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Teaching Biophysics

Strategies for Recruiting and Retaining Minorities in Physics and Biophysics

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ABSTRACT Several strategies directed toward increasing the participation of minority students in physics and biophysics are presented. Since the number of minority students entering college with an interest in science and mathematics must be increased if we expect to see more students graduating in science, several programs aimed at increasing the level of instruction of physics and biology in urban middle schools and high schools are outlined. We also describe approaches designed to increase the retention of science majors during the freshman core physics course where many potential science majors are lost. Increasing the number of minority students at the PhD level will rely increasingly on partnerships between research universities and historically black colleges and universities (HBCUs) and several programs already in effect are given as examples of such linkages.

INTRODUCTION

Recent articles have focused on the under-representation of women and minorities in science and stressed the importance of recruiting and retaining women and minorities at the undergraduate level in order to increase their numbers at the PhD level (1–5). The studies targeted areas where efforts must be directed if we are to reverse the present trends. The most significant loss of potential minority science students occurs before high school graduation, and efforts to increase the pool of minority students who enter college with an interest and background in science must begin by addressing problems with science education at the pre-college level. Most minority students attend urban public schools. Since these schools are acknowledged by many as failing badly in science and math teaching, special efforts are needed in these schools. Our approach is based on the observation that urban teachers struggle with real exigencies of urban life in their classrooms, while scientists, often a short distance away, conduct experiments at the forefront of science, completely isolated from the community. It is our opinion that researchers have much to offer pre-college science education in urban schools by providing positive role models for the students and by acting as science advisors for the teachers.

The loss of minorities from the science and engineering pipeline doesn't end after high school. Presently, ~30% of college-bound minority students are interested in majoring in science, engineering, or mathematics (S, E & M), however, between the freshman and junior year in college, 65% of minority science majors leave science in comparison to 37% of the total pool of science students (6). By the end of college, few minorities remain in the graduate school pool. In 1990, for example, 13,600 U.S. citizens received PhD degrees in S & E of which 264 were African-Americans (1). This small fraction, 1.94%, compares to a total African-American population of ~13% in this country.

In this article, we outline several programs aimed at improving science education in urban schools and universities. The intent of describing these programs is to respond to the question often asked by our colleagues as to how we can increase the number of minority graduate students in physics and biophysics. We have omitted a discussion of the complex sociology underlying the present demographics of university graduate populations as we feel these issues are better addressed elsewhere. We would also like to point out that these programs are neither intended to map a global approach to the overall problems with science education in the U.S. nor offer a comprehensive solution to the lack of participation of minorities in higher education. Our discussion, for the most part, is limited to programs that practicing scientists can initiate to increase the numbers of minority students in physics and biophysics. We hope that our ideas will stimulate recruitment efforts on the part of other institutions and individuals in the belief that programs such as the ones we have developed are within the realm of possible and reasonable activities for the physics and biophysics communities.

STRATEGIES FOR BUILDING SCIENCE INTEREST AT THE PRE-COLLEGE LEVEL

The substandard teaching facilities, uninspired teaching by poorly trained teachers, and generally low community interest in science are major hurdles for potential science students to overcome (see personal accounts in Ref. 1) and many students are "turned-off" to science well before college age. Science teachers are cut off from the scientific community,

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and more than half the teachers of high school science in this country do not have an undergraduate major in the subject they teach (7). The present system eliminates any direct way for science teachers to share in the on-going excitement of our research and increases their rate of classroom "burn-out." This separation also means that students have few opportunities to meet scientists who could act as role models and foster their interest in science, one of the most effective ways of recruiting future scientists. At universities, the nonoverlapping academic disciplines of education and science also ensure that graduate students in the sciences who aspire to become good teachers are not exposed to new ideas and research in instructional methods. In this section, we outline two projects designed to develop and encourage the interest of urban students in physics and biology and reduce the barriers between science teachers and scientists.

Early alert for physics

Students with interest and ability for science are often readily identifiable at an early age. Early Alert programs, run by scientists and teachers, can select these students and have them participate in hands-on learning activities which have a proven ability to excite and teach students about science. One of us (LDG) participates in an Early Alert program which selects promising students by personal interviews from a pool who have been recommended by local teachers and administrators. Thirty-five 7th grade students and thirty-five 8th grade students from Philadelphia urban middle schools meet every Saturday for 4 h of hands-on experiments in physics and biology. Typical experiments involve hands-on exploration of physical phenomena unfamiliar to the students. For example, magnetic induction is explored by having students measure the difference in transit time for disk-shaped magnets dropped down conducting and nonconducting tubes of the same length (8). Optics is explored by having students dissect bovine eyes, noting observations and speculations on the various parts of the eye. Students record their observations in a journal and discuss their results and conclusions in small groups under the guidance of mentors who are undergraduate or graduate students in physics or biophysics. University researchers select and direct the mentors, define the hands-on activities to be done, prepare the curriculum in collaboration with experienced middle school teachers, aid in leading discussion, and serve as positive role models. The importance of "humanizing" the image of a scientist by providing students and mentors the opportunity to interact with one cannot be overemphasized.

Since role models are important in the process of directing students toward science, it is crucial to ensure diversity in the mentors chosen for the program. Our Early Alert program is a joint project between the University of Pennsylvania and Lincoln University, an historically black university located 35 miles from Philadelphia. Both universities draw students from the Philadelphia urban area, so it has been possible to select a significant number of undergraduate mentors who share backgrounds and educational experiences with the middle school students.

Summer workshop for urban high school teachers

In order to develop hands-on activities for a larger population of students than can be reached by the Early Alert program, one of us (JCT) has designed a summer workshop for urban high school teachers in which they develop hands-on activities for use in their classrooms during the school year. The workshop concept is predicated on the assumptions: 1) that scientists have an important role in the development of a relevant, up-to-date science curriculum 2) that knowledgeable teachers are important partners in curriculum design since they can best make connections between science and the classroom and 3) that students benefit from hands-on activities, especially when learning scientific principles.

The workshop, designed with input from an experienced high school science teacher and 12 graduate students from the University of Pennsylvania, will focus on the Biology of the Brain. Different aspects of brain function will be covered each day. The day will begin with an overview of current knowledge and research in the area presented by a University of Pennsylvania faculty member. The teachers will then rotate through three labs which have been designed by graduate students to illustrate principles of the selected topics and introduce teachers to current research techniques. At least two of the labs will provide the teachers with hands-on activities designed to aid them in developing experiments for their students. Examples of the daily topics, Day 1–4, are: The Brain and Neuron, the Peripheral Nervous System, Neurochemistry and Psychiatric Diseases, and neurological dysfunction. The activities include measuring muscle contraction with skin surface electrodes, conducting a neurological reflex exam, and reading the DNA base sequence from a gel to demonstrate how genetic lesions related to neurological dysfunctions are screened. The remainder of each day will be spent working in groups to develop the student experiments. Equipment for these experiments will be loaned to the teachers on a rotating basis during the school year. The workshop directors and graduate students will interact with the teachers during the curriculum development phase of the workshop which will allow the scientists and graduate students to offer scientific expertise while learning from the teachers about teaching science at the high school level.

STRATEGIES FOR INCREASING MINORITY UNDERGRADUATE RETENTION

Undergraduate retention in science was recently studied by Hewitt and Seymour (2). The intent of the study was to explore why S, E & M majors experienced such high attrition rates compared to other undergraduate majors, especially since the entering pool of applicants were among the most qualified high school students entering college.

The authors of the ethnographic study entitled their findings "The Problem Iceberg," by which they meant to imply that the factors contributing to a switcher's decision to change majors did not differ from the concerns and complaints about the S, E & M curriculum expressed by nonswitchers. The most frequently mentioned concerns listed by both groups (switchers and nonswitchers) were: allegations of poor teaching and faculty unapproachability for help with academic problems, feeling overwhelmed by the pace and work load, and inadequate help and advice through periods of academic difficulty. The significant differences between the groups were that S, E & M seniors (nonswitchers) had discovered ways of coping with the feelings of discouragement and low self-esteem generated by the curriculum.

Two factors mentioned most often by students as reasons for switching from S, E & M majors related to financial difficulties and poor high school preparation. It is worth noting that Hewitt and Seymour found that problems previously suggested to contribute to attrition in science such as large class size, poor laboratory or computer facilities, and language difficulties with foreign faculty and teaching assistants contribute to the poor teaching quality and access problems cited by students but were never mentioned as the pivotal factors contributing to the decision to switch majors. What was much more significant than these institutional problems was the attitude and teaching or advising style of the faculty.

In order to focus on the higher-than-average attrition of women and minority students, these groups were oversampled. Apart from the shared effects of cultural alienation reported by most minority students, there was no distinctive set of factors to characterize the minority students who switched from the group at large who switched. In general, students who switched majors had less high school preparation and fewer resources, both financial and emotional, as compared with nonswitchers.

In light of the Hewitt and Seymour study, as well as the examples of successful undergraduate programs in chemistry and physics discussed by Tobias (7), programs for increasing retention of students in science should include the following objectives 1) establish strong self-esteem and reinforce self-motivation for students, 2) encourage and maintain the scientific interests among students, especially those in the first year of science or engineering study, 3) teach effective study and work habits necessary for success in the rigorous, fast-paced curricula demanded of science and engineering majors, 4) promote a strong sense of involvement with the institution, and 5) have advanced students become positive role models for future incoming classes of science majors. The most straightforward means of maintaining scientific interest among students are through personal experience in the activities of teaching and research. The philosophical basis of any research university is the belief that the most effective and active researchers in an academic field are also best able to train young minds engaged in the study of that field. It is therefore essential that freshman science majors, especially minority and women students, be coupled directly into the research and teaching endeavors of science faculty members. These faculty members must be capable of serving as mentors to the students and willing to take personal responsibility for the progress of each student under their care.

Introductory courses—the "stretch" concept

The process of coupling students to teaching and research begins with the introductory core courses in science and mathematics. These courses formulate the first introduction of students to science and scientists and hence are enormously important in deciding the direction of their college careers. Major stumbling blocks for potential science majors are the freshman core courses in basic fields such as calculus, introductory physics, and inorganic chemistry. The central role of these elementary courses demand that they be taught with strict mathematical rigor. The course material is, therefore, usually challenging even for students with relatively strong high school training in these fields hence students who have had no previous experience (or at best a very poor one) in physics, calculus, or chemistry are at a significant disadvantage.

The spread in educational experience among entering students makes it impossible to arrive at an optimal pace for these courses. Nor is there much incentive for inspired teaching in "service" courses, because students who go on to major in the field comprise only a few percent of the usually enormous number of course matriculants. A few of the problems that afflict these courses are: (*a*) Many potential science majors perceive the faculty as uninterested in undergraduate learning (see Ref. 2). (*b*) Few examples of applications of basic principles to real-world problems are provided so students have little sense of the importance and relevance of the material being presented. (*c*) Social factors tend to exclude minority students from collaborative study groups thereby contributing to their sense of isolation and frustration with their academic institution. Some attempts at resolving the problems with introductory courses have stretched the courses over more than one semester, thereby lengthening the time allotted to teach basic concepts. This leads to problems in self-confidence for students enrolled in these courses since they carry the stigma of being remedial and they also add significant delay to a costly college education.

From personal experience, we find that, while extra time is needed for the core courses, usually an entire extra semester is not required. To ease the transition to the college environment for "at risk" freshmen entering Penn, a prefreshman summer program (PFP) was initiated. PFP lasts for 4 weeks and includes academic course work in English, mathematics, and a third course from within the student's undergraduate division (e.g., physics for engineers, economics for business majors, etc.). The courses are designed by the academic departments responsible for the subject and taught by faculty members chosen by the departments. An essential element in enhancing the student experience during PFP is collaborative learning, which encourages students to work within the context of a small team focused on individual achievement rather than strictly competitive grade-earning.

Participants reside together in university housing along with peer advisors chosen from a pool of undergraduate applicants.

For those students taking physics, the PFP period forms the first 4 weeks of a "stretch" course in physics. The stretch curriculum involves students in combined studies of math and science and emphasizes the use of mathematics for problem-solving. The physics course work is continued into the fall semester of the freshman year. The stretch course was designed to introduce students to a collaborative approach to learning science and mathematics. This approach has been well-documented as an effective method for teaching these subjects (9).

A crucial component of the stretch approach is the one-on-one interaction students have with each other and with the faculty advisor. During the pre-freshman (PFP) part of the stretch course, both faculty and advanced students act as mentors to maintain the focus of the student study groups. During the regular semester, students are encouraged to maintain study groups and the faculty advisor (LDG) attends at least one evening group session each week.

Undergraduate research

The coupling of students to research begins with undergraduate research projects. Our experience shows that research projects, even in the first year, are not only possible for students, but important in formulating their self-images as future scientists. It should be noted, however, that designing a proper undergraduate project is nontrivial. As opposed to designing projects specifically for undergraduates, the students should be coupled as closely as possible to the leading-edge research of faculty members. The best projects are those that involve work directly with faculty or post-doctoral personnel.

Successful undergraduate research projects promote and enhance student interest in science while providing the needed faculty contact for the students. Faculty members who are excited by their field of study provide the best role models for students just starting on the academic path to a research career. By choosing freshmen for the program, we are assured that these students are caught up in the excitement of science before becoming discouraged by the harsh environment of the academic institution. In addition to gaining invaluable research experience, the students will form the ties with faculty that are essential for guiding them toward post-graduate study (e.g., career guidance, personal recommendations to graduate programs, etc.).

Examples of research projects at the University of Pennsylvania in which freshman students interested in physics and engineering have participated are:

1) Testing of a novel low level light detector using cesium iodide as a solid-state photocathode. This device shows great promise as a device for doing subatomic particle identification through the detection of Cerenkov light.

2) Computer study of protein folding and determination of structure function of biologically active molecules.

3) Solving simultaneous equations and plotting of the equation solutions as part of a theoretical study of perturbative corrections applied to lattic gauge theories in particle physics.

4) Developing and testing an analog computer, whose design is based on the neural system of the brain, for general pattern recognition. This project has possible uses in voice recognition and real-time language translation.

The work described above spans several disciplines including physics, biophysics, electrical engineering, computer science, etc., hence there is a broad base for appeal to students initially interested in a number of science and engineering fields. Broadly based projects appeal to the largest number of students and help ensure a good match of talents to tasks.

To prepare students for front-line research, they should be provided with one-on-one training by faculty members, graduate students, and experienced undergraduate students. The assumption that undergraduates, especially freshman, are incapable of making significant progress in front-line research is quickly dispelled if the projects are chosen with care and the level of preparation of the student before the project begins is sufficient. Having explanations of tasks from several viewpoints significantly aids student understanding. It also emphasizes the team approach to research that underscores the success of the collaborative learning methods the students have used in their course work. The optimal project has several students working on different, overlapping tasks which allows students to interact with each other for aid in understanding and solving problems and facilitates the feeling of acceptance in the laboratory setting.

The research experience is invaluable in helping students see the relevance of their classroom study of physics, chemistry, and mathematics. It is also helpful for both faculty and students if timelines for various tasks are clearly defined. Having students deliver regular progress reports provides students with readily identifiable milestones and provides a natural mechanism for faculty feedback and guidance.

Undergraduate tutoring project

Students advanced beyond the freshman level should be incorporated into the training and/or teaching of younger students (either freshmen or high-school level). Nothing solidifies a student's knowledge of basic science or underscores the importance of thoroughly learning it as the requirement of explaining it to others. Using students as assistants to researchers and teachers ensures their identification with the academic institution and melds them thoroughly into the academic process.

As a follow-up to their freshman year experiences, students are asked to serve as mentors for the incoming freshman science students during the summer stretch course. Students also serve as mentors in the Early Alert program discussed above. The mentor role in the PFP program requires the advanced students to provide tutorial help, initiate collaborative learning activities during recitation sessions held in the PFP dormitory, inform and advise the PFP students on the learning resources available to them during the academic year, offer advice on the engineering and science curriculum, and provide valuable feedback to PFP instructors on student understanding of the PFP curriculum material. The one-on-one interaction between mentors and students and mentors and faculty provides advanced students with a "teaching" clinic that improves their verbal communication skills and gives them invaluable insight on the learning process.

STRATEGIES FOR RECRUITING MINORITIES AT THE GRADUATE LEVEL

"Tuple" concept linking HBCUs with majority research institutions

Efforts at increasing minority enrollment in university graduate programs depend critically on identifying an appropriate pool of talented applicants. HBCUs, founded as schools for freed slaves because major universities barred their doors to blacks (see the article on black colleges in Ref. 1), provide a large fraction of the total pool of minorities who continue their education past college. In 1989, HBCUs awarded 40% of all B.S. degrees to blacks, although less than 20% of the total pool of black students attended HBCUs. Of the 700 blacks who received PhDs in S & E from 1986 to 1989, 29% earned their bachelor's degree at black colleges. As a result of the large pool of minority students at these schools, recruitment strategies will increasingly rely on the HBCUs to supply future scientists and engineers.

Most HBCUs have a strong emphasis on undergraduate teaching and only a few offer graduate work in science. Faculty at the HBCUs are often heavily loaded with teaching responsibilities, leaving considerably less time for active research, in comparison to faculty at major research universities. Coupling traditionally strong research universities to HBCUs through joint research projects provides one means for increasing the research opportunities available to large numbers of minority students. The coupling of a research university and a neighboring HBCU to form a "tuple" also promotes the building of a research infrastructure at the HBCU while simultaneously increasing minority contributions to scientific research. As an example, we note that seven such tuples, including the one mentioned here between the University of Pennsylvania (of which LDG is a member) and Lincoln University, have been formed by physicists interested in future particle physics experiments.

Currently, Lincoln University graduates roughly 45% of all African-American physics undergraduate majors in the state of Pennsylvania. Its pre-college program successfully recruits many students from inner-city Philadelphia into science and engineering fields. The "tuple" formed between Lincoln University and the University of Pennsylvania offers Lincoln students an opportunity to work on research projects which span both campuses and exposes the students to the graduate school faculty and research environment. The linkage also provides minority students at Penn an opportunity to find role models among the Lincoln faculty, who participate fully in the research projects.

Seminar series at HBCUs

In addition to the "tuple" linkage between the physics departments at Lincoln University and the University of Pennsylvania, a seminar series was held at Lincoln University for biology, chemistry, and psychology majors. The informal seminars were presented by faculty members from the University of Pennsylvania and focused on current research topics with an informal discussion of some of the personal reasons for choosing a research career.

The response to the seminar series has been very positive. The faculty as well as the students at Lincoln University are enthusiastic and the seminars are well attended. The organizing team from the University of Pennsylvania, which includes the author (JCT) and several graduate students, provides a continuity to the series and is available to talk informally with students and faculty following each seminar. The topics for the series entitled The Decade of the Brain were chosen jointly based on the interest of the Lincoln students as well as the available pool of potential speakers. The topics in the series include: "Why Baseball Players Don't Wear Shades," "Building Neural Networks That See," "Sleep and Its Disorders," "Born to Die: Suicide Programs of Cells in the Developing Nervous System," "Sickle Cell Disease: A Single Amino Acid Change with Global Implications," and "Biological Basis of Psychiatric Disorders." As a result of contacts made during these seminars, a number of Lincoln students will carry out summer research projects at Penn this year.

Upper level undergraduate course in biophysics shared between the campuses

The interest among the students and faculty in the seminar series at Lincoln University suggests to us that another idea for recruiting students in biophysics is the development of an upper level undergraduate course in biophysics at Lincoln taught by University of Pennsylvania faculty members. Such a course will provide physics or biology students their first in-depth opportunity to cross disciplines and consider relevant biophysical problems. The personal interactions between the University of Pennsylvania faculty and HBCU students provide students with important links to the graduate school environment and the research community. Such a course will help students build the necessary confidence for applying to graduate school and enlarge their view of academic possibilities at the graduate level. Less tangible but important benefits from these faculty-student contacts are opportunities for HBCU students to join research projects in biophysics. Without these bridges between the campuses, not only are HBCU students unaware of research opportunities at nearby universities but they have no academic exposure to biophysics to prepare them for these research opportunities.

PROGRAM EVALUATIONS AND FUNDING POSSIBILITIES

PFP and stretch

For the evaluation of the PFP and stretch course in physics, at-risk Penn matriculants were first identified on the basis of the Predictive Index (PI), a prediction of the freshman year cumulative grade-point average (GPA) based on its correlation with high school class rank and standardized admissions test scores. The 450 incoming freshmen having the lowest PIs were screened by telephone in June prior to the start of the PFP program in August, 1991. This process yielded about 250–300 students who would attend PFP if invited. This group was then stratified by undergraduate division, race, and gender. Pairs of students were selected at random from each subdivision using matrix sampling to ensure proportional allocation. One member of each pair was assigned to the group of students invited to PFP, while the other member was assigned to the control group. PFP implementation was evaluated through direct observation by the evaluator, a member of the Graduate School of Education at Penn, through observation of both formal and informal activities. The effect of the program was determined through the student GPA for fall and spring semesters, use of on-campus academic support services, and scores on two standardized psychometric instruments, the *College Student Experiences Questionnaire* (10) and the *Student Adaptation to College Questionnaire* (11). Sustained effects will be assessed by examining retention statistics and ongoing GPA, as well as in follow-up interviews with participants.

Positive teaching evaluations and personal responses from the students involved in past stretch courses indicate that the objectives previously stated are met by the program we have described. For example, the performance of students in the 1991 stretch physics program was evaluated at the end of their second semester at Penn. When compared with a control group not attending stretch physics, these students scored one letter grade higher in cumulative grade point average for the freshman year. All of the students from the 1991 stretch physics class subsequently joined in as research students during the summer of 1992.

Workshop for high school teachers

Two evaluation procedures are proposed for the workshop. The first is a questionnaire for each teacher to evaluate the hands-on activities they designed and implemented. Teacher feedback will include specific comments about the student responses to the activities as well as suggestions for designing the next generation of activities.

We have also proposed an ethnographic study in order to better understand how urban students develop an interest in science. The paradigm is to videotape small groups of students from the classes of teachers selected for the workshop before the workshops are held. The discussions will be directed by open-ended questions from graduate students which will relate to the students' attitudes toward science. For example, is the science they learn relevant to their lives, what do they like/dislike about science class, and have they considered a career as a scientist? The results from the discussions will be analyzed using standard ethnographic approaches (see Ref. 2 for a more complete description of ethnographic research methods and analysis). Matched groups will be studied the following year, after the teachers have implemented the activities developed in the workshop, and the results compared.

Resources for minority recruitment, educational programs, and research participation

In 1991, the total fraction of African-American faculty members in U.S. medical schools was 2.8% in the clinical sciences and 1.4% in the basic sciences. Recognizing the important role of HBCUs in training science undergraduates, funds have been allocated for minority institutions to develop their involvement in biomedical research. The Minority Biomedical Research Support Program (MBRS) of the Division of Research Resources at the National Institutes of Health (NIH) administers awards for providing scientific equipment, facility renovations, support of students, and faculty release time for biomedical research projects. Supplements are also available to principal investigators from majority institutions with NIH research grants to recruit and support minorities in their research laboratories. The supplements are part of an initiative to support minority involvement in research at all levels. The supplements fund minority participation, from high school students to visiting faculty, in ongoing research projects. Certain restrictions apply for these administrative supplements, and additional information is available from the NIH institute staff. The National Institute of General Medical Sciences (NIGMS) sponsors special minority research and research training programs as well. One program, Minority Access to Research Careers (MARC) provides research training opportunities in biomedical sciences for students and faculty at schools in which substantial student enrollments are drawn from minority groups.

In addition to the funding available for minority participation in research projects, the National Science Foundation funds a number of programs such as the Early Alert program described here as well as programs for developing curriculum materials and improving classroom instruction in science and engineering. Large science projects are also increasingly more likely to have some portion of their budgets devoted to outreach education. For example, "tuple" collaborations in high energy physics are being funded by agencies supporting the Super Superconducting Collider accelerator currently under construction in Texas. These agencies include the Department of Energy and the Texas National Research Laboratory Commission.

SUMMARY

The strategies outlined above are grounded in general educational principles reviewed in the references listed and are applicable to any student population. The general themes carry through from the Early Alert program for 7th graders to recruitment at the graduate level. They include: (*a*) personal contact with scientists; (*b*) collaborative learning; (*c*) joining a research team; (*e*) faculty interest and commitment to science teaching; (*f*) hands-on experiences which reinforce the learning and build self-confidence.

In closing, we would like to make two final points. First, programs designed to recruit minority students must make every attempt to involve minority role models. One advantage in linking majority research institutions with minority teaching institutions is that the HBCU minority faculty can serve as role models for minority students at both institutions. In return, the research institution provides an important research link for HBCU faculty and students. Finally, we would like to encourage the viewpoint that minority students are an underdeveloped national resource rather than a "problem." This term is too often associated with minority recruitment efforts.

We thank our colleagues at Lincoln University and the classroom teachers who have aided in the design and implementation of the programs described here as well as the undergraduate and graduate students at Penn who have contributed immeasurably to these programs. We hope our students will continue to view research and teaching as inseparable activities. We also thank our friend and colleague Dr. Suzanne Amador for sharing her ideas and enthusiasm about teaching physics and biophysics at the undergraduate level.

REFERENCES

1. Culotta, E., and A. Gibbons, editors. 1992. Minorities in science: the pipeline problem. *Science (Wash. DC).* 248:1176–1237.
2. Hewitt, N. M., and E. Seymour. 1991. Factors contributing to high attrition rates among science, mathematics and engineering undergraduate majors. Bureau of Sociological Research, University of Colorado, Boulder, CO.
3. Kahn, S. 1992. University science teaching must reach out to women and minorities. *J. NIH Res.* 4:56–60.
4. Benditt, J., editor. 1992. Women in science. *Science (Wash. DC).* 255: 1365–1389.
5. Rawls, R. L. 1991. Minorities in science; special report. *Chem. Eng. News.* 69:20–35
6. Malcom, S. 1991. Plugging the pipeline. *Science (Wash. DC).* 254:353.
7. Tobias, S. 1992. Revitalizing Undergraduate Science. Research Corporation, Tucson, AZ.
8. Doherty, P., and Rathjen, D. 1991. Science Snackbook. The Exploratorium, San Francisco, CA.
9. Treisman, P. U. 1985. A study of the mathematics performance of black students at the University of California, Berkeley, CA. (Available from the author, University of California at Berkeley.)
10. Pace, C. R. 1988. Measuring the quality of college student experiences. UCLA Center for the Study of Evaluation. Los Angeles, CA.
11. Baker, R. W. 1989. Student adaptation to college questionnaire manual. Western Psychological Services. Los Angeles, CA.