science education. Driven by funding initiatives from federal, state, and private agencies and the pioneering efforts of many university scientists and K–12 educators, these programs have resulted in increased communication between institutions, innovative K–12 science curricula, greater presence of scientists in K–12 schools, and an increased interest in collaborations among K–12 teachers and students and university scientists and students. Many outreach programs, including our own, have made successful initial forays into K–12 science education reform. Yet, they have been largely unidirectional in their goals and activities, focusing primarily on the challenges and shortcomings of K–12 science education. In looking forward, we propose that the role of institutions of higher education must change, moving from initial efforts in outreach, a stance characterized by offering expertise and supporting external reform, to a more enduring approach of partnership, which demands that both partners examine their own science teaching and learning and promote both external and internal reform. Many wonderful outreach programs that have not been bi-directional in their goals and activities are poised to blossom into partnerships in which K–12 teachers and university scientists collaborate to create a coherent and articulated science education experience for students across the K–20+ science education system (Tanner et al., 2003).

In this Point of View we argue that crafting effective science education partnerships requires moving beyond K–12 science education reform and toward examination of the connections and disconnections between K–12 and university science pedagogy. In particular, we believe that three major shifts must occur: 1) the adoption of a mutual learning model of partnership, 2) the integration of partnership into the training of scientists, and 3) the development of sustained infrastructures for partnership. Such shifts, we believe, are the stuff of Kuhnian revolutions and could catapult us toward what we all desire: a coherent, articulated, and inquiry-based approach to science education from kindergarten through graduate school.

A MUTUAL LEARNING MODEL OF PARTNERSHIP

Few would question that legions of university scientists and K–12 educators share a common interest in improving science education for our nation's young people. In our opinion, however, an effective reform effort must be grounded in a genuine commitment to mutual learning. In many instances, relationships between the K–12 and university systems have adopted a "provider-recipient" approach in which scientists are placed in the role of content providers and K–12 educators as recipients of this scientific expertise. We believe that this approach overlooks a rich opportunity for deep reflection about science teaching and learning. The old adage that "we teach the way we are taught" places university scientists in a position of great influence in the pedagogical training of future science teachers. In addition, college and university faculty have both the opportunity and responsibility to engage their students in deep science learning and to guide them in becoming scientifically literate citizens. Consider the words of senior scientist and long-time science education reform leader, James Bower:

> In this workshop, I was, as usual, haranguing the participants about the importance of inquiry-based science teaching. Accordingly, there was an almost audible sigh of relief when I announced that I had to leave to give a lecture on the neural control of eye movements. Fortunately, I had remembered to bring my lecture notes to the workshop, so I could maintain my fervent support for inquiry teaching techniques up to the very last second. However, as I rushed to the lecture hall, it occurred to me what I was about to do. ... At that moment a connection was made between my experiences observing outstanding elementary science teachers and my own responsibilities as a science educator. For the first time I realized that I had not done the hard work of converting what I preached into what I practiced. All my zealous efforts at early science education reform had not, until that moment, penetrated my own approach to science teaching.
> —James Bower, Professor, California Institute of Technology and Co-Founder of the Cal Tech Pre-college Science Initiative (CAPSI)

Partnerships are outstanding venues through which scientists grapple with their knowledge about teaching and to learn from professional educators. As a scientist, what have you struggled with in your own teaching experiences? What is your philosophy and how does it influence your approach to assessing what students know, addressing students' misconceptions, using appropriate vocabulary, involving all students, engaging multiple learning styles, and managing classroom behaviors? What teaching strategies and skills could you learn from your teacher partners? In addition to scientists adopting a learning stance, K–12 teachers must also be willing and given license to share their expertise about teaching science to young people. With partners taking on these additional roles, collaborations can shift from a provider-recipient model to a mutual learning model. While some individual programs have gravitated toward mutual learning, the National Science Foundation's recent Math Science Partnership (MSP) initiative has been pioneering in its requirement that proposed programs identify and pursue reform strategies in both the K–12 and collegiate settings. Yet, with the anticipated conclusion of the federal MSP initiative, this driving force for a mutual learning model of partnership may wane just as it is beginning.

INTEGRATION OF PARTNERSHIP INTO THE TRAINING OF SCIENTISTS

Because many of the scientist partners engaged in collaborative work with the K–12 system are graduate students, postdoctoral fellows, and other scientific trainees, science education partnerships provide a wonderful opportunity to integrate teaching and learning into the routine training of scientists. There is emerging evidence from many efforts that scientists, unsurprisingly, benefit from their involvement in partnerships with K–12 educators with respect to their communication and pedagogy skills (Tanner, 2000). In addition, the majority of these trainees will go on to teach undergraduates. Yet most join partnerships and pursue careers as university faculty without even a crash course in the teaching and learning of science. How can partnerships explicitly engage trainees in reflection and scholarly learning about their emerging teaching practice? How can course work in pedagogical methods be integrated into the training of future scientists? What roles can K–12 educators play as teaching mentors for scientific trainees? Although a few outreach programs have offered formal training in science pedagogy for scientific trainees, the NSF has once again led the way with the GK–12 Fellowship Program. More than 100 institutions around the country now engage science, math, and engineering graduate students in intensive partnerships with K–12 teachers and students, supplemented by course work on the theory and practice of science education. Still, we are decades away from the systematic inclusion of training on science pedagogy in the preparation of future scientists.

DEVELOPMENT OF SUSTAINED INFRASTRUCTURES FOR PARTNERSHIP

> Working with K–12 schools is not like crop dusting—you can't just sprinkle information around and go away. New students come each year who can benefit from school partnerships with universities. There needs to be a long-term, sustained and sustainable relationship.
> —Mary Margaret Welch, Mercer Island High School, Mercer Island, WA

What efforts and infrastructure are necessary to foster large-scale K–20+ partnerships? Although each partnership has unique needs, sustained infrastructure is necessary to support long-term programming and innovation, rather than efforts developed and supported on a grant-by-grant basis. The mundane but crucial infrastructural needs of partnerships include money and space, but these alone are insufficient for strategic development of programs by numerous stakeholders from multiple participating institutions. Universities and K–12 institutions have limited resources to develop and sustain partnerships without grant funding. How can decision-makers at both types of institutions be convinced to use scant resources to foster partnerships? Coordinated efforts across departments and colleges would begin to build a sustainable infrastructure in which partnerships could endure and expand. Yet, only through a shift from the mindset that partnership is an admirable but dispensable community service to an acknowledgment that partnerships generate internally valuable knowledge, will the commitment of resources be justified and infrastructure established. Such a shift requires changes

Table 1. Changing emphases

Moving away from...	Moving toward...
Outreach	Partnership
Reform of K–12 science education	Reform of K–20+ science education
Provider-Recipient model in which university scientists provide content expertise that K–12 educators receive	Mutual Learning model in which university scientists gain pedagogical skills and insights, and K–12 educators learn about the culture, content, and process of science
Individual, isolated science education programs and efforts	Institutionalization of multiple, coordinated programs and efforts within university science departments and K–12 school districts
Science education efforts as optional service by some scientists within some universities	Science education efforts as an integral part of the scientific endeavor in universities that is acknowledged and rewarded
Universities develop science education programs that are offered to K–12 schools	Universities and K–12 schools collaborate to determine disconnects across the K–20+ continuum of science teaching and learning and work together to develop mutually beneficial programs
Universities and K–12 schools operate in isolation	Universities host teachers learning scientific content and experiencing research, and K–12 schools host scientists learning pedagogy

in scientists' perception of the boundaries of science and in the reward structures within colleges and universities, as well as cross-institutional planning and commitments. In looking toward the future, the development of sustained infrastructure is furthest from reach, with no clear driving force for reform in this direction.

THE CODA: MOVING FROM OUTREACH TO PARTNERSHIP

We believe that effective science education improvement lies in moving from initial outreach to sustained partnership, considering K–20+ science education reform as a discipline within the realm of responsibility and expertise of the sciences. Such a movement will require changing emphases in university and K–12 relationships, as highlighted in Table 1. Although there are seeds of change in institutions all around the country, we present this as a vision for the future, because no effort we are aware of, including our own, has conquered all of these challenges or achieved all of these goals. Much as the National Science Education Standards put forward Changing Emphases tables as roadmaps to a vision for K–12 science education (National Research Council, 1996), the table represents ideas to ponder in moving from outreach to partnership, not goals already achieved nor easily reached.

AN EMERGING DISCIPLINE OF K-20+ SCIENCE EDUCATION PARTNERSHIP

Finally, we believe that a movement from outreach to partnership can serve as the groundwork for a new discipline of science education partnership. As efforts in this arena are increasingly studied, theorized, and assessed, one can sense a scholarly field operating at the intersection of teaching, learning, cognitive theory, assessment, and inquiry, developing its own theoretical underpinnings, standards of evidence, and professional specialization. Consider the field of neuroscience, in which we were both trained. This discipline developed at the intersection of psychology, biology, cognitive science, and chemistry. Thirty years ago, there was no distinct field of neuroscience, no Society for Neuroscience (now 30,000 members strong), no *Journal of Neuroscience*, no doctoral degrees awarded in neuroscience, nothing but a strong vision for a new field of inquiry that could address driving questions about brain and behavior that were unstudied and under-theorized. What are the implications for the field of science education partnership, currently understudied, under-theorized, and lacking in field-based studies of specific models? Science education partnership may not ever enjoy the expansive growth and lucrative funding that neuroscience has. Yet, increasing study of partnerships that are achieving the shifts described above will produce an evidence-based literature that can guide the development of theoretical frameworks for successful partnerships and make this vision for the future a reality.

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REFERENCES

Alberts, B. (1994). Scientists have important roles, responsibilities in future of science education. National Academy of Science's Resources for Involving Scientists in Education. http://www.research.att.com/~kbl/APS/nov94/alberts.html (accessed 19 December 2004).

Bower, J. Scientists and science education reform: myths, methods, and madness. National Academy of Science's Resources for Involving Scientists in Education. http://www.nas.edu/rise/backg2a.htm.

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

Tanner, K.D, Chatman, L. and Allen, D.E. (2003). Science teaching and learning across the school-university divide—cultivating conversations through scientist-teacher partnerships. Cell Biol. Educ. 2, 195–201.

Tanner, K.D. (2000). Evaluation of scientist-teacher partnerships: benefits to scientist participants. National Association for Research in Science Teaching Conference Paper, New Orleans, LA, April.

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